Steve H. Murdock
David Swanson
Editors

Applied Demography in the 21st Century

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Selected Papers from the Biennial Conference on Applied Demography, San Antonio, Texas, January 7–9, 2007

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INTRODUCTION

Chapter 1
Applied Demography at the Beginning of the 21st Century

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Applied Demography is evolving as its practitioners become involved in the emerging trends of the 21st century. Data bases, substantive issues, and methodological approaches seldom considered just a few years ago have become mainstream concerns in the area of applied demography. For example, the availability of current micro-data only dreamed of a generation ago – annual data for block groups – will be a reality by the end of the first decade of the century, while estimates and projections of disaster-impacted populations, although of periodic concern, have become major areas of analysis in this post-9/11 and post-Katrina era. Similarly, spatial measures and increasingly sophisticated forms of GIS-related analyses previously used only in specialized analyses in geography have become of central concern.

At the same time, many issues of concern in the 20th century continue to challenge the discipline. Should applied demography be seen as a separate discipline and be organized as such? What are the best and most appropriate areas of training for Applied Demographers? What are the most appropriate methodologies for estimating and projecting small area populations? How can temporary populations be more adequately estimated and projected? What potential possibilities and problems will result from new data bases such as the American Community Survey? How can progress be made in such continuing areas of concern as the assessment of market area populations, of school district enrollments, of the demographic components of disease incidence and prevalence, and of the implications of aging populations for pension plans and retirement systems; the examination of international populations and markets; and the appropriate use of new data, technology, and methodologies? Applied Demography in the 21st century is clearly an increasingly diverse area with an expanding number of professionals with both continuing and emerging concerns.

Existing overviews of the most critical issues and practices in the field are now increasingly dated although still very valuable. Foremost among these is *Applied Demography* by Jacob Siegel (2002) and several now-dated books such as *Introduction to Applied Demography by Rives and Serow* (1984), *Applied Demography: An Introduction to Basic Concepts, Methods and Data* by Murdock and Ellis (1991), and *Demographics: A Casebook for Business and Government*, by Kintner et al.

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(1994). Closely related works (see Pol and Thomas 1997, Swanson et al. 1996) and very useful overviews of the development of the field or subareas within the field (Swanson and Pol 2005, Smith and Morrison 2005) also have been completed. The most current ongoing publications that regularly contain works of interest to applied demographers are *Population Research and Policy Review* and the *Applied Demography Newsletter*. No available work, however, provides an overview of the current range of interests in applied demography in the first part of the 21st century. Hence, we believe that a volume which presents an overview of some of the increasingly rich diversity of the field of Applied Demography is needed.

This volume represents an attempt to provide a current overview of the increasing breadth and depth of the field of applied demography. It contains selected papers from the first post-2000 national conference on Applied Demography held in San Antonio, Texas, January 7–9, 2007, under the sponsorship of the Institute for Demographic and Socioeconomic Research at The University of Texas at San Antonio. Fifty-seven papers by applied analysts from the United States and several other nations were presented. These papers covered a variety of issues important to both the public- and private-sectors and provide an overview of many of the concepts, methodologies, and applications of applied demography in the 21st century; hence the title of this volume of the edited papers from this conference, *Applied Demography in the 21st Century*.

After the conference was completed, the editors of this volume sent an invitation to all participants to submit their works for possible publication. Those works received were then sent out for peer-review and those found to be acceptable are included in this volume.

The volume is intended for a wide range of potential users including practitioners of applied demography, students in courses in the field in colleges and universities across the world and private and public-sector persons interested in how demography can be applied to address important issues and concerns. It should be of particular interest to people in business and government who are involved in activities related to the substantive topics and processes addressed by authors in this volume. In addition, the volume should be appropriate as an accompanying text for courses in marketing, media analysis, and business management, as well as basic and applied graduate and undergraduate demography and social science courses.

The Content of the Work

The volume is organized into five sections in addition to this introduction and a summary chapter. Each of the five substantive sections focuses on a specific set of factors critical to applied demographic analyses. Together they examine the data and estimation and projection methods used to extend such data; present specific examples of the use of applied demographic techniques in analyses in one of the most important substantive areas in demography – health, disease, and mortality assessment; provide papers exemplary of the wide diversity of interests in applied demography; and examine the potential future of applied demography as it is reflected in new academic programs and approaches to teaching key methods of data collection and analysis.

Section I examines specific data and measurement use issues with particular reference to two key data sources for the re-engineered census in the United States: the American Community Survey; and the Master Address File. Section II delineates a variety of statistical issues related to two of applied demographers most powerful tools, population estimation and projection. Section III provides a specific focus on health demography, including analyses of factors affecting the incidence and measurement of mortality and different forms of disease incidence as well as factors related to specific causes of mortality. Section IV introduces the reader to some of the diversity of interests of applied demographers, including two papers on time expenditures and household consumption patterns in China, as well as papers on the application of demographic data and methods to the analysis of church membership, educational planning, and labor force turnover. Concluding the work, Section V presents discussions of two factors impacting the future of applied demography, one examining unique methods for imparting detailed knowledge of the theory and practice of survey applications and the second delineating the need for, and dimensions of, the first Ph.D. program in applied demography in the United States.

Section I consists of three chapters focusing on data and measurement issues with a specific focus on the American Community Survey (ACS) and the Master Address File. The ACS is arguably the most important data innovation by the Census Bureau in decades but brings with it a number of new challenges relative to data collection, analysis, and interpretation issues. The first part of Section I includes two pieces, one by Howard Hogan from the U.S. Bureau of the Census and comments by Patricia Becker from APB Associates. Hogan describes the ACS and its close interrelationship with the population estimates program in the Bureau. He delineates the data sets used in each and how each is completed. He places particular emphasis on the potential confounding effects of differences in residence criteria and time referents between the two data sources. He also notes the difficulties in interpretations likely to be involved in the use of smaller (compared to the census long-form used in previous decennial censuses) samples and the resultant use of three and five year averages for small population areas in the ACS. Hogan provides one of the most succinct and candid discussions available of the difficulties entailed in merging results from the estimates and ACS and of the likely user difficulties created by such divergent data sources and changes in sampling rates. Patricia Becker provides a brief but well-informed critique of the difficulties she has encountered in an attempt to use current ACS data and alludes to the additional difficulties likely to be entailed in the use of data based on three- and five-year averages. Becker specifically notes the difficulties she has encountered in attempting to build a comprehensive profile for a specific area in Michigan. Rather than simply critiquing the system she provides concrete suggestions for improving the utility of ACS data for small areas. Together these works suggest some of the challenges entailed in the use of this important new data source.

The final paper in Section I provides an assessment of the coverage of the Master Address File (MAF). The Decennial Census and the ACS survey are based on listings of housing units and component households and persons in such households and group quarters. The key to obtaining an accurate count in a decennial census or an appropriate sample for the ACS is a complete listing of housing units' addresses and or locations. This listing is the Master Address File. Susan Perrone who formerly worked at the Census Bureau describes the Census Bureau program for assessing the completeness of coverage of the MAF involving a comparison of estimated numbers of units and those obtained from the address listing efforts of census survey analysts in the field. Perrone's analysis describes the complexity of measuring the coverage of MAF and its importance, showing how the accuracy of MAF is a major determinant of the accuracy of the census. Together the papers in Section I provide important insights into the strengths and potential flaws in key census data collection and measurement sources.

Section II includes six papers on population estimates and projections. The paper by Beth Jarosz describes an extension of the most well known and certainly one of the most detailed population estimation programs in the United States, that of the San Diego Association of Governments (SANDAG), to include parcel level estimates. This article describes the use of ArcGIS methods with tax assessor data. The author thoroughly describes the intricate process of using such data, given the differences in census and tax assessor parcel geographies, and also how such data have substantially increased the accuracy and timeliness of the data provided by SANDAG.

The second paper in this section is by Lori Post, Artem Prokhorov, James Oehmke, and Sarah Swierenga and provides a projection of the number of cases of elderly abuse in Michigan counties through 2030. The chapter uses multiple data sources and rates to arrive at its projections. Among the factors used by the authors is the ratio of elderly to the working age population, levels of caregiver stress, and the prevalence of elderly abuse. The findings are sobering, showing a potential tripling of abuse cases in some counties and large numerical increases in urban counties. The authors stress the implications of such findings for the need for additional attention to the prevention of elderly abuse.

The third paper is by Gregory Stone and provides an excellent example of the types of extraordinary challenges faced by applied demographers. This work examines the problem of estimating the population of New Orleans after Hurricane Katrina. The author's discussion indicates how standard factors used to estimate populations such as housing data on structures were simply not available because the infrastructure was not operational Using data from three different forms of surveys he shows how reasonable estimates can be obtained by bringing together diverse data sets. The work is an excellent example of the developing area of "disaster" demographics within the field of applied demography.

The work by Nazrul Hoque provides an evaluation of the accuracy of county and place estimates for Texas for 2000 produced by the Texas Population Estimates and Projections Program at The University of Texas at San Antonio. Such ongoing evaluations are essential to the development and maintenance of a quality estimates program, and Hoque's evaluation is comprehensive and insightful. Its findings support the long-established premise in population estimation that the accuracy of the average of several alternative methods is generally superior to that for any one method alone. This is important because there are numerous programs that have become single estimation methods systems without adequate evaluation of the costs in accuracy that may be associated with the use of a single method.

The paper by Don Warren is an interesting work bringing together the methods of short-term and long-term forecasting. The premise of this work is that traditional population projections may serve as a means of extending the utility of short-term estimation methods that otherwise have a number of statistical strengths and advantages. Using time series methods that often statistically collapse when used over extended time frames, Warren demonstrates how a "demographic assist" may extend the utility of short-term forecast methods, thus allowing for the detailed time frames needed for program management but difficult to obtain in traditional long-term demographic forecasts. This paper represents a quite unique and needed attempt to combine the strengths of long-term and short-term forecast methods in a manner likely to be of utility, and of interest, to many applied demographers.

The final paper in this section is by David Swanson and extends earlier work by Swanson and others on the development of a measure of uncertainty for population projections. Swanson's work represents an attempt to develop a set of confidence intervals for short-term population projections. Swanson's measure, the Mean Square Error Confidence Interval, takes into account bias and random error. Although it requires making assumptions about trends in the components of population change, it provides an innovative approach for assessing the accuracy of a short-term projection. It is likely to be of value to nearly all who engage in population projections.

Section III consists of three papers that address issues in the rapidly growing cross-section of demography and health. Health demography has long been an impetus for the development of demographic analyses and methods and an important area within the analysis of mortality, but interest has increased noticeably as the population of the world diversifies and grows older. This section consists of three chapters addressing very different topics within this broad-based area.

The first paper, by Mary Bollinger, examines differentials in the perceptions of risk of getting tuberculosis among native and foreign born persons in the United States. Using data from the 2005 National Health Interview Survey, Bollinger examines whether perceptions of risk, which are key predictors of seeking preventive health measures, are a function of a variety of demographic and other variables. Bollinger specifically examines whether being from an origin area with high levels of TB and having characteristics that increase levels of risk increase perceptions of risk. This work convincingly demonstrates that, unfortunately, being at risk does not necessarily increase the likelihood that people perceive they are at risk, showing that perceptions and reality are often not sufficiently linked.

The second paper in this section is by Donna Shai. It examines deaths and injuries due to fires in Anchorage, Alaska, and provides an excellent example of the utility of demographic data for policy development at the local level. This paper provides an example of how demographic factors may determine exposure to risk and the level of experience with the actuality of increased risk. After reviewing the unique factors about the Alaska population that might be related to failure to take adequate measures to avoid death and injury due to fires, the author provides data demonstrating that demographic and related housing factors, such as low household income, limited English proficiency, and high levels of crowdedness, were related to increased incidences of death and injury. Shai then draws policy implications that demonstrate how more extensive use of demographic data could help local officials pinpoint areas of high risk where additional structural and educational measures might be introduced to reduce fire-related death and injuries.

The third paper is by Bo Eriksson, who evaluates a specific reporting issue within the area of mortality. The author examines the question of whether, given that disease and death increase with age, there is a similar increase in number of reported causes. Using Simpson's D, the author analyzes more than 350 causes but finds a bimodal pattern at middle age and older ages as well. The reasons for this unexpected pattern are then examined and potential reasons discussed. The paper presents an excellent example of the need to assess what may appear reasonable to determine whether it is verified empirically and how demography can play a critical role in the assessment of that validity.

Section IV consists of five papers presenting an overview of some of the diversity of topics and issues examined by applied demographers. These contributions demonstrate much of the ingenuity and the ability of applied demographers in bringing their craft to bear on important issues. The first paper is by Michael Cline, who examines factors associated with church membership in two Methodist congregations in San Antonio, Texas. Noting that congregations often emphasize congregational leadership as the key to membership growth, Cline shows how demographic and socioeconomic characteristics may play a role in determining membership. His analysis indicates that it is not only the total number of persons in close proximity to a church that determines its membership growth, but also income, age, and other sociodemographic characteristics. His work shows that even for factors that are often seen as not related to conditioning or external factors, demographic characteristics may play an important, and in some cases, unexpected role.

The second paper, by Richard Lycan, provides a good example of how the applied demographer seeks out data sources to address the issues of concern and merges them with other secondary data to complete an analysis. Focusing on school demography and school planning, the paper provides a detailed examination of how the author utilized a variety of data bases to improve his school enrollment forecasts. Lycan innovatively links tax data on property lots, which show structures and their characteristics, with census data and student record data on area and student characteristics. Noting that changes in housing characteristics are closely tied to student numbers and characteristics, he shows the utility of linking numerous sources of data to improve school forecasts.

The paper by Giuseppe DeBartolo is an example of the important role being played by international scholars in the development of applied demography. The paper examines the role of demographic factors in the determination of laborforce turnover and provides a review of literature linking laborforce turnover to demographic characteristics. The paper demonstrates that demographic characteristics such as age and gender affect rates of turnover and notes that the contributions of applied demography to such analyses are at their beginning stages with extensive opportunities for additional contributions by applied demographers.

The next chapter by Farhat Yusuf, Gordon Brooks, and Ping Zhao is one of two works analyzing changes in the world's largest nation. The paper describes an application of demography in the area of business demography. The authors address the pragmatic issue of whether segmenting markets into rural and urban components is necessary in China, which is rapidly urbanizing but also has a large rural population. The analysis demonstrates that although rural and urban differences are diminishing, rural and urban differences in product adoption levels remain substantial for many products. It provides an example of how demographic considerations remain of key importance in marketing analyses.

The final paper in this section is by Hongwei Xu and Elisabeta Minca, who examine differentials in time use among children in China. It demonstrates how the applied demographer can use variation in individual demographic characteristics, differences in household structures and types, and differences in community characteristics to understand differentials in use characteristics. The results of the authors' analysis indicate that the largest differences are not in the time spent by children in specific activities but in the likelihood of participating in given activities and find that the children from more privileged households are more likely to be able to participate in activities that increase their academic achievement.

Section V provides a glimpse of factors impacting the education of applied demographers. The first paper, by David Smith and Stephanie McFall, describes work in a specific area of training in applied demography, the use of survey data, with special emphasis on the use of such data for surveillance and assessment in health analyses. The paper delineates the characteristics of a course specifically designed to educate applied demographers in this area, pointing out that it builds on basic courses in biostatistics and behavioral science and includes work on questionnaire design, sample design and selection, as well as analyses of individual problems using large scale national health related sample surveys. The course as outlined recognizes a need that is especially relevant to applied demographers: that is, the need to be able to design and carry out their own surveys as well as the need to appropriately use secondary survey data. Although some social science fields appear to be almost totally dependent on secondary surveys for their analysis of key issues, applied demographers are often required to do their own survey work and hence such courses are essential to an applied curriculum.

The paper by Steve Murdock and Mary Zey delineates what they believe to be the essential elements of the training of applied demographers and then describes a Ph.D. program developed at The University of Texas at San Antonio in Applied Demography. This program is the first one in the United States. These authors suggest that the skills needed by the applied demographer demand the breadth and depth of knowledge associated with a Ph.D., that the methodological and conceptual basis entailed in a Ph.D. are as essential in applied demography as in demography as a whole and that the need for a Ph.D. is suggested by the fact that many of the traditional programs in which demography is included make it difficult to obtain the breadth of knowledge needed to operate in an applied setting. They outline the necessary skills for an applied demographer and then describe the program at The University of Texas at San Antonio, which is a standard 60 hour Ph.D. with 48 hours of coursework and 12 hours of dissertation with tracks in applied demography and health and applied demography and policy. The authors note that the curriculum includes standard demographic coursework but also additional statistical, computer, and GIS training, as well as substantive and methodological coursework in the chosen track. The initial students enrolled in the program are older, more diverse, and have more life experience than the typical Ph.D. candidate in the social sciences but are progressing well. Although it has yet to be seen whether the program will be successful, the authors suggest that such a program may represent the future of applied demography and assist in obtaining further recognition of the importance of the profession of applied demography.

The final chapter by Steve Murdock and David Swanson provides a summary of the current state and challenges in applied demography and those opportunities likely to characterize its future. The authors maintain that although the challenges are substantial, the potential for the further development, maturation, and expansion of applied demography is even more extensive, and its future potential, one of extensive growth and inclusiveness.

Overall, this volume provides a rich sampling of the fare of applied demography. Although no single work can pretend to adequately cover the work in applied demography, this work should provide the reader with an excellent introduction to the breadth and depth of the discipline. At the same time, we believe that the works in this volume will provide the reader with a feel for the extensive challenges presented to, and the resultant creativity required of, the applied demographer in the 21st century.

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Section I

DATA USE AND MEASUREMENT ISSUES

Chapter 2
Measuring Population Change Using the American Community Survey*

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Introduction

Since the American Community Survey (ACS) was first conceived, statisticians and demographers have been aware of many of the opportunities and the challenges that it would create (see Symens Smith 1998; Alexander and Wetrogan 2000). When the ACS was struggling to get funded and implemented, these challenges seemed far off. Now, the ACS is fully launched. The data released in 2006 covered all households in the United States as well as Puerto Rico. The data collected in 2006 and released in 2007 cover the whole population, including group quarters.

This paper discusses, within a framework that is both demographic and statistical, issues that arise from the existence of two separate measures of population size and change, the ACS and the Population Estimates Program.

On the first day of Demography 101, we are taught that if you want detailed information for small areas and small population groups, take a census. Because taking a census every year is not possible, other methods fill the gap, such as those used in the Population Estimates Program and the ACS. They provide useful information, but they are not censuses. If users, including government officials and reporters, expect "census like" accuracy, they will be disappointed. Further, the two systems will not be fully reconciled with each other. It is important that the applied demographer community be prepared to wrestle with these differences.

As conceived, these two programs have different purposes. The Population Estimates Program is, in essence, designed to bridge the gap in data between decennial census "short forms." It provides counts of population for a few basic demographic variables, such as age, sex, race, and ethnicity. The ACS is designed to provide information about detailed characteristics, specifically the distribution of the population with respect to the many variables formerly measured by the census "long form." However, the two programs provide information about the same population,

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* This report is released to inform interested parties of research and to encourage discussion. Any views expressed are those of the author and not necessarily those of the U.S. Census Bureau.

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and applied demographers will need to reconcile inevitable disparities between the two data sets. Many users of the ACS will be interested not just in the distributions but also in the actual numbers of people in particular categories. They will want to use the ACS estimates as detailed counts. This might be stretching the data past their limits, but it will certainly be done.

The Population Estimates Program begins with the latest decennial census counts as its base and develops measures of change to produce population estimates. The ACS is not set up to measure year-to-year change, even for areas large enough to produce annual ACS estimates. Implausible annual changes in some components of the population are a predictable outcome of the design. These changes will not result from errors but from limitations of the ACS's design.

Another important difference regards the defined universe or population. Some demographers will be more comfortable with the ACS's concept of "current residence" than with the decennial census's concept of "usual residence." A well accepted demographic way to look at a population is in terms of "person years lived." Often, when demographers use "mid-year population," they do so as a substitute for or approximation of "person years lived." The ACS concept of "current resident" provides a good approximation of "person years lived." Recognizing this difference is important to understanding the system. The implications of the use of two different concepts of residence are discussed below.

The ACS and the Population Estimates Program together constitute a complex system. Examining them as one system illuminates the limitations of the estimation processes. Figure 1 gives a schematic overview of the entire system. The Population Estimates Program uses data from many sources, including the ACS. The ACS is controlled for age, sex, race, Hispanic origin, and housing unit estimates produced in the Population Estimates Program.

This paper first reviews the Population Estimates Program, which includes housing unit estimates. Then the paper does the same for the ACS. The paper frames some of the key measurement issues in integrating the ACS and the Population Estimates Program. Finally, it discusses some of the more relevant research projects at the Census Bureau.

Population and Housing Estimates Program

The Population Estimates Program explicitly begins with the population numbers from the most recent decennial census (in this decade, Census 2000). These numbers are nominally counts of the "usual residence population as of April 1," carried forward to reflect the population on July 1.

The decennial census concept of "usual residence" is quite complex. It is not the *de jure* population. Nor is it the *de facto* population. It includes past behavior, asking in effect, "Where have you been staying most of the time 'recently'?" It also includes the concept of intention, again asking in effect, "Where do you plan to stay in the near future." (See National Research Council, 2006, for a discussion of the

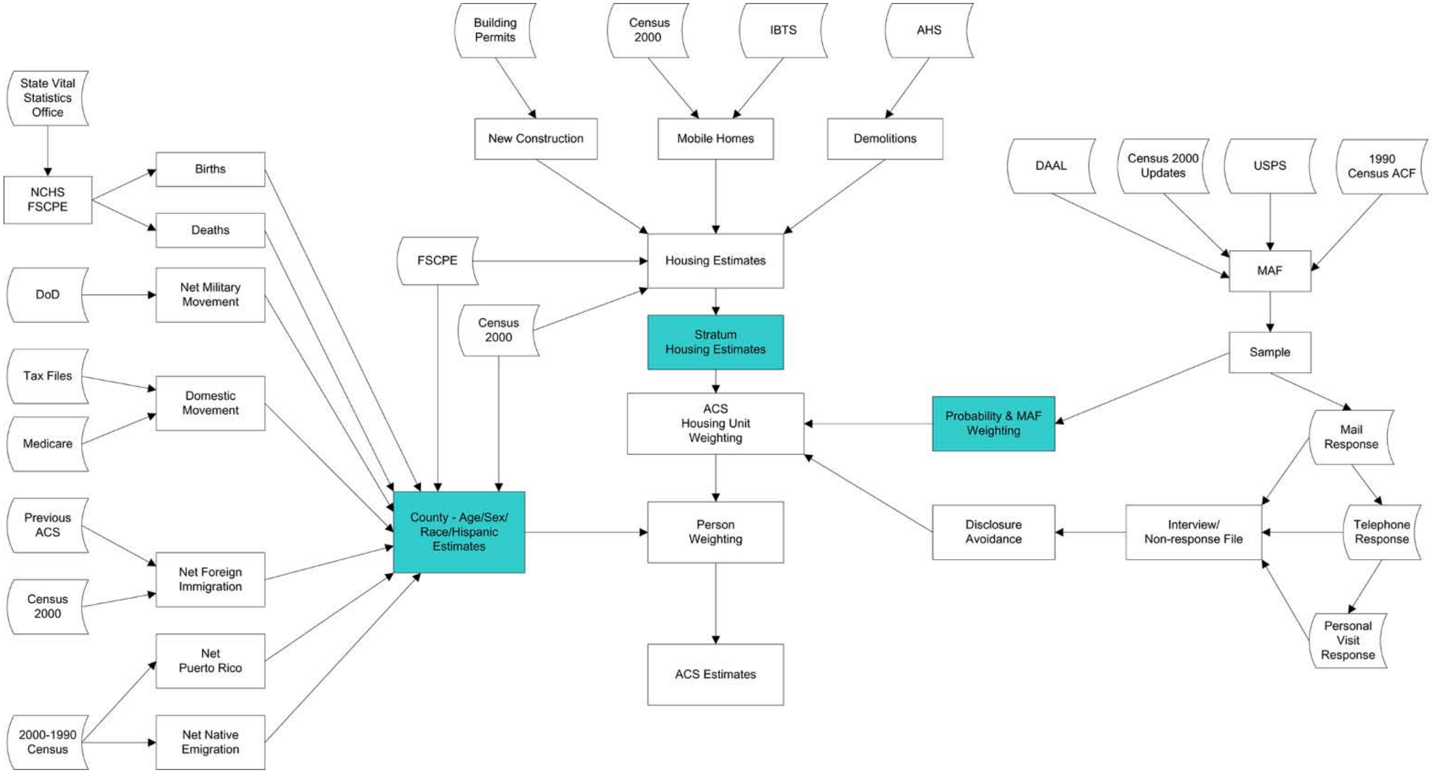

Fig. 1 Schematic overview of ACS estimation system.

complexity of this concept.) A foreign visitor who decides not to return to his home country conceptually becomes a ‘usual resident’ the day that decision is made, not the day he crossed the border. People staying and working in an area for a short time are not part of the usual residence population, unless they have no other “usual residence.”

The census population is carried forward based on measurements of the components of population change. It is important to keep in mind that the Population Estimates Program is designed to be census consistent. It begins with the census and measures change. It does not try to correct for census errors. This approach has advantages when trying to measure change. Still, cities that identify what they believe, sometimes correctly, to be census errors are disappointed when the Census Bureau does not make the correction in the population estimates.

At the county level, the measures of change are relatively straightforward for the household population. Births to mothers living in the county are added; deaths to county residents are subtracted. The Census Bureau uses data from federal income tax returns supplied by the Internal Revenue Service to measure the domestic migration of the population under age 65. The data are limited to filers and their exemptions who are under 65. The Census Bureau estimates domestic migration rates by matching the tax records on a filer’s social security number (SSN) between two consecutive years to determine the migration status of filers and their exemptions, and then applies these rates to the household population under 65. This estimation procedure is currently done only for returns as a whole, but the Census Bureau is working to apply this method on an individual basis by matching all SSNs, and not just the filer’s, between two consecutive years on tax records.

The use of tax data allows up-to-date and detailed analysis of flows. It represents a considerable achievement. It is, of course, not perfect. Not all people who change their “usual residence” change their tax domicile. For example, someone who attends college (and lives in a housing unit there) may well continue to file taxes at the former residence. Since the method measures change, those moving to college are to an extent cancelled by those moving back. However, the population of a college town with significant growth in off-campus housing during the decade may not be well measured.

One recent achievement has been the use of the United States Postal Service (USPS) National Change of Address file (NCOA) to track people displaced by the 2005 hurricanes in the Gulf of Mexico. Since these people were granted an automatic tax filing delay, the Census Bureau could not rely wholly upon tax returns to track population movement. Using the USPS NCOA data to supplement the tax data, the Census Bureau was able to produce estimates that took the displacement from the hurricanes into account.

The estimate of net international migration for the household population includes three separate pieces: net international migration of the foreign born, net movement between Puerto Rico and the United States, and native emigration. The Census Bureau produces each of these three pieces of international migration at the national level and then distributes them to counties based on the Census 2000 geographic distributions that are most appropriate for each piece.

One area where the ACS and the population estimates explicitly come together is in the measurement of the net change in the foreign-born population. To produce an estimate of net international migration of the foreign born, the number of foreign-born residents in the previous ACS estimate is subtracted from the number in the most recent estimate and an adjustment is made for deaths to the foreign born during the period. Thus, for the 2006 controls, the number of foreign born residents from 2004 estimates are subtracted from those in 2005 to determine the growth of the foreign born population. This calculation is currently done at the national level. The net foreign-born international migration is then distributed to counties based on the Census 2000 distribution of the non-citizen foreign-born population who entered in the prior five years. The Census Bureau demographers believe that this method represents an improvement over the 1990 – 2000 estimates. For those, the Census Bureau estimated the net change of the foreign born largely on the basis of change measured between the 1980 and 1990 censuses, supplemented to some extent with Immigration and Naturalization Service (INS) data on temporary migration and green cards issued. The lack of current data on what was happening with international immigration was one cause of error in the 1990s. Although an improvement, it is doubtful that the ACS fully captures all international migrants, and research continues on improved methods.

Net movement between Puerto Rico and the United States is estimated by comparing Census 2000 data with 1990 Census data and spreading the 10-year estimate evenly across the current decade. Native emigration is estimated using a combination of statistical reports from other countries and State Department data.

Similar methods are used for those 65 and over, but Medicare data rather than IRS tax data are used to measure the domestic migration component.

Net Change in the Group Quarters Population

Group Quarters (GQ) population change is estimated separately from change in the household population because of the character of the GQ population and the Census Bureau's ability to acquire direct data on it. The technique for estimating the GQ population starts with the Census 2000 enumerated GQ population.

Representatives of states that participate in the Federal-State Cooperative Program for Population Estimates (FSCPE) develop an independent list of GQ facilities and populations in their states, and changes since Census 2000. In turn, the Census Bureau calculates the implied change in the GQ population. This change is then applied to the Census GQ base to come up with the estimate of the total GQ population in each state. Finally, these state and county totals are distributed by age, sex, race, and Hispanic origin using the distribution of the GQ population within each GQ type from the state's base GQ population.

State and County Estimates by Age, Sex, Race, and Hispanic Origin

State and county estimates of the resident population by age, sex, race, and Hispanic origin are produced separately but by essentially the same method.

The process begins by developing an initial estimate by age, sex, race, and Hispanic origin using a cohort component technique. Adding to the complexity is the inconsistency in race categories between the decennial census (the base population used in the estimates process), the vital statistics data supplied by the National Center for Health Statistics, and the race categories used in the estimates process. Great efforts have gone into developing algorithms to achieve consistency.

The key issue for the production of these estimates is the development of components of change with full age, sex, race, and Hispanic-origin detail. For the subcomponents of net international migration, these characteristics are assigned using the distributions of the appropriate populations from Census 2000. The Census Bureau assigns characteristics to domestic migrants using the Census Bureau's Person Characteristics File, which is developed from data supplied by the Social Security Administration and other administrative records.

The National Center for Health Statistics (NCHS) provides birth and death data with all necessary characteristics, but NCHS uses the old four-race system, while the Census Bureau uses six race categories. To use NCHS data in its estimates, the Population Estimates Program uses a variant of the NCHS bridging algorithm to convert these data into race categories consistent with Census 2000.

The process of collapsing and expanding the race/ethnicity groups is complex. It is needed to deal with both small-population cells and differing levels of detail of incoming data. The Census Bureau collects data on race for each of the five specific categories and for "Some other Race" (SOR). Respondents can choose one or more categories as best describing their race. One example of the complexity of race data is seen in how the Population Estimates Program deals with the "Some Other Race" category. First the SOR population is distributed. SOR-alone responses are distributed using a hot-deck procedure controlling on Hispanic/Non-Hispanic. A response of SOR in combination with one other race is allocated to the specific race group. State estimates are produced at this level. When carrying down to the counties, races are grouped separately by the following categories:

- Hispanic.
- Non-Hispanic White alone.
- Non-Hispanic Black alone.
- Non-Hispanic American Indian and Alaskan Native alone.
- Non-Hispanic Asian alone.
- Non-Hispanic Native Hawaiian and Other Pacific Islander alone.
- Non-Hispanic All multiple-race combinations.

After the raking is complete, these are expanded to the full race and Hispanic classification using the proportions from the Census 2000 data for the county.

Housing Units

The Census Bureau measures housing unit change since the last census using building permits, mobile home shipment records, and estimates of housing unit loss. Statistics on housing units authorized by building permits are the only data that are available at a small geographic area level. Actual construction of a housing unit is not completed for two percent of all building permits. Therefore, a factor of 0.98 is used to estimate completed new units. Some new residential construction work in building permit jurisdictions escapes recording. The number of such unrecorded units in most places seems to be small. However, identifying and recording new units that are created inside old structures, especially in formerly non-residential buildings, may be an issue in some areas.

The portion of residential construction measurable from building permit records is inherently limited, since such records do not reflect construction activity in areas without local permit requirements. For the nation as a whole, less than 2 percent of all privately owned housing units are constructed in areas not requiring building permits. However, this proportion varies from state to state and among metropolitan areas.

The annual Survey of Construction (SOC) produces regional estimates of housing units constructed in non-permit-issuing jurisdictions. The regional SOC estimates are then distributed to all sub-county areas that have no record of issuing permits for the estimates period. This distribution is based on the sub-county area's share of the regional total of units in non-permit-issuing jurisdictions as of Census 2000.

The Census Bureau derives estimates for mobile homes by allocating state mobile home shipment data to sub-county areas based on the sub-county area's share of state mobile homes in Census 2000. Specifically, the Census Bureau receives monthly reports on mobile home shipments from the Institute for Building Technology and Safety (ITBS), a not-for-profit corporation. To allocate the state mobile home shipment data to sub-county areas, the Bureau applies the sub-county area's share of state mobile homes as of Census 2000 to the updated number of mobile home shipments. The implication of this method is that the Census Bureau does not attempt to identify new mobile home parks. It assumes the distribution of mobile homes within a state is the same in the estimate's year as it was in Census 2000. It uses the mobile home shipment data only to provide a new state total of new mobile homes. The estimates of housing unit loss are based on data derived from the 1997–2003 American Housing Survey (AHS) national sample.

The housing unit estimates at the sub-county level are summed to obtain county level housing unit estimates, which are then summed to produce state level housing unit estimates.

Sub-County Population Estimates

The Census Bureau develops sub-county population estimates using the "Distributive Housing Unit Method," which uses housing unit estimates to distribute a county's population to sub-county areas within the county.

The Census Bureau develops a household population estimate by applying the occupancy rate and average persons per household from Census 2000 at the sub-county level to the estimate of housing units. The estimates obtained from this method are then controlled to the final county population estimate. The non-household population is measured by the change in the group quarters population. The Census Bureau produces the final estimate by adding the population in group quarters to the household population.

Title 15 of the U.S. Code outlines the rights of states, counties, and other units of general-purpose government to challenge the population estimates produced by the Census Bureau. The Census Bureau requests local governments that wish to challenge their population estimate to provide data on housing unit change, such as building permits or utility connections, in order to calculate a new estimate of housing units. Both the occupancy rate and the Persons Per Household (PPH) are taken from Census 2000 and applied to the updated estimate of housing units to create a new estimate of the household population. The method used in the challenge procedure is essentially the same as the sub-county estimate method except the sub-county estimate is controlled to the county population estimate while the challenge estimate is not.

The American Community Survey's Design

The ACS design begins with the Census Bureau's Master Address File (MAF), which is a nationwide database containing address and location information for every living quarter in the United States. While the MAF was initially created to support Census 2000, it also serves as the main source of the housing unit sample for the ACS. In addition, the housing unit counts contained in the MAF play an important part in the ACS editing, weighting, and data tabulation process. The MAF was initially constructed by matching the 1990 Census Address Control File (ACF) to the United States Postal Service (USPS) Delivery Sequence File (DSF), a file containing the address of every delivery point in the country, and adding the results of a dependent canvassing operation, called block canvassing, conducted prior to Census 2000. This method for building the MAF worked relatively well for areas of the country with city-style addressing systems; however, there were problems associated with matching the two files together in areas of the country with other addressing systems. In those areas, the MAF was built using an independent address listing operation conducted prior to Census 2000.

Following the initial creation of the address list, the Census Bureau gave local and tribal governments an opportunity to review and update the address list in the

Local Update of Census Addresses (LUCA) program. In areas of the country with city-style addressing systems, local and tribal governments were able to provide individual address updates. The Census Bureau then validated these updates either in the block canvassing operation or in subsequent field operations. In other areas of the country, local and tribal governments challenged block counts. Challenged blocks were recanvassed to verify all addresses on the list and to add any addresses that may have been missed in the initial address listing operation.

A critical element in the overall success of the ACS is the ability to keep the MAF accurate from year to year. Census 2000 field operations provided the most comprehensive updates to the MAF. The Census Bureau has regularly updated the MAF with new city-style addresses from newer versions of the DSF since Census 2000. Non-city-style addresses can be updated only by field operations. In addition, the MAF is updated based on field visits conducted as part of the Demographic Area Address Listing program and any update discovered as part of the Decennial Census field tests are also added.

ACS Reference Period

The *raison d'être* of the ACS is to provide detailed small-area information about population characteristics via continuous data collection. Interviewers are in the field throughout the year asking questions, so the reference period must be adjusted to reflect the time of the interview. In January, the ACS cannot reasonably ask, "Who lived here last April 1?" Nor would it make sense for the ACS to ask, "Who will live here next April 1?" Thus the ACS is forced to use a sliding residence rule:

- LIST everyone who is living or staying here for more than 2 months.
- LIST anyone else staying here who does not have another usual place to stay.
- DO NOT LIST anyone who is living somewhere else for more than 2 months.

Even these instructions are somewhat flexible, as the actual reference date for a sample housing unit will change depending upon whether the household responds by mail (month one), by telephone (month two), or in person (month three). The reference date is then both rolling (according to sampling wave) and sliding (according to response wave). The rolling nature produces a population measure closely related to "person-years-lived." For example, the ACS intends to include temporary foreign visitors and workers (staying here for more than two months), while this is not the intention of the decennial census. Demographers should not despair because the ACS is measured on the "current population" basis. That concept is close to the demographic concept of "person-years-lived." Applied demographers should accept that concept as a useful one.

Like all surveys, the ACS suffers from both sampling and non-sampling errors. The national ACS sample size is extremely large and, therefore, its sampling variance for large areas is small. For small groups or small areas, the sampling error can be quite large. In addition, an important source of non-sampling errors is coverage.

Relative coverage is measured by the ratio of the ACS "direct" estimates to those provided by the Population Estimates Program. The overall estimated coverage ratio of the ACS varies from year to year but trends about 95 percent relative to the population estimates, which are, in turn, based on the census coverage. The coverage for Blacks and Hispanics is nearer 90 percent, with coverage ratio of groups such as adult Black males lower still. Since the two programs use different residence rules, they can differ for reasons other than the ACS undercoverage of the "current residence" population. For example, the coverage ratio can be very low in student housing during the summer months. Still, for broad areas, the Census Bureau statisticians believe that a coverage ratio of less than one, which is nearly always the case, results from true ACS undercoverage. To address these issues, the ACS is controlled to the population estimates.

Since the ACS is measured on a "current population basis" and the population estimates are produced on a "usual residence basis," controlling one to the other requires forcing the detailed characteristics of the "current residence" population on to the number (by age, race, sex, Hispanic origin) of the "usual residence" population. The result can be logically inconsistent and confusing.

The statistical justification is that, at the county level where the adjustment is made, the improvements in relative coverage out-weigh the problems introduced by the logical inconsistency. The evidence is that the adjustments are overwhelmingly positive, that is, virtually all counties have their population adjusted up, as one would expect from the usual undercoverage of a survey relative to the census. If seasonal population movements were driving the process, one would expect a mix of upward adjustments ("usual population" higher than "current") and downward adjustments ("usual" lower than "current"). Still, there is no doubt that the statistical and demographic nature of this adjustment needs to be better understood.

The ACS weighting is complex and begins with the inverse of the sampling probabilities applied to the housing unit. A number of ratio adjustments are then applied to the housing units to bring the total up to the number in the sampling frame.

The interaction with the population estimates program begins with controlling the ACS weighted housing unit numbers to the independent housing unit estimates from the estimates program. This calculation is done at the estimation stratum level or weighting area. These are groups of counties defined, using Census 2000 data, by:

- Percent in poverty.
- Percent renting.
- Percent in rural areas.
- Race, ethnicity, age, and sex distributions.
- Core-based Statistical Area status.
- Distance between centroids between the counties.

The optimal size of an estimation stratum is around 30,000 people.

This procedure has important implications. Since the strata are already groups of counties, the ACS totals and the population estimates will not completely agree, except in large counties that are single-county strata. There will be no agreement in the population numbers from the two programs for sub-county areas, nor for any age, race, or ethnic group that was not also an estimation stratum.

The person weighting starts with the housing unit weights controlled to the population estimates by age, race, sex, and Hispanic origin. Again, these are controlled at the estimation stratum level, which is a county or groups of counties.

The demographic groupings are collapsed. The groupings used are:

- Non-Hispanic White.
- Non-Hispanic Black.
- Non-Hispanic American Indian or Alaskan Native.
- Non-Hispanic Asian.
- Non-Hispanic Native Hawaiian or Other Pacific Islander.
- Hispanic.

A major issue is the collapsing of the race detail collected in the ACS into race categories used in the weighting procedure. At this step, the Census Bureau uses the "majority-minority" rule to handle the multi-race non-Hispanic allocation to single race. This means that the multi-race group is combined with the largest of the minority component race groups. An SOR multi-race response is always allocated to the other specified race in the case of a two-race response.

For the 3-race response, the "majority-minority" rule is also used, grouping them with the largest minority race. Hispanic responses are always assigned to Hispanic regardless of race. The SOR-alone responses are allocated to one of the non-Hispanic race groups based on an algorithm that is consistent with the one used in the Population Estimates Program. Basically, the SOR responses are allocated to a non-Hispanic single-race group based on the ACS race distribution using a state-level hot-deck imputation procedure.

A final step in the weighting process aligns the number of households with the number of occupied housing units. Logically the number of householders, households, and occupied housing units should be the same. There is a one-to-one relationship between householders and households by definition. The concepts of household and occupied housing unit are identical. Therefore, these three estimates should be consistent at all tabulation levels. A new step instituted for processing the 2006 data forces agreement through the use of "raking" ratio estimation. Two dimensions of the "raking" matrix are householder/non-householder and base demographics, that is age, sex, race, and Hispanic origin.

This step in the person weighting process assigns all person records to one of two cells: householders and non-householders. The marginal for householders is the estimate of occupied housing units based on the previously assigned housing unit weight. The marginal for non-householders is equal to the total from the Population Estimates Program minus the marginal used for the first cell. This raking process is done in order to control for the total population. The second dimension of the raking matrix is the base demographics. All estimates of occupied housing units, households, and householders are based on the same weight, the householder weight, and therefore all three estimates are consistent.

Fewer steps are needed for GQs because all of the ACS data are collected *via* personal visit, and the tabulation month is not used in any adjustments of GQ weights. The base weight is the reciprocal of the sampling rate. A non-interview factor is calculated to account for GQ residents who do not complete an interview. The ACS data are controlled to estimates at the state level by type of GQ provided by the Population Estimates Program.

Measurement Issues

The published ACS estimates are the result of many measurement processes, each developed separately. While much of the information comes from the ACS interviews, because the controls used are from the Population Estimates Program, data on estimated housing units from building permits, mobile home shipment reports, and the American Housing Survey are also inherently included. Population totals come from birth and death records compiled by the states as well as from federal tax records. Census 2000 data are used in several processes. The concepts of race and ethnicity differ among the sources: vital records, administrative records, and censuses and surveys. The ACS uses the concept of "current residence." Census 2000 records and the population estimates use the concept of "usual residence." The residence rules of the tax records reflect the idea of legal domicile. Birth and death records reflect the concept of usual residence of the mother (birth) or most recent residence of the decedent (death). When one controls one to the other, what is being measured?

Have applied demographers been using "usual residence" because that is the concept we want, or have we been using it to approximate person-years-lived because that is how the data were made available? It is not that "current residence" can be used to "approximate" the mid-year population; it is the mid-year population that has approximated the person-years-lived. Perhaps demographers should accept that the ACS is trying to measure the "current resident" population, persons-years-lived. What are the implications?

Controlling to the housing unit estimates is logical. Seasonality in the number of housing units occurs in only a few places, for example seasonal mobile home parks. Controlling to the population estimates can also be justified. In essence, one is trading a reduction of sampling variance and improved coverage, especially for minority groups, for a confusion between two population residence concepts.

This process has an interesting implication. For bigger areas (e.g., the state of California), the ACS estimates have a sampling variance that is quite low, so there is little variance improvement from controlling to the population estimates. However, it is exactly at these larger areas where one would normally expect little difference in seasonal population. The bias increase from using the population estimates (with respect to residence concepts) is probably small. Still, there may be some large places with high seasonal variation in the population, perhaps a place like Palm Springs. The Census Bureau should explore this issue further.

Controlling to the population estimates serves another purpose, which is to reduce the coverage bias in the ACS relative to that in the decennial census. Even for large places with seasonal variation, controlling makes sense if the bias due to coverage is larger than the bias due to residence rules. So even though the ACS sampling variance for the State of California is very small, the coverage ratio (0.94) indicates the need to control to the population estimates.

The ACS also has another unique source of bias, although one not well measured. The rolling ACS interview process spreads out the interview over three months and three collection modes. If non-response at each stage is "at random," then the bias is small at worst. However, we know that it is not "at random." Vacant units are unlikely to mail back the questionnaire or respond by telephone, so the ACS is likely to underestimate the vacancy rate. There are probably other more subtle variables that have the same bias. We know some ethnic groups are more likely to respond by mail. Again, the importance is yet to be determined.

The purpose of the ACS is to provide detailed social, economic, housing, and demographic characteristics – that is, distributions – at the local level. It was not intended to provide improved estimates of population counts, but the numbers are available. This availability has already caused confusion with the first release of the ACS estimates in 2006, which gave a figure for the total household population. Since these estimates were for the housing unit population only, they could not be directly compared with the population estimates. However, since the numbers were not well labeled, comparisons were made and confusion generated.

The ACS was not designed specifically to measure year-to-year change in the population counts. The Current Population Survey, by contrast, is designed specifically to provide good measures of change. Certainly, this does not mean that the annual estimates will not reflect the change in the underlying population. The ACS estimates will obviously reflect changes over time. The point is that the design is crafted to produce good estimates annually; it is not specifically focused on measuring annual change. For example, the ACS asks "Did you receive any wages, salary, commissions, bonuses, or tips in the PAST 12 MONTHS?" and instructs, "The 'past 12 months' is the period from today's date one year ago up through today."

To simplify somewhat, those interviewed in January 2005 would be reporting on January 2004 through December 2004, those interviewed in February would report February 2004 through January 2005. Thus in the year 2005 interview data, January 2004 would be represented once, February twice, etc. Thus, we might represent the income data from interview year 2005 as:

$$1^{*}\text{Jan04} + 2^{*}\text{Feb04} + 3^{*}\text{Mar04} + \ldots + 12^{*}\text{Dec04} + 11^{*}\text{Jan05} \ldots + 2^{*}\text{Oct05} + 1^{*}\text{Nov05}.$$

Similarly the 2006 interview year data reflect

$$1^{*}\text{Jan05} + 2^{*}\text{Feb05} + 3^{*}\text{Mar05} + \ldots + 12^{*}\text{Dec06} + 11^{*}\text{Jan06} \ldots + 2^{*}\text{Oct05} + 1^{*}\text{Nov06}.$$

If we look at the change between interview years by subtracting 2005 from 2006 data, we get the following coefficients on the representation of each month's data:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2006	11	10	9	8	7	6	5	4	3	2	1	
2005	–10	–8	–6	–4	–2	0	2	4	6	8	10	12
2004	–1	–2	–3	–4	–5	–6	–7	–8	–9	–10	–11	–12

One should take the exact form of this equation with caution. There are serious issues of sampling, weighting, and estimation, as well as the fact that the interviews are conducted throughout the month. What should be clear is that comparing the 2005 with the 2006 estimates is not really comparing the conditions in 2005 with those in 2006. Although the ACS will certainly show the trend over time, precise year-to-year comparisons can be misleading.

The challenge for the Census Bureau is that once the data begin to be released annually, people will notice changes, some real but some due to the limitations of ACS design. Even if the ACS works perfectly, it will show implausible changes for some groups and areas, and, implausible or not, the changes its data indicate will not agree with the measures provided by the Population Estimates Program.

The ACS is controlled to the population estimates only for modified race groups and only for the weighting areas. These weighting areas are counties or groups of small counties. The modified race groups constitute a rearranging and collapsing of the full cross-classification of race (including multiple races) and Hispanic origin. There is no population control for smaller groups or for sub-county areas. Sound statistical reasons dictate this limitation. Controlling to very small cells defeats the purpose of reducing variance and can make the estimates worse.

This limitation, however, is sure to produce oddities in some of the many data cells released by the ACS. The change in population size for towns that are not also counties is certain to differ from the Population Estimates Program's results. Further, the ACS's implied changes will not be believable in many cases. The ACS population total for a city may rise or fall simply because of variance. The number of people in a small group may also rise or fall, again simply because of variance. Given enough cells, the law of probability says that in a few cases these implied changes will be dramatic. A town growing in the Population Estimates Program may be shown to be losing population by the ACS. The Hispanic population of a city, as measured by the ACS, may suddenly change from being Salvadorans to being Guatemalans.

One important issue is the level of possible confusion for data users created by two conceptually different measures of the population. Even if the differences are conceptually explainable and statistically valid, they create the need to integrate the two systems in users' plans and decisions.

Professional demographers who have studied the ACS will understand that these changes may not be real, nor do they necessarily result from an ACS processing error. Rather, they may be the result of the design and the basic limitations of a survey sample. Applied demographers need to be ready when a newspaper reporter calls or a city administrator calls. It will be all too easy for someone to produce a story that seems to discredit the ACS data.

Important Avenues for Research on the ACS and the Population Estimates Program

The Population Estimates Program, including its housing unit estimates, and the ACS, need to be considered as a system designed to meet user needs. How can this best be done?

Controlling to the Population Estimates

One area for possible research is in further controlling the ACS to the population estimates. This control could be a two-way raking, raking first to the age/sex/race/Hispanic controls at the county level and then to the population totals at the sub-county (or sub-weighting-area level). This two-way raking would be similar to the method described above to force agreement between occupied housing units, households, and householders. The Census Bureau staff has been reluctant to do this step for two important reasons. First, the Census Bureau may not have the time and resources to do this every year. What was possible every 10 years may not be possible every year. Moreover, it may not be possible to do this raking well enough to meet the Census Bureau's quality standards and users' needs. Absent two-way raking by the Census Bureau, users may be trying to do this control on their own on an *ad hoc* basis. If this is true and a strong need exists that the Census Bureau can meet, then it will need to re-consider. The Census Bureau certainly is interested in what the professional community thinks.

Integration with Housing Estimates

The integration of the ACS and the Census Master Address File with the housing estimates program has already created much interest. [See, for example, Swanson 2006]. With the updates to the MAF to prepare for the 2010 Census now taking place, a change in housing estimates methods to rely on the MAF needs to wait. The issue is not just overall national completeness. It is how changes in the MAF reflect changes in the housing unit stock and not just changes produced by the Census Bureau's update cycles. This research may call for more integration between the American Housing Survey, the MAF, the housing estimates unit estimates, and the building permit program of the Survey of Construction.

HUBERT

The Housing Unit Based Estimates Research Team (HUBERT) was formed as a response to calls from external data users to move from a reliance on one methodology for county-level population estimates to the use of multiple methods and to advance the understanding of the housing unit estimate method. The use of the housing unit estimates as controls for the ACS, new opportunities offered by the full implementation of the ACS, and the ongoing maintenance of the Master Address File (MAF) make this the right time to both review the current methodology and explore future possibilities for these estimates. The HUBERT project has combined research in three areas with the practical goal of producing county-level population estimates. Included in the three areas are a review of the components currently used to produce the housing unit estimates, the use of the ACS to obtain estimates of Persons Per Household (PPH) and vacancy rates, and the use of the inputs to the MAF to improve the housing unit estimates.

The full implementation of the ACS may provide an opportunity to obtain estimates of PPH and vacancy rates throughout the decade at levels of geography previously not possible. However, a great deal still needs to be understood before the use of the ACS in this way would be accepted by external data users. The Population Estimates Program explicitly begins with housing unit counts from the most recent census and also relies upon data on vacancy and PPH from the most recent census. The use of the ACS for estimates of PPH and vacancy would result in a break from the current practice. Through HUBERT, the Census Bureau is looking at differences between ACS data and census data due not only to residence concepts but also to coverage differences, data processing differences, and differences in questionnaire design. In terms of estimates of PPH and vacancy rates, the continuous nature of the ACS and the cross-sectional design may be among the greatest strengths of the ACS, as the same level of error would be expected whether the estimates generated from the ACS are one year out from the decennial census or nine years, rather than the current expectation that the error in the estimates will get larger with each year away from the census. In order to develop a better understanding of the implications of the use of the ACS for estimates of PPH and vacancy rates, Census Bureau staff is examining the measures that will allow statements about the error that would be introduced into the estimates to be made.

One of the greatest challenges associated with the use of the MAF is the identification of “existing housing units.” Depending on how addresses included in the previous census are handled during the creation of the MAF extracts, this process may represent another point where the link between the estimates and the previous census is broken. The goal is to develop a complete enough understanding of the MAF and the sources used to update it that criteria can be identified for what constitutes a valid housing unit, producing the best housing unit estimates possible.

Group Quarters

The ACS now includes the Group Quarters population. Certainly the ACS will provide additional information about group quarters, but it faces an interesting challenge. Important parts of the group quarters population are more seasonal than the overall housing unit population (e.g., college dormitories). As we deal with the group quarters population, the differences between the “usual residence” population and the “current residence” population will be highlighted.

Statistical Modelling

The Census Bureau is also investigating an approach to reduce the variance of sub-county estimates, namely, the use of generalized regression estimation (GREG) as an additional component of ACS estimation. The GREG methodology is applied to data from administrative records, changing the ACS weights. In this approach, a step of GREG estimation is added to the existing estimation methods, so that the other steps of ratio estimation to control totals remain.

Seasonal Populations

Additional areas of research interest include understanding seasonal populations in order to understand the differences between the ACS and the population estimates, and soon, the 2010 Census. It is also of interest in its own right because locations with large seasonal populations could use more accurate data. One area of opportunity is the National Change of Address File (NCOA) that the Census Bureau recently received from the USPS. As noted above, the Census Bureau used a smaller version of the NCOA to measure post-hurricane population movements. Using the national file is much more challenging, but it may provide a data source to track seasonal movements as well as moves of “residence” not related to changes of tax domicile.

Internal Migration

Another promising opportunity is integrating the ACS estimates of internal migration with those derived from IRS tax return data. The Census Bureau is already using the ACS as an informal check on its models. A more formal integration may be helpful.

Modified Race Data

An interesting but complex area of integration is in consistency of race data. New steps are needed because measures from birth records on race and Hispanics are not consistent with those from the Census Bureau. The ACS provides annual information on births last year that can be reconciled and possibly matched to birth records. These added data may help correct a source of inconsistencies.

Summary

The ACS was primarily designed to measure characteristics, not population totals or year-to-year change. The Population Estimates Program, in turn, was designed to measure totals and annual changes. Since many users will need to associate the characteristics with the counts, the ACS will inevitably be used to look at changes for small group totals. The users' responsibility is to understand the limitations of the statistical and the demographic measurement processes. The Census Bureau's responsibility is to better integrate the overall system and to work with users to make the estimates as useful as possible.

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Chapter 3
Using the 2005 American Community Survey

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Using ACS Data

In August through October 2006, the Bureau of the Census released the first products from the nationwide American Community Survey. Eagerly awaited by users, this data set provided the first update to 2000 Census numbers for small areas across the nation. A full range of variables is available for states, for counties and places of 65,000 population or more, and for towns/townships of the same size in selected states. The release also included other geographic areas, such as congressional districts and school districts, which meet the 65,000 population threshold. The data are all available on the Internet through the Census Bureau's American FactFinder website.

The products take a variety of forms. They include:

- *Profiles for geographic areas*. These profiles are useful, but take too many pages in printing. They need to be more compact and print in a neat format suitable for lay consumption.
- *Selected population profiles*. These are available for only a few population groups in a few areas. They are difficult to use because, to compare groups with each other, the user must download each profile separately and then cut and paste to make a comparison document.
- *Subject tables*. These tables are useful if the particular tabulations happen to meet the user's needs. They are likely most helpful in libraries. One flaw is that only one geographic area can be examined at a time.
- *Geographic comparison tables*. These tables are of limited use because they show only one variable at a time. They are helpful for such inquiries as, "what county has the highest median income in the state?," although at this time only counties of 65,000 or more population are included.
- *Thematic maps*. These maps have a fairly high learning curve. The effort is worthwhile for some applications.

S.H. Murdock and D.A. Swanson (eds.), Applied Demography in the 21st Century, 31–35.

This brings us to the product that most applied demographers use most of the time, the detailed tables. Prior to receiving the 2005 data, we had worked with data delivered in this format on several projects, using tabulations for national data and data for places of 250,000 or more that were made available from earlier, smaller ACS samples. With the 2005 data release, we planned a Michigan profile, consisting of 6 pages of tables including 30 to 35 subtables, or variables. The profile was to include 63 geographic areas: the State of Michigan, 26 counties, 22 cities and townships, and 12 PUMAs to provide data for areas of the state not otherwise covered.

The process for creating the profile entailed the following steps:

1. Write the table outlines, using our 2000 profile as a guide
2. Create an AFF query with the right geography and save it, so that we could "load query" each time we accessed the data set.
3. Identify the correct tables.
4. Download the tabulations to Excel.
5. Manipulate the data to create the presentation rows for the profile.

Specific Problems in the Tables

The powerpoint presentation at the January 2007 Applied Demography conference illustrated a variety of specific problems with the detailed tables, which may be taken as examples. These include the following:

- There is no easy way to obtain the unemployment rate for a community. Using Table B23001, the user must add together the individual figures for each age/sex group, separately for the counts of employed and of unemployed, to obtain the numerator and denominator for the statistic.
- Spanish is, by far, the most common non-English language in the country; therefore, it is the language of most interest for social programs. The detailed tables on language include too many languages, including those which are rarely spoken anywhere, and thus were suppressed in many geographic areas. This makes it impossible to look at how well Spanish speakers speak English, even though the items are on the questionnaire and even where the count of Spanish speakers is quite high.
- Most users calculate vacancy rates on the basis of year-round housing units; i.e., seasonal units are omitted from both the numerator and the denominator. Table B25004 has the required variables, but is suppressed for a large number of areas. This is likely (we do not know for sure) because there are few seasonal units in urban areas, and the low count in this one cell of the table causes the entire table to be suppressed. Table C25004, the collapsed version, omits the seasonal detail. We did the calculations using the two tables together, and assumed that, in areas where the seasonal counts were unavailable, the number of seasonal vacancies was zero. This is an imperfect solution, at best.

General ACS Table Problems

There are many other problems with the ACS tables. For example:

- It is almost always necessary to add counts for male and female to get the "both sexes" count for a specified characteristic, even when interest in the variable cross-tabulated by sex is low.
- It is very difficult to see the universe for the table. It should be part of the title.
- C tables should have different titles from B tables, even if they are just preceded by the word "collapsed."
- The table numbering is arcane. Most users are familiar with the sequencing of tables used on the decennial census summary files, which is fundamentally the sequence of items on the questionnaire itself. ACS sequencing appears to be random.
- ACS detailed tables should be designed to support the lowest level of geography, not the highest. Suppression should be rare even for the smallest geographic areas in the data set; here, those which are close to 65,000 population. A detailed table which contains data only when the geographic area is large, say 500,000 population or more, is not useful most of the time. Users desiring this level of detail, for geographic areas of this size, are better off using the Public Use Microdata Sample (PUMS) file.

Problems with American FactFinder

There are also a number of issues with the design of American FactFinder (AFF). Users are required to reload screens too often and to move across screens with the keyboard arrows because the view is incomplete. The subject matter search does not "hold," requiring a new search every time the button is clicked. There is no way to save geography and table selection queries separately. AFF is scheduled for a major revision beginning later this year; we hope that users will be heavily involved in the process.

Margins of Error

Inclusion of margins of error (MOE) in ACS tabulations has been the subject of much discussion and debate. We agree that they need to be there. In user-ready presentations, such as the profiles and the subject tables, we would prefer that MOE be shown in plus/minus percentage terms rather than as whole numbers, even when the statistic itself is reported as a count. This would make it much easier for lay users to observe when the MOE matter, and when they are relatively trivial.

In the profile we created, we did not pass the MOE down to the end user. Instead, recognizing the important role of the intermediary, we smoothed the data by rounding whole numbers to ’00s and by avoiding the use of decimals in percentage distributions. This makes overinterpretation less likely.

The arrangement of MOE data in detailed tables, in the columns immediately to the right of the estimates, makes manipulation of these tables in spreadsheets very difficult, especially when multiple geographic areas are downloaded at the same time and when these areas need to be aggregated into a custom statistical area.

Summary File

After we had completed the work of creating our profile, the Census Bureau released a prototype summary file (SF) with the same data as presented in the detailed tables. We have not had the opportunity to work with this product. It is clear, however, that the tables need a complete redesign (noting the types of problems cited earlier) so that they work well for small area geography. It would also be helpful if software were provided that made it easier to create MOE for custom geography created by aggregating groups of census tracts, communities, or counties.

Looking to the Future

First and foremost, future ACS products need the benefit of real user input. Our recommended form of input would begin by creation of a working group of expert users from around the country who could examine the issues and make recommendations. We have been told that the current tables were designed with input from the subject experts inside the Census Bureau. With all due respect to their expertise, they are not small area data users and do not have the appropriate experience for this task. While there was one opportunity for users to comment on the products, via a Federal Register Notice, responses did not affect the design of the detailed tables themselves.

The other required new initiative concerns statistical geography. The bureau made a good decision when it agreed to publish the ACS data for PUMAs. However, the 2000 PUMAs were not designed for use with ACS data; a new look is needed. Ideally, these statistical geographic areas should be explicitly designed for the delivery of data at the one-year (65,000 population) and three-year (20,000 population) data releases. The current PUMAs are all at least 100,000 in population size. A prototype for such a project can be found in the existing Participant Statistical Areas Program used by the Geography Division to solicit local input on the delineation of census tracts, block groups, and census designated places.

Conclusion

None of what has been written here deals with the problems that will emerge with the upcoming release of three-year and five-year data tabulations. This is an entirely new challenge, one that is part of the paradigm shift taking place in the data sets used by planners to understand demographic and socio-economic conditions.

It is time for the ACS to emerge from the private corner it has occupied for many years within the Census Bureau, and to benefit from the user input that is required if it is to, in fact, be a long-form replacement and meet the user needs of the nation.

Chapter 4
Address Coverage Improvement and Evaluation Program – 2005 National Estimate of Coverage of the Master Address File*

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This evaluation reports the results of research and analysis undertaken by the U.S. Census Bureau. It is part of a broad program, the Address Coverage Improvement and Evaluation Program, designed to assess a range of issues related to housing unit coverage and quality of the Master Address File. In the U.S. Census Bureau Strategic Plan for fiscal years 2006 through 2010, strategic goal #3 requires that the Census Bureau "implement a comprehensive plan for periodic Master Address File/Topologically Integrated Geographic Encoding and Referencing evaluation and corrective activities that will guide planning for cost-effective improvements to coverage and geocoding operations" (U.S. Census Bureau 2006). The plan for meeting these goals included the production of an annual report of the National Estimate of Coverage of the Master Address File.

We calculate the National Estimate of Coverage each year using the Census 2000 housing unit count as our baseline housing unit estimate for the fifty states and District of Columbia for April 1, 2000. We then use the Population Division's housing unit estimates to calculate the change in the housing unit count for years subsequent to 2000. We use this change estimate to update the 2000 baseline and obtain truth estimates for the number of housing units for 2002 through 2005. Finally, we compare the estimated true housing unit count to annual housing unit counts from the Master Address File, which is the Census Bureau's continually updated database of living quarters, to arrive at net coverage estimates.

The main use of the Master Address File in intercensal years is as the sampling frame for the American Community Survey. In this report, we estimate that the sampling frame for the American Community Survey had 3.36 percent net overcoverage in 2005. We also estimate the net coverage for subsets of the American Community Survey sampling frame to give an idea of Master Address File coverage

* This report is released to inform interested parties of ongoing research and to encourage discussion. The views expressed are those of the author and not necessarily those of the U.S. Census Bureau.

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for other Census operations. When we remove “excluded from delivery statistics”[1] records from the full sampling frame we find 0.13 percent net undercoverage, and when we remove ungeocoded[2] records from the full frame we find 1.08 percent net undercoverage in 2005. Finally, we remove both excluded from delivery statistics and ungeocoded records from the full sampling frame and find net undercoverage of 3.33 percent in 2005. Note that this is more than six-percentage points less than the net coverage estimate of the full American Community Survey frame.

From 2002 to 2005, the net coverage estimates have diverged for the full American Community Survey sampling frame and the subsets of the frame, mainly due to increases in the number of excluded from delivery statistics and ungeocoded records on the Master Address File. Accurately maintaining the national list of addresses continues to be a challenge for the Census Bureau, and we must work throughout the intercensal years to minimize coverage problems and to ensure that the Master Address File provides a good representation of all valid living quarters throughout the nation.

Background

Master Address File Basics and Previous Evaluations

The Census Bureau created a nationwide address list, called the Master Address File (MAF), to document the physical street address (or comparable location description), the mailing address, and the census block location of all living quarters in the United States and related Island Areas. This address list was created with extensive cooperation from the United States Postal Service (USPS), in accordance with the provisions of Public Law 103–430, the “Census Address List Improvement Act of 1994” (U.S. Census Bureau, Geography Division 2004).

In 1998 the Census Bureau conducted the MAF Quality Improvement Program (QIP) to assess coverage, geocoding, and other characteristics on the initial MAF within Census 2000 mailout/mailback areas. The initial MAF consisted of the 1990 Address Control File merged with the November 1997 Delivery Sequence File (DSF) from the USPS and only existed for areas of the country contained within the mailout/mailback areas. Mailout/mailback areas are those where predominately city-style (house number/street name) addresses are used for mail delivery by the USPS.

[1] When a record is Excluded from Delivery Statistics, it means that the U.S. Postal Service is not currently delivering mail to that address. This could occur for a variety of reasons. One example is in new subdivisions where the postal carrier may add the addresses to the database before the units are completed and occupied. Until the unit is ready for mail delivery, the postal carrier will list it as an Excluded from Delivery Statistics record.

[2] Geocoding is the process by which an address is assigned numeric codes that identify its geographic location (for example: state, county, census tract, census block). When a record is ungeocoded, it means that the record has no block code on the Master Address File.

The following national-level estimates were produced in the QIP (Burcham 1999):

- 9.08 percent gross undercoverage (existing housing units that were missing from the MAF)
- 12.84 percent gross overcoverage (non-existent housing units that were on the MAF)
- 6.23 percent geocoding error (existing addresses that were geocoded to the wrong block on the MAF)
- 6.40 percent ungeocodable match rate (existing addresses that were ungeocoded on the MAF)
- 0.13 percent non-residential coding error (existing housing units that were incorrectly coded as non-residential on the MAF).

After the creation of the November 1997 MAF, the Census Bureau used several different address sources to update the MAF prior to and during Census 2000. This updating included several different deliveries of the DSFs as well as field operations and local government operations (Bureau of the Census 2001).

Following Census 2000, the Census Bureau conducted the Accuracy and Coverage Evaluation (ACE) to measure the nationwide coverage of housing units and persons in the Census 2000 inventory, in both mailout/mailback and non-mailout/mailback areas. The following national level estimates were produced in the Census 2000 Housing Unit Coverage Study (HUCS) using data from the ACE (Barrett et al., 2003):

- 0.61 percent net undercoverage
- 3.62 percent P-sample[3] non-matches (gross undercoverage)
- 2.31 percent erroneous enumerations (gross overcoverage)

(Note: One may expect that the net percent undercount above would be similar to the difference between the percent of P-sample non-matches and the percent of erroneous enumerations. This is not the case because different denominators were used for the three calculations.)

Lastly, the Census Bureau produced annual National Estimate of Coverage reports for 2002 through 2004. These reports found the following national estimates of net coverage of American Community Survey (ACS) eligible units using the most current baseline estimates available at the time:

- 2.05 percent net overcoverage for 2002
- 2.30 percent net overcoverage for 2003
- 2.67 percent net overcoverage for 2004

Unlike the ACE and QIP, the evaluations for the Address Coverage Improvement and Evaluation Program (ACIEP) do not have a field component to establish truth. Instead, we use estimates from the Census 2000 HUCS and from Population Division as truth. A field exercise was considered, but the Geography Division (GEO),

[3] The P-sample, or population sample, was the set of housing units that were confirmed through the ACE independent listing to have existed in the sample block clusters on census day.

the sponsors of the evaluation, determined that there were not sufficient budget resources to perform a field component.

Motivation

As a primary source of addresses for a range of demographic statistical operations that the Census Bureau conducts, it is important that the MAF be as accurate as possible. Errors in the MAF could potentially lead to, for example, under or over-representation of certain demographic populations, or inadequate or unessential funding for social programs (Bureau of the Census 2004).

In the U.S. Census Bureau Strategic Plan for fiscal years 2006 through 2010, strategic goal #3 requires that the Census Bureau "implement a comprehensive plan for periodic Master Address File/Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) evaluation and corrective activities that will guide planning for cost-effective improvements to coverage and geocoding operations" (Bureau of the Census 2006). In the Annual Performance Plan for fiscal year 2002, two goals were that the address list for the 2010 Census be "at least as complete as it was for Census 2000" and that the Census Bureau "prepare plans and systems by the end of fiscal year 2002 to measure housing unit coverage of the address list" (Bureau of the Census 2005). The plan for meeting these goals included an annual report of the National Estimate of Coverage of the Master Address File. The first report was produced in September 2004, the second annual report was produced in September 2005, and this report is the next step toward satisfying the requirement.

Question Answered in this Report

At the national and regional levels, "On July 1, 2005, what is the estimate of net coverage on the MAF?" The estimates are produced including and excluding the ungeocoded records and the records classified by the USPS as "Excluded from Delivery Statistics" (EDS). Therefore, four estimates are produced at the national and regional levels. Additionally, this year's report includes supplemental research about the MAF, including tracking the status of EDS and ungeocoded records, information about the MAF Geocoding Office Resolution (MAFGOR) program, and ACS final disposition for EDS and ungeocoded records in 2004.

Methodology

Housing Unit Filters on the MAF

The MAF is a database of records that represent living quarters. Users of the MAF can define which records they consider valid so as to best fit their application. The set of rules that define valid housing units is called a filter and the resulting address list is called an extract. The MAF is the primary source of addresses for both the decennial census and the ACS. During the intercensal period the ACS is the primary recipient of extracts from the MAF. Due to the operational differences between the decennial census and the ACS, there are differences in their definitions of a valid housing unit on the MAF (Pennington and Loudermilk 2003).

For example, since it is important for the ACS to minimize undercoverage, ungeocoded addresses (that are new since Census 2000) from counties inside the blue line,[4] possibly representing new construction, are included in the ACS definition of a valid housing unit. This can be done because the ACS procedures allow the field representatives to search within county boundaries for each address. Census operations, on the other hand, require geocoded addresses for the initial address lists. In census operations such as Address Canvassing, individual enumerators are given assignment areas and initial lists of addresses in those areas. These assignments are created by census block so if a housing unit is not geocoded (assigned to a census block) it cannot be placed in an assignment (Pennington and Loudermilk 2003). Ungeocoded units are captured during these operations only if they are found in the assigned block and added by the lister.

Another difference between the ACS and census filters is the treatment of the EDS records. In the past, the ACS included these records in the sampling frame, and they were excluded for decennial census operations. EDS records are those records from the DSF that are excluded from the USPS delivery statistics for various reasons (see Appendix C for EDS codes and descriptions). These have also been referred to as “no-stats” or x-records. We suspect that some of these records may also represent new construction. For example, in a new housing development, the USPS may add the addresses to its database but will not deliver mail until the homes are finished. In the time between the addition of that record to the address list and when the sampling takes place, these houses will most likely be finished and occupied (Pennington and Loudermilk 2003). Recently, decennial operations have begun considering a change in the treatment of EDS records. In the 2006 Census Test Address Canvassing operation, the EDS records were included in the address list to research the outcomes in a decennial operation. Other research into the EDS records is ongoing as well. Based on these results, it is possible that the 2010 Census filter

[4] The “blue line” is a term used to describe the delineation of areas that are termed mailout/mailback for census operations and those that are not (such as update/leave, update/enumerate, and others). Mailout/mailback areas are termed “inside the blue line” and have mostly city-style addresses.

will be changed to include some or all of the EDS records that previously would have been ineligible for census operations.

Since the purpose of this project is to evaluate the coverage of the MAF, we need to look at the primary user of the MAF. Currently, the MAF is being used mainly as a source of addresses for the ACS. Therefore, we use ACS rules when defining valid housing units on the MAF in this analysis. However, estimates based on ACS housing rules alone do not give an adequate picture of the behavior of the MAF. Unlike the census, which canvasses the ground and has methods to add new construction after the address list is received from the MAF, the ACS must make its sampling frame as inclusive as possible *a priori* to meet the goal of minimizing undercoverage. This inclusiveness leads us to expect that counts based on the ACS rules alone will show a net overcoverage. Therefore, in addition to estimates of coverage using the ACS housing unit rules, we also show estimates of coverage when the EDS and the ungeocoded records are removed.

Computing the National Estimate of MAF Coverage

To evaluate the housing unit coverage of the MAF without a field operation, there needs to be a definition for the true number of housing units in the United States.[5] In keeping with the previous National Estimate of Coverage reports, our definition of truth for the number of housing units is derived from two sources: housing unit Dual System Estimate (DSE) from the Census 2000 HUCS and the Population Division's annual housing unit (POPHU) estimates. DSEs are evaluative and are used here for research purposes only. They do not constitute the official census count of housing units for Census 2000.

We use the Census 2000 housing unit DSE to assist in estimating truth for each year beyond 2000. Each year's estimates are calculated by computing the percent change between the POPHU estimates from 2000 and the POPHU estimates from the year of interest. This calculation establishes a change estimate. Multiplying this change estimate by the DSE yields the estimated housing unit increase. Adding the increase to the original DSE gives the estimate of the true number of housing units for the year of interest. We then compare these estimates to the counts of ACS-defined housing units on the MAF to arrive at net coverage estimates.

One limitation in this methodology is that using the DSE as the base for annual truth estimates assumes that the coverage error measured in the HUCS is the same for all subsequent years. In other words, adjusting the DSE to come up with truth estimates through 2005 gives a "best case" estimate of the number of units on the ground because it is reasonable to assume that coverage has deteriorated over time.

Additionally, this methodology assumes that the change in the POPHU estimate is similar to the actual change in housing units on the ground and therefore the POPHU estimate will show a constant rate of coverage relative to the truth. The

[5] In this report, the national housing unit counts and coverage estimates do not include Puerto Rico.

POPHU estimates themselves show undercoverage relative to our definition of truth, but this is to a large degree due to the fact that the estimates are baselined from the most recent census. Any coverage problems in the census will then, by default, also be reflected in the POPHU estimates. The Population Division invests considerable resources in the accurate production of its estimates and has shown in the past that it is successful in capturing housing unit change; the April 1, 2000 POPHU estimates computed from the 1990 baseline were only 0.3 percent lower than the Census 2000 housing unit counts (Devine and Coleman 2002).

The formula for computing the net coverage rate on the MAF for year y is as follows:

$$\text{Net}_y = \frac{\text{MAF}_y - \text{DSE}(1 + C_y)}{\text{DSE}(1 + C_y)} \times 100\%,$$

where C_y = the POPHU change estimate (see below), DSE = dual system estimate of housing units from year 2000, MAF_y = MAF estimate of housing units from year of analysis using ACS filters with and without the EDS or ungeocoded records where $y = 2002, 2003, 2004$, and 2005.

The formula for the change estimate is as follows:

$$C_y = \frac{\text{POPHU}_y - \text{POP}_{2000}}{\text{POP}_{2000}},$$

where POPHU_y = the Population Division's national estimate of housing units for year y, where $y = 2002, 2003, 2004$, and 2005, POP_{2000} = the Population Division's national estimate of housing units for April 1, 2000.

The estimate of truth for each year is $\text{DSE}(1 + C_y)$.

Housing Unit Counts

The DSE, POPHU estimates, and MAF counts each have their own methodology to arrive at their respective values. The POPHU estimates and MAF counts are created every year in July while the housing unit DSEs were created for Census 2000. The methodology for each of these is detailed below.

Housing Unit Dual System Estimate

As stated earlier, the housing unit DSE was developed during the Census 2000 HUCS using data collected during the ACE. The ACE used a nationwide area sample designed to measure the net overall and differential coverage of U.S. population and housing units in Census 2000. To avoid confusion, it should be noted that there was a revision to the original ACE estimates released in March 2003, but these revisions applied to coverage estimates for persons only. Housing unit estimates such as those used in this report were not revised.

In the HUCS, housing unit records from the census were compared to housing unit records from an independent listing in the sample areas. The following formula was used to produce an estimate of total housing units in the nation (Barrett et al. 2003):

$$\mathrm{DSE} = \frac{(C)(\mathrm{CE}/N_e)}{M/N_p},$$

where C = the count of housing units in the census (*does not include reinstated*[6] *units*), CE = the weighted estimate of the number of correct enumerations in the E-sample,[7] N_e = the weighted number of E-sample housing units, M = the weighted number of P-sample[8] matched housing units, N_p = the weighted number of P-sample housing units.

The ACE was designed to produce the most accurate estimate of housing units possible by estimating the number of housing units that were missed by the census listing, by the independent listing, and by both listings.

Population Division Estimates

The Population Division computes estimates of housing units for each county in the nation (summed up from sub-county data). At each census, these estimates are adjusted, or baselined, to closely match the housing unit counts from the census. From this baseline count, the subsequent yearly estimates are computed.

The Population Division develops yearly housing unit estimates using building permits, mobile home shipments, and estimates of housing unit loss to account for housing unit change since the last census. The estimates are also revised backwards in time, so estimates in previous National Estimate of Coverage reports will be out of date. In this report we use the most current estimates available (Bureau of the Census, Population Division, County Housing Unit Estimates, August 21, 2006).

The Population Division produces housing unit estimates for each area by the component model described below. The July 1, 2005 estimates are used here as an example (Bureau of the Census, Population Division, August 20, 2006.

$$\mathrm{HU}_{05} = \mathrm{HU}_{00} + (\mathrm{NC}_{05} + \mathrm{NM}_{05}) - \mathrm{HL}_{05},$$

[6] Before the start of the ACE, certain units were flagged as potential duplicates and removed from the housing unit inventory. Some were *reinstated* into the housing unit inventory. Reinstated units were not in the ACE universe. Refer to Barrett et al. (2003) for more information.

[7] The E-sample, or enumeration sample, was the subset of housing units that were enumerated in the census and also in the ACE sample block clusters.

[8] See footnote 3.

where HU_{05} = Estimated 2005 housing units, HU_{00} = Geographically updated Census 2000 housing units, NC_{05} = Estimated residential construction, April 1, 2000 to July 1, 2005, NM_{05} = Estimated new residential mobile home placements, April 1, 2000 to July 1, 2005, HL_{05} = Estimated residential housing loss, April 1, 2000 to July 1, 2005. (Note: The Population Division assumes that using one-fourth of the housing unit input data for the year 2000 represents the three-month period from April 1, 2000 to July 1, 2000.)

In the following list, each of the five components of the Population Division's housing unit model is described in greater detail. (Bureau of the Census, Population Division, August 20, 2006)

1. *Census 2000 Housing Units* (HU_{00}) – Census 2000 counts of housing units at the subcounty level reflect Boundary Annexation Survey (BAS) updates that are legally effective as of January 1, 2005. The housing unit counts also include Count Question Resolution (CQR) actions, and administrative revisions benchmarked in the TIGER System and the MAF through May of 2005.
2. *Estimated Residential Construction* (NC_{05}) – New residential construction is calculated using the following formula:

$$NC_{05} = (BP_{05} * 0.98) + NPC_{05},$$

where NC_{05} = Estimate of new residential construction for the period: April 1, 2000, to July 1, 2005, BP_{05} = The residential building permits that result in the construction of new units for the period April 1, 2000, to July 1, 2005, include permits issued in calendar years 2000–2004 (accounting for a six-month lag time between permit issuance and completed construction), NPC_{05} = Estimate of new residential construction in non-permit issuing areas for the period: April 1, 2000, to July 1, 2005. (Note: The Population Division assumes that using one-fourth of the residential construction input data for the year 2000 represents the three-month period from April 1, 2000 to July 1, 2000.)

Building permit data are compiled from internal data files developed by the Manufacturing and Construction Division (MCD). These files include imputed permits where a jurisdiction did not report permit issuance for the entire year. Housing growth calculated from building permits employs a six-month lag time between the issuance of permits and completion of construction.

Two percent of all building permits never result in the actual construction of a housing unit (as derived from U.S. Census Bureau Current Construction Reports, Series C-20 and Series C-22). Therefore, a factor of 0.98 is used to estimate completed new units.

The annual Survey of Construction (SOC) produces regional estimates of housing units constructed in non-permit issuing jurisdictions. The regional SOC estimates are then distributed to all subcounty areas that have no record of issuing permits for the estimates period. This distribution is based on the subcounty area's share of the regional total of units in non-permit-issuing jurisdictions as of Census 2000.

3. *Estimated New Mobile Home Placements* (NM_{05}) – The Census Bureau does not collect updated data at the subcounty level on mobile home placements. We derive estimates for mobile homes by allocating state mobile home shipment data to subcounty areas based on the subcounty area's share of state mobile homes in Census 2000.

   We receive monthly reports on mobile home shipments from MCD. These monthly reports are then summed to calculate the annual total of state mobile home shipments.

   To allocate the state mobile home shipment data to subcounty areas, the Population Division applies the subcounty area's share of state mobile homes as of Census 2000 to the updated number of mobile home shipments. Because type of structure (the item indicating that a housing unit is a mobile home) was not a 100-percent item in Census 2000 (meaning it was only asked on the census long form), sample data are used to produce the 2005 estimates of mobile homes at the subcounty level.
4. *Estimated Housing Loss* (HL_{05}) – The 2005 estimates of housing unit loss are based on data derived from the 1997–2003 American Housing Survey (AHS) national sample. The following three types of AHS non-interviews were considered to represent permanent loss of a housing unit.

   - Interior exposed to the elements
   - Demolished or disaster loss
   - House or mobile home moved

   Housing unit loss rates based on these non-interview types are then developed for housing units based on structure type and age of structure. The rates are as follows:

   Mobile Homes: 1.58 percent

   House, Apartment, or Flat built in:

   1990–1999: 0.031 percent
   1980–1989: 0.054 percent
   1970–1979: 0.103 percent
   1960–1969: 0.172 percent
   1950–1959: 0.249 percent
   1940–1949: 0.324 percent
   Pre-1940: 0.364 percent

   Other: 0.019 percent

   Overall loss rate: 0.295 percent

   The type and age of housing units in Census 2000 for each governmental unit are used to estimate its housing unit loss. Other housing includes a variety of situations not defined above, including boats, recreational vehicles, or other housing arrangements.

5. *Final State and County Housing Unit Estimates* – The housing unit estimates at the subcounty level are summed to obtain county level housing unit estimates, which are then summed to produce state level housing unit estimates.

The county-level housing unit estimates are compared to county level population estimates. This comparison may reveal problems with the housing unit data. In some cases, these problems may be resolved by making changes to one of the housing unit components so that the housing unit estimates are consistent with the county population estimates. These are places where it is obvious that there was a problem with building permit data. An example is a city that crosses county boundaries and only one portion is receiving building permits. The number of these changes is usually small (i.e., around 4 or 5 counties). Once this step is completed, the Population Division has its final housing unit estimates (Devine 2004).

MAF Housing Unit Counts

The MAF, as noted earlier, is a database of living quarters. Records are added to the database in a variety of ways including USPS file updates and Census Bureau field operations such as the Demographic Area Address Listing (DAAL). Much is done during the updates to find and flag addresses that are erroneous or are duplicates of other addresses. The Census Bureau does not delete addresses from the MAF; rather, they are flagged so that they can be filtered out (U.S. Department of Commerce 2002).

Additionally, records are not always complete. Incomplete records may have some or none of the information needed to locate the unit. The decision of whether a record is a valid unit can be quite involved and may vary depending on the operation requesting the addresses. The Decennial Statistical Studies Division (DSSD) is the division responsible for deriving the logic that defines a valid housing unit for the ACS and the decennial census.

Each record must pass two filters to be included on the ACS sampling frame. The first filter is given to GEO, and from it an extract of the MAF with a flag called the ACS Delivery Flag is produced. This flag is not the final indication of valid status though. After ACS receives the extract, a second and final filter is performed. This filter removes records that do not have enough information to locate the structure or have values for certain fields that are known from prior experience to be erroneous. The rules for this second filter did not change from 2004 to 2005.

The housing unit filter rules have evolved and improved over time as new information is revealed and new census operations are undertaken. For example, in 2005, records from certain blocks with mixed city-style and non-city-style addresses were included in the ACS sampling frame for the first time. These differences in filter rules, of course, make year-to-year comparisons difficult; further research on the filter changes comparing 2004 and 2005 is found below.

Limitations

The methodology of this study entails certain limitations that must be kept in mind when considering the results.

Changes in Housing Unit Rules between Years

The ACS is a relatively new survey. Changes and enhancements have been made to the ACS housing unit filter rules as the survey has grown and developed over the last few years. These changes make direct year-to-year comparisons of the net coverage estimates difficult because the universe of records is not identical. Unfortunately, it is not possible to simply take the current filter rules and apply them to a MAF extract from an earlier year. Fields that are referenced in the newer rules may not exist, or might not be populated, on earlier extracts. The three major changes since the 2004 ACS extract delivery that impacted the ACS eligible units in the July 2005 extract are shown below:

1. A unit status of "Invalid September 2004 DSF address" was added to the MAF and records with this status are considered invalid for ACS.
2. The values for the Address Characteristic Type (ACT) code on the MAF were changed between the July 2004 and July 2005 extracts. The previous code of "Mixed city-style and non-city-style addresses, some have a DSF source" (M2) was replaced by the following seven codes:

   - MA: 95%–99.99% city-style addresses, some have a DSF source
   - MB: 90%–94.99% city-style addresses, some have a DSF source
   - MC: 85%–89.99% city-style addresses, some have a DSF source
   - MD: 80%–84.99% city-style addresses, some have a DSF source
   - ME: 75%–79.99% city-style addresses, some have a DSF source
   - MF: 70%–74.99% city-style addresses, some have a DSF source
   - MG: 0.01%–69.99% city-style addresses, some have a DSF source

   This change on the extract was reflected in the 2005 filter rules. Housing units added by the USPS after Census 2000 are now considered eligible for ACS if they are in blocks with the following ACT codes (see Appendix D for a listing of all ACT codes):

   - MA, MB, MC,
   - MD *only* if they are in a county that was not outside the Census 2000 blue line, and
   - M3: Mixed city-style and non-city-style addresses, all have a DSF source (note that this ACT code existed on the July 2004 MAF extract but was not considered eligible for ACS until 2005).

3. Addresses that were added, verified, moved, or changed by a Special Census operation were considered eligible for the ACS.

The current filter rules are shown in Appendix B, and further discussion of the effect of the filter changes on the number of ACS eligible units follows below.

Definition of EDS Record

In previous National Estimate of Coverage reports, the DSF *Delivery Point Type Code* on the MAF was used to identify EDS records. The possible values for this variable are:

- A–H: Residential (included in delivery statistics)
- I–P: Business (included in delivery statistics)
- Q: General delivery (included in delivery statistics)
- R–W: Residential (excluded from delivery statistics)
- X: Unknown (excluded from delivery statistics)
- Y–Z: Residential (excluded from delivery statistics)
- 1–8: Business (excluded from delivery statistics)
- Blank: Not a DSF unit

Records with a Delivery Point Type Code of R–Z were considered EDS for report purposes. Since the last report, we have uncovered some discrepancies between this variable and the most recent DSF Flag on the MAF. (There is a dated DSF Flag variable added to the MAF every six months when the DSF is used to update the MAF.) The DSF Flags have the following possible values:

Blank: DSF not yet loaded

0: Not indicated in the DSF
1: Flagged as residential on the indicated DSF
2: Flagged as commercial on the indicated DSF
3: Flagged as an EDS record on the indicated DSF

One would expect the records with a Delivery Point Type Code of 1–8 and R–Z on a given extract to have a DSF Flag equal to 3. However, there are some cases where the two variables do not coincide and some cases where the delivery point type code is blank but the record is on the DSF. We hypothesize that the vast majority of these cases occur because the Delivery Point Type Code variable is not updated for records with a ‘0’ DSF Flag, thus the Delivery Point Type Code is old for these records. Because of these discrepancies and because the dated DSF Flags are used for the MAF extracts, we determined that the DSF Flag variable was more reliable for determining DSF status. We updated the counts of EDS records for 2002 through 2005 with this new definition of EDS. Therefore, the definition is consistent throughout this report, but is not consistent with previous National Estimate of Coverage reports.

Estimates of Coverage – Net Versus Gross

One large limitation in the methodology for this report is that we use independent housing unit estimates in place of a full-scale field operation. As a result, we do not have separate measures of how many units are on the frame and not on the ground or how many exist on the ground but are not on the frame. In other words, we are limited to estimates of net coverage only.

It is important to keep in mind that this report provides no indication of the extent of the gross coverage problems on the MAF. For example, an estimate of 2 percent net overcoverage could comprise 3 percent gross overcoverage and 1 percent gross undercoverage (assuming the same denominators for the gross measures), or 13 percent gross overcoverage and 11 percent gross undercoverage.

Reference Periods

The different estimates that are used in the initial phase of the ACIEP represent slightly different time frames. The POPHU estimates represent the nation on July 1 of a given year based on the assumption of a 6-month time lag between issuance of a building permit and the actual construction and occupation of the house.

The MAF is updated by the USPS delivery sequence file semiannually in September and March, so changes that occur after the updates will not be reflected in the MAF until the next update occurs. Thus the MAF counts could potentially be lower than the actual number of units on the ground on July 1.

Geocoding Error

When addresses are geocoded, there is the potential for some to be coded incorrectly. As we are not in the field checking units in person, we do not have a way to directly evaluate how many addresses are geocoded correctly.

Reinstated Units and DSEs

During Census 2000, evidence indicated a potential overcoverage problem and that many duplicate addresses may exist on the MAF. The Housing Unit Duplication Operation was implemented to identify and remove duplicates. Potential duplicate addresses (2,374,271 excluding Puerto Rico) were flagged and temporarily disregarded from further census processing until their final housing unit status was determined. During the ACE, the status of these units was not yet finalized and ACE determined that the estimates would be more accurate if units were missing than if there were extra units present during matching. Therefore these units were not in the ACE universe for matching and consequently were not in the process for computing the national housing unit DSE used in this report. Resulting research concluded that 1,002,951 (excluding Puerto Rico) of these records should have been reinstated as valid housing units (Nash 2000)[9].

While the issue of reinstated units exists, it is not believed to be a significant source of bias in the computation of the housing unit DSE if we can assume that the probability of a late add being excluded from ACE processing is statistically independent of its inclusion probability in the ACE sample. This is the traditional dual system independence assumption. In order to introduce an appreciable bias, two conditions must occur:

1. A large proportion of correct enumerations must have been excluded, and
2. These correctly enumerated units must have a different probability of inclusion in the ACE than the non-excluded cases.

Neither of these conditions is likely to occur so we see no reason to believe that excluding these cases from ACE processing introduced significant bias (Hogan 2001).

Group Quarters

Group quarters are structures such as college dorms or prisons where occupants do not live separately or have direct access to their living areas. The housing unit DSE excluded these records from their tallies, as do the ACS and POPHU methodologies. However, incoming records to the MAF from the USPS database are not identified as group quarters, so some of the new DSF records may be group quarters. This same issue is also present in the data collected by the Population Division for the housing unit estimates. Therefore, the net effect on our counts is expected to be minimal.

Measures of Error

The four housing unit counts from the MAF are not subject to sampling error because they are tallies of all the units on the entire frame. The standard errors of the net undercoverage estimates from the Census 2000 HUCS, which were used to create the DSE for the U.S. and regions, are presented in Appendix A, Table A11 to give a rough indication of minimal variance. Additionally, the POPHU estimates, which are used to calculate the coverage estimates listed in this report, do not have published measures of error.

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[9] Note that the numbers in Nash (2000) include Puerto Rico. The numbers shown in this report have excluded Puerto Rico to maintain consistency with the rest of the report.

Results

As explained above, the number of housing units on the MAF extracts is defined by using specific filters that exclude business addresses, duplicate addresses, and addresses believed to be erroneous. Other restrictions, such as geocoding status, may also be in place. The national and regional estimates of net coverage will change with different address universes. Consequently, we present multiple estimates of net coverage using four different housing unit definitions. These four universes are defined as:

- ACS-eligible housing units (full sampling frame)
- ACS-eligible housing units excluding EDS units
- ACS-eligible housing units excluding ungeocoded units
- ACS-eligible housing units excluding EDS/ungeocoded units

Recall that an EDS record is an address that did not receive USPS mail delivery at the time of the DSF delivery to the Census Bureau. There are multiple reasons why an address might be labeled this way. Refer to Appendix C for a list of EDS codes. Ungeocoded addresses are those addresses that have not been assigned census block codes. Like EDS records, there are multiple reasons why an address might not be geocoded. One example is when a new street with housing units has not been added to TIGER. It can also occur if the address is not complete enough to place it in a specific block. Ideally, we want to minimize ungeocoded and EDS records on the MAF extract.

In sections that follow, we first present the national estimates of net coverage for 2002 through 2005, for all four universes. Then we provide regional results for 2005, including a comparison among the results of 2002 through 2005.

Formulae outlined above use the housing unit DSE and the POPHU estimates to calculate our estimates of "truth" for each year. The housing unit DSE for Census Day (April 1, 2000) is 116,586,458 and the POPHU estimate for census day is 115,904,474. The POPHU estimate for July 1, 2005 is 124,521,886. The estimated "true" number of housing units in the U.S. used in this report is 125,254,575 for July 1, 2005. The previous and updated POPHU estimates for 2002, 2003, and 2004 can be found in Appendix A, Table A10.

From the July 2005 MAF extract, the number of residential housing units in the nation that were eligible for the ACS sample was 129,459,517 (see Appendix A, Table A1). Of this total, about 4.4 million qualify as EDS records and about 5.6 million are ungeocoded (see Appendix A, Table A3). Combining these two groups yields about 8.4 million units that are either EDS, ungeocoded, or both. These housing units accounted for about 6.47 percent of the ACS-eligible units on the 2005 MAF extract.

For a complete listing of counts from the MAF for all regions and universes for 2005, refer to Appendix A, Table A1.

Table 1 National Estimates of Net Coverage for the United States: 2002 to 2005.

Year	ACS[‡] Eligible Units	ACS without EDS Records	ACS without Ungeocoded Records	ACS without Ungeocoded or EDS Records
2002	2.00%	-0.09%	-0.93%	-2.07%
2003	2.22%	-0.10%	-1.12%	-2.44%
2004	2.66%	0.11%	-1.03%	-2.54%
2005	3.36%	-0.13%	-1.08%	-3.33%

[†]ACS means American Community Survey.

2005 National Estimates of Net Coverage

Table 1 shows the national estimates of net coverage for 2002 to 2005. Positive values in the table represent net overcoverage relative to our "truth" baseline and negative values represent net undercoverage. All estimates are based on July 1 of the given year.

(Note that the calculation of these estimates uses the most recent updated housing unit data from the Population Division and therefore will differ from ACIEP estimates produced in previous years. Refer to Appendix A, Table A9 to see the previous net coverage estimates.)

The first column of Table 1 (labeled "ACS Eligible Units") includes the EDS and ungeocoded records. In 2002, the full ACS frame showed a net overcoverage of 2.00 percent. Over the next three years, the net overcoverage increased 1.36 percentage points to 3.36 percent. We can see that the rate of increase is growing as well, with changes of 0.22, 0.44, and 0.70 percentage points for the respective years.

The second column (labeled "ACS without EDS Records") starts with the full ACS frame and removes the EDS records. In 2002, we see a net undercoverage of 0.09 percent. The net undercoverage grew slightly from 2002 to 2003, and then in 2004 it changed in the opposite direction to 0.11 percent net overcoverage. Then in 2005 it changed back to net undercoverage at 0.13 percent. For this frame, there is not a steady percentage increase or decrease across the four years, even though the number of EDS records has grown each year.

The third column (labeled "ACS without Ungeocoded Records") starts with the full ACS frame and removes ungeocoded records. In 2002, this frame had a net undercoverage of 0.93 percent. The net undercoverage rate grew in 2003 (when the ACS modified the filter rules to be more selective about allowing post-census ungeocoded units into the address frame), fell back in 2004, and then increased again in 2005. By 2005, the net undercoverage rate was 1.08 percent.

Finally, the fourth column (labeled "ACS without Ungeocoded or EDS Records") starts with the full ACS frame and removes any records that are EDS, ungeocoded, or both. In 2002, this frame saw a net undercoverage of 2.07 percent. The net undercoverage grew each year through 2005, although the rate of increase did not show an accelerating pattern like the full ACS frame did. In 2003, the net undercoverage rate grew by 0.37 percentage points to 2.44 percent. Then, in 2004, the rate grew by 0.10 percentage points to 2.54 percent, and finally in 2005 it grew by 0.79 percentage points to 3.33 percent net undercoverage.

Figure 1 plots the data from Table 1 and helps to visualize the relationship between the different frames over time and relative to the "truth" baseline. We notice that the first and fourth frames follow a consistent trend throughout our time period. Both move farther from the "truth" baseline with each subsequent year, with the full frame increasing each year in net *overcoverage* and the ACS without EDS/ungeocoded frame increasing in net *undercoverage*.

The middle two frames follow a different pattern but are somewhat consistent with each other. Both have a decrease in net coverage from 2002 to 2003, then reverse to have an increase in net coverage in 2004, and then reverse again to have another decrease in 2005. We do notice, however, that in 2005 the ACS without EDS frame sees a more dramatic decrease in net coverage than the ACS without ungeocoded frame. Note again that there are no measures of error and that these are net coverage measurements and give no indication of how the gross undercoverage and overcoverage rates are changing.

The net coverage estimates are influenced by several factors; the interaction of these individual elements yields the final net coverage results. To understand each factor's effect on net coverage, we explore each of the elements while controlling for the others:

- POPHU estimates: Larger POPHU estimates tend to lower net coverage of all four frames because the baseline is increased.
- Geocoded and non-EDS units: Larger numbers of "good" units tend to raise the net coverage of all four frames by increasing the number of units in each frame.
- EDS units: Larger numbers of EDS units tend to lower the net coverage of the second and fourth frames by decreasing the number of units on these frames.
- Ungeocoded units: Larger numbers of ungeocoded units tend to lower the net coverage of third and fourth frames by decreasing the number of units on these frames.

Each year the POPHU estimates increased, as did the number of regular units, EDS units, and ungeocoded units on the MAF. Additionally, the difference between the full ACS frame and each of the other frames has increased since 2002, indicating that the EDS and ungeocoded categories grew faster than the estimated true number of housing units. Over time there was also a smaller percentage overlap (units that are both EDS and ungeocoded) in the fourth frame than in earlier years (23.4 percent in 2002, 21.7 percent in 2003, 20.0 percent in 2004, and 18.4 percent in 2005). This leads the fourth frame to diverge from the baseline faster than the middle frames, as can be seen with the bottom line of Figure 1. Table 2 shows the difference between the net coverage of the full ACS sampling frame and each of the three subframes over all four years. Notice that for each row, the difference between the net coverage estimate of the subframe and the full frame increases over time.

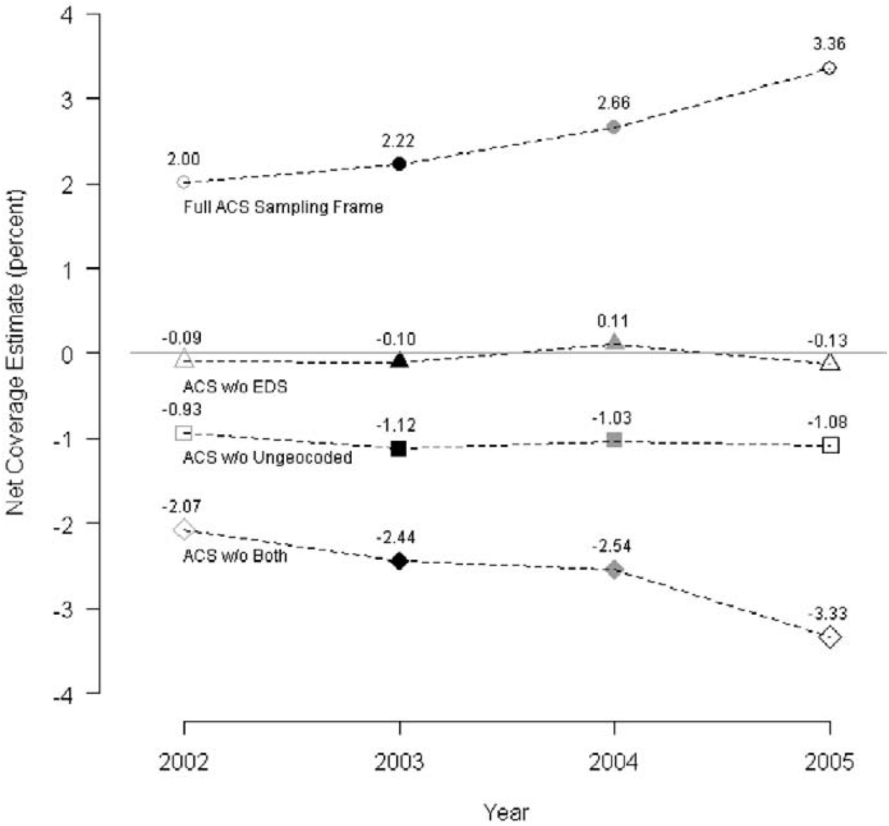

Fig. 1 National estimate of net coverage by frame: 2002–2005.

Table 2 Difference of net coverage estimates between full ACS frame and each subframe: 2002 to 2005.

	Difference from full ACS frame			
Subframe	**2002**	**2003**	**2004**	**2005**
ACS w/o EDS	2.09%	2.33%	2.55%	3.48%
ACS w/o Ungeocoded	2.94%	3.35%	3.69%	4.43%
ACS w/o Both	4.07%	4.66%	5.20%	6.69%

Next, we look at the growth in the sampling frame each subsequent year. In Table 3 we see this total and the categorization of the growth into “regular”[10]

[10] “Regular” units are defined for the purpose of this report as those units that were eligible for ACS sampling and were geocoded and included in delivery statistics.

Table 3 Growth in categories of units on the ACS sampling frame.

	Growth Between		
	2002 - 2003	**2003 - 2004**	**2004 - 2005**
Full ACS Frame	1,896,984	2,296,017	2,777,052
"Regular" Units	1,116,015	1,551,142	816,900
EDS/Ungeocoded	780,969	744,875	1,960,152
EDS	319,494	314,531	1,219,941
Ungeocoded	545,888	483,784	997,268
Total Expected†	1,597,021	1,717,320	1,856,075

†Expected growth is the difference of the truth estimates for each year.

units and EDS/ungeocoded units. Additionally, we see the expected growth of the sampling frame based on our truth estimates.

When we look at the differences in the growth of each category of units from year to year, we gather some very important information. Looking at the third row of the table, we see that the growth of EDS and ungeocoded units in the ACS frame decreased from the first to second year, but then from the second to third year the growth increased dramatically; these records represented 41.2 percent of the growth from 2002 to 2003, 32.4 percent from 2003 to 2004, and 70.6 percent of the growth between 2004 and 2005. Looking at the fourth and fifth rows, we see that the growth of the EDS units in 2005 was almost four times that of the previous years, and the growth of the ungeocoded units in the third year was more than double that of the second year. It is clear that the full ACS frame grew over the three years but the "regular" units – those that were not EDS and were geocoded – became a much smaller source of growth in 2005 than they had been previously. The EDS and ungeocoded units represented a much larger percentage of the ACS eligible housing units on the July 2005 MAF extract than previous years. We examine the EDS and ungeocoded records, including the status of some of these records through time and the effect of filter changes on the large growth in these two types of records, in more detail in sections to follow.

2005 Regional Estimates of Net Coverage

Next we look to Table 4, which shows the regional estimates of net coverage for each of the four universes in 2005. The national estimates are included for comparison. Refer to Appendix A, Table A1 for the actual housing unit counts. As with Table 1, positive numbers in Table 4 represent net overcoverage and negative numbers represent net undercoverage.

Table 4 2005 regional estimates of net coverage with and without EDS and ungeocoded records.

Census Region	ACS Eligible Units	ACS without EDS Records	ACS without Ungeocoded Records	ACS without Ungeocoded or EDS Records
Northeast	3.56%	1.48%	1.23%	-0.32%
Midwest	3.38%	-0.10%	-0.18%	-2.55%
South	4.29%	0.03%	-1.54%	-4.25%
West	2.04%	-1.31%	-2.72%	-4.67%
National	3.36%	-0.13%	-1.08%	-3.33%

In the first column (labeled "ACS Eligible Units") the West stands out with a lowest net coverage estimate (2.04 percent), and the South stands out with the highest net coverage estimate (4.29 percent).

In the second column (labeled "ACS without EDS Records"), the West again stands out with a net coverage estimate (-1.31 percent) that is much lower than the other three regions. The South, however, no longer has the highest net overcoverage, but is nearer the baseline (a decrease of 4.26 percentage points). This drop indicates that the ACS frame for the South has a higher percentage of EDS records than the other regions.

In the third column (labeled "ACS without Ungeocoded Records"), all regions show decreases in net coverage compared to the first two frames. Only the Northeast (1.23 percent) shows a net overcoverage. Additionally, of all four regions, the Northeast has the smallest difference from column 1 (2.33 percentage points). The other three regions have a difference from column 1 of more than three percentage points. This implies that there are not as many ungeocoded units in the Northeast, as a percentage, compared to the other regions. As with the second column, the West has the lowest net coverage (-2.72 percent) of the four regions, but the South was the most affected by the removal of ungeocoded units from the frame. The net coverage estimate for the South dropped 5.83 percentage points when those records were removed, indicating a higher percentage of ungeocoded units than any of the other regions.

In the fourth and final column (labeled "ACS without Ungeocoded or EDS Records"), both the EDS and ungeocoded records have been removed from the full ACS frame. In this column the South and West, which were very different in column 1, are much closer. Once again, this indicates that the South has the greatest percentage of units that are EDS, ungeocoded, or both. The change in net coverage for the South from the full ACS frame (column 1) to the smallest frame (column 4) is 8.54 percentage points. Contrast this with the Northeast, which saw a change of 3.88 percentage points, and the Nation, with a change of 6.69 percentage points.

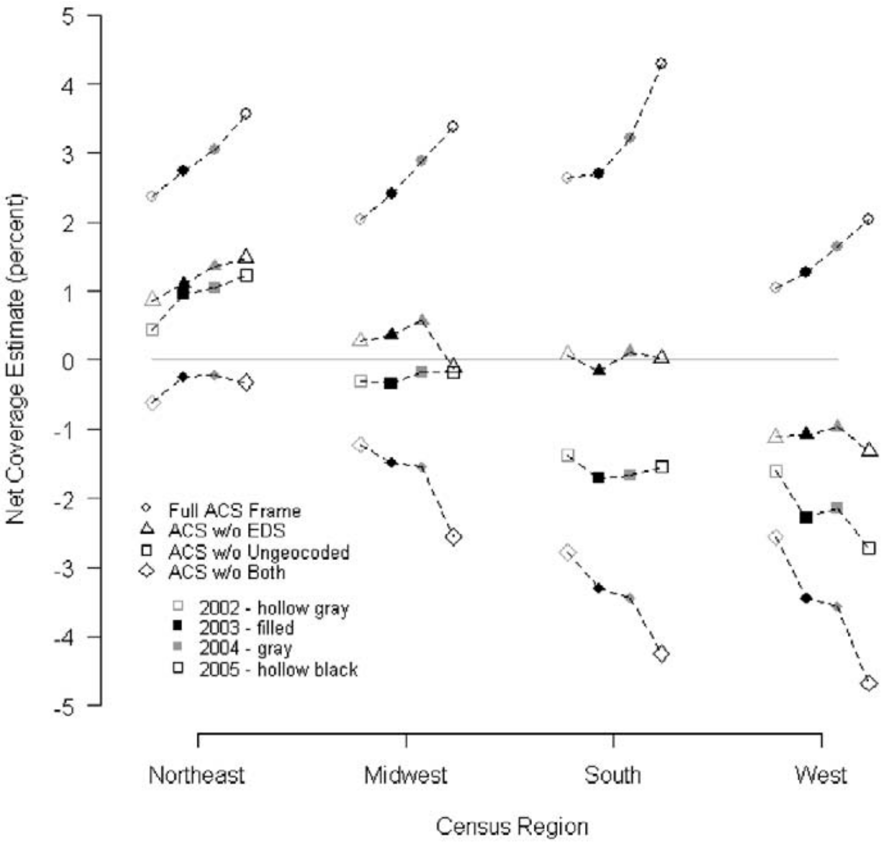

Fig. 2 Regional estimates of net Coverage by frame: 2002–2005.

Comparing 2005 Regional Estimates with 2002, 2003, and 2004

Figure 2 plots the regional data from Table 4 and helps to visualize the differences in the universes between the regions relative to time and our estimate of truth. Points above the horizontal line represent net overcoverage and points below the line represent net undercoverage. Vertical comparisons look at relationships within regions and horizontal comparisons look at relationships between regions.

In Figure 2, the triangles represent net coverage estimates when the EDS records have been removed from the ACS frame and squares represent net coverage estimates when ungeocoded records have been removed from the frame. If, within a region, the squares are close to the triangles, it means that the region has roughly similar numbers of EDS and ungeocoded records.

We see in Figure 2 how the range (from top to bottom) and direction (relative to the zero line) of the estimates tend for each region. Starting at the left, we can see that the Northeast has the tightest distribution and is the least affected by the removal of EDS/ungeocoded records. We also see that the net coverage estimates in this region tend toward overcoverage. Moving over to the Midwest, we see that removal of EDS/ungeocoded records has a larger influence on the coverage estimates and the coverage estimates are roughly centered over the baseline. Next, we look at the South region. Note that about a third of the nation's housing units are in the South, so this region has the largest effect on the national estimates of net coverage. We see that this region has the largest range in net coverage between universes, indicating that it also has the greatest number of and percentage of EDS and ungeocoded records of all the regions. Additionally, the rate of increase in net overcoverage of the full ACS frame is greatest in the South. Finally, looking at the West region we see a range that is wider than that of the Midwest but smaller than that of the South. Additionally, we see that the net coverage estimates in this region tend in the direction of net undercoverage.

Additional Research

EDS and Ungeocoded Records

As shown in Figure 3, the universe of EDS and ungeocoded records that are eligible for ACS is growing with each subsequent year. This leads us to the following questions:

- What happens to the status of EDS and ungeocoded units over time?
- Are EDS and ungeocoded units being added to the MAF faster than we are able to resolve them, or are the filter changes making more of them eligible for ACS each year?

Tracking EDS and Ungeocoded Records from 2002 to 2005

Table 5 helps answer the question of what is happening to the EDS and ungeocoded units over time. This table looks at all the units that were valid for the ACS in 2002, but were ungeocoded or EDS, and tracks their status through 2005. The rows of the table represent the 2005 status of the units. A record could improve in quality by changing from ungeocoded to geocoded. It could also be improved by no longer being an EDS record, although such an improvement is out of the Census Bureau's control. Alternatively, the record might experience no change in either category or it might be changed from a non-EDS record to an EDS record. Lastly, the 2002 record could be no longer valid for the ACS in 2005 because of some change in the housing unit filter or an update from a recent census operation that causes it to be excluded.

Units that are ungeocoded or are EDS can be thought of as deficient. We want to have addresses that are as complete as possible, so receiving an upgrade in one

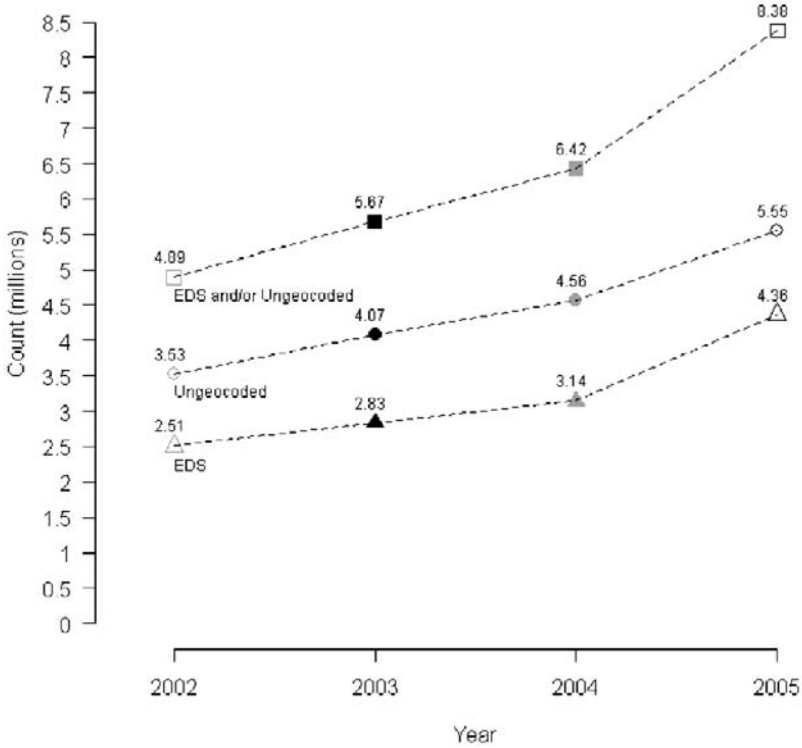

Fig. 3 Total number of EDS and ungeocoded records: 2002–2005.

Table 5 Status of 2002 ACS valid EDS/ungeocoded records in 2005.

			2002 Status		
			Geocoded	Ungeocoded	
			EDS	Not EDS	EDS
2005 Status	Geocoded	Not EDS	44.9%	37.3%	22.9%
		EDS	44.4%	1.2%	3.4%
	Ungeocoded	Not EDS	0.0%	41.3%	34.2%
		EDS	0.0%	1.7%	18.9%
	Not Valid in 2005		10.8%	18.5%	20.5%
	Total Percent		100.0%	100.0%	100.0%
	Total Count		1,365,102	2,381,950	1,145,659

Shading indicates no change in geocoding or EDS status from 2002 to 2005

or both of these categories is a positive change. Ideally, we want to see the largest numbers in the top row of Table 5. The top row represents addresses that were deficient in 2002 but saw an improvement in one or both categories by 2005. The shaded cells show the percentages of units that had the same status in both years. The cells below the shaded diagonal generally represent negative changes, such as an address that was not EDS in 2002, but is EDS in 2005. We hope for these occurrences to be relatively small, and indeed they are. In the table, the zero percentages actually represent zero counts because records cannot go from geocoded to ungeocoded. For a full table of counts instead of percents, or to see tables tracking 2002 through 2003 or 2002 through 2004, refer to Appendix A Table A4 through Table A8.

The first column (labeled "Geocoded – EDS") tracks units that were valid for the ACS in 2002 and were geocoded, but were considered EDS by the USPS. This group has one possibility for improvement, which is to no longer be an EDS record. For these cases, 44.9 percent of the 1.4 million units received this upgrade. About the same percentage (44.4 percent) received no improvement by the USPS. This category also saw the least percentage of its units become invalid for the ACS in 2005 (10.8 percent) when compared to the other columns.

The second column (labeled "Ungeocoded – Not EDS") includes records that were good in the sense that the USPS did not classify them as an EDS record in 2002, but they had not yet been geocoded by the Census Bureau. This group was the most numerous with about 2.4 million units. Since these units already were not EDS records, there was one possibility for improvement, which was to become geocoded. Of the 2.4 million, 37.3 percent were geocoded and still not EDS by 2005. A small number of units (1.2 percent) were geocoded by 2005, but were changed to EDS by the USPS over the same period. The largest group of units in this column (41.3 percent) saw no change in either category. Finally, 1.7 percent of the units received a downgrade in EDS status by the USPS and no improvement in geocoding status, and the balance (18.5 percent) was no longer valid for the ACS in 2005.

The third and final column (labeled "Ungeocoded – EDS") consists of those units that were deficient in both categories. That is, they were not geocoded and the USPS considered them EDS in 2002. They could be improved in one or both of these categories. Some units (22.9 percent) saw improvements in both categories, while others (3.4 percent) saw improvements in geocoding status only. Many of the records in this column saw either an improvement in EDS status only (34.2 percent) or no change in either category (18.9 percent). The remaining 20.5 percent were no longer eligible for the ACS sample in 2005.

We learn from Table 5 that many ungeocoded and EDS records saw no change in status from 2002 to 2005 (represented by the shaded cells). The next table helps to emphasize this point by grouping the EDS and ungeocoded records across the columns of Table 5. The columns in Table 6 show how the status of the units changed from 2002 to 2003, 2002 to 2004, and 2002 to 2005; the top half shows the changes in EDS records and the bottom half shows the changes in ungeocoded records.

In the top half of the table, we can see that with each subsequent year, more EDS units are "upgraded" from their 2002 status and changed over to "Included in Delivery Statistics"; by 2005 about half of the units had been upgraded. These results make sense since some EDS records might never receive mail and others probably represent new construction and are entered into the USPS file essentially as a placeholder until the units begin receiving mail. So over the years, some units that

Table 6 Summary of the types of changes in the 2002 EDS and ungeocoded units eligible for ACS, through 2003, 2004, and 2005.

Type of Change in DSF Status from 2002 to:	2003	2004	2005
EDS to EDS (no change)	53.7%	40.4%	34.3%
EDS to Not EDS (upgrade)	35.5%	45.2%	50.5%
EDS to Not eligible for ACS sampling frame	10.7%	14.3%	15.2%
Total Percent	100.0%	100.0%	100.0%
Total Count	2,510,761	2,510,761	2,510,761

Type of Change in Geocoding Status from 2002 to:	2003	2004	2005
Ungeocoded to Ungeocoded (no change)	68.3%	54.6%	46.3%
Ungeocoded to Geocoded (upgrade)	14.6%	26.0%	34.5%
Ungeocoded to Not eligible for ACS sampling frame	17.1%	19.4%	19.1%
Total Percent	100.0%	100.0%	100.0%
Total Count	3,527,609	3,527,609	3,527,609

started out as EDS in 2002 were increasingly inhabited and having mail delivered. We also note that over time there is an increasing percentage of 2002 EDS units that become ineligible for ACS. By 2005, this category reached 15.2 percent, and the remaining 34.3 percent of the 2002 EDS records were still EDS in 2005. We should also note that some of the non-EDS records from 2002 were “downgraded” to EDS over the subsequent three years. This is not shown in the table, but by 2005, 2.9 percent of the non-EDS units from 2002 had become EDS.

Next we examine the bottom half of Table 6, which shows the changes in status for the ungeocoded records from 2002. This is of interest to the Census Bureau because, unlike the EDS status that is determined by the USPS, we are responsible for fixing the geocoding status. There is a program called MAFGOR that works on geocoding records that are not assigned to a block (this program is discussed further below). Looking at the second row (labeled “Ungeocoded to Geocoded”) in the bottom half of the table, we can see that 14.6 percent of the 2002 records had been geocoded by 2003. This increased to 26.0 percent by 2004, and by 2005, 34.5 percent of the 2002 records had been geocoded. The percentage of units in this status change category increases cumulatively over time because with each subsequent year, more of the ungeocoded records from 2002 are assigned a block code and are “upgraded”. Additionally, we can see in Table 6 that 46.3 percent of the 2002-ungeocoded units remained ungeocoded over time, and the other 19.1 percent of the 2002 units were not eligible for ACS in 2005.

Records can be excluded from the ACS frame in later years because of updates to the housing units on the ground or refinements to the ACS filter. Theoretically, these refinements are improving the ACS sampling frame. But, it is possible that the increase in the number of EDS and ungeocoded records on the frame, which in this report are considered somewhat deficient, is occurring because of filter changes.

Effects of Filter Changes on Increase in EDS and Ungeocoded Records

As we discussed in above, it is not possible to simply take the current filter rules and apply them to a MAF extract from an earlier year to produce coverage estimates that are comparable, but we can apply the rules forward in time to see what is happening with the EDS and ungeocoded records.

As we saw in Figure 3, the increase in EDS and ungeocoded records was larger from 2004 to 2005 than in any of the previous years. The ungeocoded and EDS universes have grown to 5.55 million and 4.36 million records, respectively. To determine whether the large growth in the most recent year was caused by the latest filter changes or by these universes growing substantially on the MAF, we look at tallies of the 2005 EDS and ungeocoded records through the 2004 filter rules. If a substantial number of 2005 records are invalid through the 2004 rules, then we know that the current filter caused a substantially higher number of these old records to be eligible for ACS. Otherwise, if the 2005 records would have been valid in 2004, then we have good evidence that these universes are growing faster on the MAF than we are able to resolve them.

To begin this analysis, we first test our replication of the filter rules for 2004 and 2005 to ensure that they are setting the ACS Delivery Flag values correctly. We examined the frequencies for the actual ACS Delivery Flag variable and for the replicated variables for both years. We found that the replication of the 2004 filter rules resulted in no miscategorized records, and there were 1,720 records miscategorized with the replicated 2005 filter rules (185 records got a flag value of “0 – Invalid for ACS” with the replicated filter). Since this is such a small number of records compared to the 8.38 million total records, we accept this as a small limitation to this analysis.

To determine the cause of the increase in “deficient” records we take the replicated filter rules for 2004 and apply them to the 2005 EDS and ungeocoded records that were valid for ACS. If the increase in “deficient” records was caused by filter changes, we would expect to see a large number of records with an ACS Delivery Flag of “0 – Invalid for ACS” (see Appendix B for complete definitions of all the ACS Delivery Flag values). The results are in Table 7.

In the first row of Table 7 we see that about 100,000 records in 2005 would have been invalid in 2004 based on those filter rules. When we compare this to the 2 million record increase in EDS and ungeocoded records from 2004 to 2005, it is clear that the increase is not strictly because of new filter rules but mainly because substantially more of these units are on the MAF. There is nothing the Census Bureau can do to decrease the number of EDS records on the MAF (although we can change filter rules that determine what units are valid for certain operations), but the next section provides more information on one of the programs that is working to fix the ungeocoded units.

Table 7 Applying 2004 filter rules to 2005 EDS and ungeocoded records.

ACS Delivery Flag Value		2005 EDS and Ungeocoded records under filter rules from		
		2005†	2004	Difference
0	Invalid for ACS	185	100,606	100,421
1	Census 2000 Addresses	1,970,073	1,970,073	0
2	CQR Adds/Reinstatements	275	275	0
3	Post-Census DSF Adds	6,402,326	6,301,316	-101,010
4	Census Deletes Persisting on DSF	0	0	0
5	DAAL Adds	5,785	6,374	589
6	Census Test/Special Census Adds	63	63	0

†We use the replicated 2005 variable for comparison.

MAF Geocoding Office Resolution

The ungeocoded records can be resolved if the Census Bureau can determine the block in which these units exist. MAFGOR is the operation that works to resolve these cases. The MAFGOR universe consists of all records that come in from the DSF every six months. When the DSF is delivered for MAF updating, the records are compared to the TIGER database as well. All records that match to an existing address range in TIGER are assigned to the appropriate block and become the geocoded portion of the MAFGOR universe. Records that do not match to an existing address range in TIGER become the ungeocoded portion of the MAFGOR universe. The MAFGOR clerks in the Census Bureau’s regional offices then use local source materials, such as atlases, maps, and city directories, to insert address ranges into TIGER that will allow these ungeocoded records to be assigned to the appropriate block. In some areas there is no local source material or the material is not sufficient for MAFGOR needs. In those cases, the records remain ungeocoded until adequate source material becomes available.

Tracking the ungeocoded records on the MAF from 2002 through time, we saw in Table 6 that from 2002 to 2003, 14.6 percent of the ungeocoded records eligible for ACS in 2002 became geocoded. By the next year (July 1, 2004), 26.0 percent of them had been geocoded, and finally by July 1, 2005, 34.5 percent of the 2002 records had been geocoded. So over three years, MAFGOR was able to resolve a little over one-third of the ungeocoded records that were on the MAF and valid for ACS back in 2002. This does not account for the new ungeocoded records that were eligible for ACS starting in 2003, 2004, and 2005.

In Table 8, we see two sets of estimates for the number of addresses in the ungeocoded portion of the MAFGOR universe from September 2006 through October 2008. The table compares the number of DSF addresses (including commercial units) in the ungeocoded universe with and without funding for MAFGOR. Based on a small sample of DSF deliveries, the Geography Division determined that, on average, 2.8 million ungeocoded addresses are added to the MAFGOR universe each

Table 8 Ungeocoded portion of the MAFGOR universe* – Estimates for 2006 through 2008.

	Projected MAFGOR Workload	
	With Funding for FY 2007 and 2008	**Without Funding for FY 2007 and 2008**
September 1, 2006	9,563,927	9,563,927
October 1, 2007	10,453,417	12,315,937
October 1, 2008	11,342,907	15,067,947

* The MAFGOR universe includes residential, commercial, and EDS units.

year by the DSF[11] (Bainter 2006). Currently, with funding for 31 clerical staff, the Geography Division reported that the MAFGOR operation can geocode approximately 1.9 million of these addresses each year, leaving a remainder of about 0.9 million ungeocoded records that carry over to the following year's workload (Bainter 2006).

With the current level of funding, the ungeocoded universe continues to grow faster than MAFGOR is able to geocode the records. This research makes it apparent that MAFGOR would need even more resources to decrease the total number of ungeocoded units on the MAF and therefore in the ACS sampling frame. Nevertheless, it is likely that funding for the MAFGOR program will not be provided in FY 2007. Table 8 shows that the estimated growth in the ungeocoded universe without the MAFGOR operation is almost three million records each year, with the universe reaching over 15 million records by October 2008 (Bainter 2006).

In the next section, we further examine the effects of the ungeocoded and EDS records on the ACS eligible universe by looking at the final dispositions for records selected in the ACS.

ACS Outcomes for EDS and Ungeocoded Records

In this section we look at the outcome codes of EDS and ungeocoded records that were sampled by ACS. The following is a brief description of the methodology for the tables in this section (for complete information see Colosi et al., 2006).

The general methods for this section use an ACS evaluation data file to examine the validity of the EDS and ungeocoded records included in the 2004 ACS sample (this is the most recent year for which we have complete data including outcome codes). The Census Bureau tries to complete the ACS questionnaire for each address selected into the ACS sample, so each sample address has an outcome code that records the status during the mailing (two mailouts), telephone, or personal

[11] This number is significantly higher than the growth seen in Table 3 because the MAFGOR universe includes all ungeocoded records added to the MAF by the DSF (including commercial units), while the numbers in Table 3 are limited to records on the MAF that are eligible for ACS.

Table 9 Weighted validity status for 2004 ACS by geocoded status.

Geocoded Status	ACS Status			
	Valid	Invalid	Unknown	Total
Geocoded	115,917,160	2,783,455	338,900	119,039,515
	97.38%	2.34%	0.28%	100.00%
	(192,225)	(37,618)	(13,315)	(196,323)
Ungeocoded	3,971,741	457,133	15,182	4,444,056
	89.37%	10.29%	0.34%	100.00%
	(36,054)	(16,044)	(2,937)	(39,572)
Total	119,888,901	3,240,588	354,083	123,483,572
	97.09%	2.62%	0.29%	100.00%
	(195,577)	(40,896)	(13,635)	(200,272)

Note: the standard errors are in parentheses.
*The geocoded and ungeocoded records in the Unknown and Total columns do not sum to the total due to rounding error.

interviewing phases. On our evaluation file, addresses that had a completed mail questionnaire, a completed Computer Assisted Telephone Interviewing (CATI) interview, or a completed Computer Assisted Personal Interviewing (CAPI) interview were considered valid addresses (see Appendix E for the ACS outcome flow). Addresses with address related mail, CATI, and CAPI non-interviews were considered invalid in our study. Additionally, for records with other CAPI outcome codes, the validity status is Valid, Invalid, or Unknown based on the value of the code (see Appendix E for definitions). Then using the ACS weight information, we weighted each case and drew inferences on the validity of the EDS and ungeocoded addresses at the national level for the MAF. (Colosi et al., 2006)

In Table 9, we examine the ACS outcomes for geocoded *versus* ungeocoded records. We can see that the geocoded records have a very high validity rate at 97.38 percent, and the validity for ungeocoded records is 89.37 percent, which is still fairly high. This means that the ACS interviewers are successful at locating ungeocoded records just under 90 percent of the time. Still, we must note that the ungeocoded records are a problem for decennial operations because they are not included in the frame. Unlike ACS interviewers, who can look for ungeocoded units throughout the county and are expected to find a large percentage of them, the census listers do not have this opportunity because decennial operations are block-based, not unit-based like the ACS. The ungeocoded units are not included in the initial block-level address lists, and during Address Canvassing the listers are expected to find and add any ungeocoded units they encounter in the assigned block. It would be best if the ungeocoded universe were decreased prior to decennial operations because studies have shown that the listers do not always find and add these units.

Next we look at the outcome codes for EDS records versus those that were included in delivery statistics. In Table 10, we can see that the non-EDS records have

Table 10 Weighted validity status for ACS by delivery status.

Delivery Status	ACS Status			
	Valid	**Invalid**	**Unknown**	**Total**
Not EDS	117,586,509	2,634,954	347,983	120,569,447
	97.53%	2.19%	0.29%	100.00%
	(193,159)	(36,503)	(13,509)	(197,042)
EDS	2,302,391	605,633	6,100	2,914,124
	79.00%	20.80%	0.20%	100.00%
	(30,658)	(18,440)	(1,847)	(35,824)
Total	119,888,901	3,240,588	354,083	123,483,572
	97.09%	2.62%	0.29%	100.00%
	(195,577)	(40,896)	(13,635)	(200,272)

Note: the standard errors are in parentheses.
*The EDS and non-EDS records in the Valid, Invalid, and Total columns do not sum to the totals due to rounding error.

a high validity rate at 97.53 percent. Then moving down to the EDS records we see that the validity rate drops to 79.00 percent. This gives evidence that these records are in fact problematic for ACS interviews. For about one-fifth of the records, the ACS interviewer determines that the unit does not exist on the ground. Unlike the ungeocoded records though, EDS records that have a block code can be used in decennial census operations.

Finally, we look at the geocoded status combined with the USPS delivery status to see what further information we can learn (Table 11). These results are not surprising based on the previous two tables we looked at. The "best" records are those that are not EDS and are geocoded, and the "worst" records are the EDS and ungeocoded records. And, as we saw previously, the delivery status has more of a negative effect on the ACS validity rate than the geocoding status.

Conclusions

The results of this study indicate that accurately maintaining a national list of addresses continues to be a challenge. The full ACS frame experienced national net overcoverage of 2.00, 2.22, 2.66, and 3.36 percent relative to our baseline from 2002 through 2005, respectively. As mentioned earlier, the ACS expects some overcoverage because it includes certain addresses in an effort to minimize undercoverage for new construction. Since we only have net coverage estimates, we cannot determine whether the gross undercoverage is decreasing, but when we compare the number of units on the full ACS frame to our truth estimates, which include estimated residential construction, we find increasing net overcoverage of the frame. This suggests that the MAF maintenance process is successfully identifying and adding

Table 11 Weighted validity status for ACS by geocoding and delivery status.

Delivery/Geocoded Status	ACS Status			
	Valid	**Invalid**	**Unknown**	**Total**
Not EDS/Geocoded	114,624,849	2,532,596	335,418	117,492,863
	97.56%	2.16%	0.29%	100.00%
	(190,797)	(35,725)	(13,245)	(194,564)
Not EDS/Ungeocoded	2,961,660	102,358	12,565	3,076,584
	96.26%	3.33%	0.41%	100.00%
	(30,117)	(7,498)	(2,658)	(31,150)
EDS/Geocoded	1,292,311	250,859	3,482	1,546,652
	83.56%	16.22%	0.23%	100.00%
	(23,388)	(11,784)	(1,361)	(26,224)
EDS/Ungeocoded	1,010,080	354,775	2,617	1,367,472
	73.86%	25.94%	0.19%	100.00%
	(19,822)	(14,184)	(1,249)	(24,406)
Total	119,888,901	3,240,588	354,083	123,483,572
	97.09%	2.62%	0.29%	100.00%
	(195,577)	(40,896)	(13,635)	(200,272)

Note: the standard errors are in parentheses.
*The records in each of the four categories in the Valid, Unknown, and Total columns do not sum to the total due to rounding error.

much of the new construction that is occurring on the ground. While capturing new construction is important because undercoverage is difficult to fix, it should still be noted that the ACS is also concerned about overcoverage. The ACS has mechanisms in place to deal with erroneous units that arise from overcoverage on the frame, but as overcoverage increases, the efficiency of the survey decreases and the variability of the survey estimates increases.

Unlike the ACS, the decennial census operations have excluded EDS records in the past. The second frame looked at the full ACS sampling frame without the EDS records. For all four years, the national net coverage estimates are fairly close to our baseline truth estimates, but this does not imply that the full sampling frame without EDS records is the best representation of the housing units on the ground. The net coverage estimates give no indication that the gross coverage measures on this frame are near zero, and previous studies have shown that a large portion of the Excluded from Delivery Statistics records represent valid housing units (Colosi et al., 2006).

Our third frame represents the full ACS sampling frame without the ungeocoded records. This frame best approximates the expected decennial census frame. We did not see a dramatic change in net coverage over time; the estimate stayed near 1 percent net undercoverage over all four years. It is important to note that many of these ungeocoded units do in fact exist on the ground, but they are excluded from certain Census Bureau operations, such as Address Canvassing, because the assignments are block-based rather than unit-based.

The last frame we looked at was the ACS sampling frame with both EDS records and ungeocoded records removed, which approximates the Census 2000 frame. When we remove these units, the coverage of the MAF takes on an entirely different picture. The net coverage estimates for this frame show a net undercoverage of 2.07 percent in 2002, 2.44 percent in 2003, 2.54 percent in 2004, and 3.33 percent in 2005. Note that in 2005, there is more than a six-percentage point difference between the net coverage estimate for this frame and that of the full ACS frame. Instead of increasing overcoverage like we saw on the full frame, we find increasing undercoverage on this frame from 2002 through 2005.

When we looked further at the EDS and ungeocoded units, we saw that the number on the ACS frame increased from 4.9 million in 2002 to 8.4 million in 2005. They also represented a larger percentage of the growth in ACS eligible housing units in the last year – these units represent 41.2 percent of the growth from 2002 to 2003, 32.4 percent from 2003 to 2004, and 70.6 percent of the growth between 2004 and 2005. The “regular” units – those that were not EDS and were geocoded – comprised 58.8 percent of the growth on the full ACS frame from 2002 to 2003, but were a much smaller source of growth (29.4 percent) in 2005. We also looked closer at the EDS records that were eligible for the ACS in 2002 and found that about half of those units were included in delivery statistics in 2005. When we examined the ungeocoded records from 2002, we found that about one-third of those records had been geocoded over the three years, but a higher percentage (46.3 percent) still had not been geocoded.

Updating the MAF using the DSF is important, but as shown above, one result of the DSF updates is an increasing number of EDS records on the MAF and in the ACS sampling frame. While we have no control over the status of these records coming in from the USPS, the Census Bureau can improve how we handle them by updating the filter rules. Neither including nor excluding all of the EDS records is ideal in terms of the effect on net coverage because some records are not valid units on the ground. The 2006 Census Test allowed EDS records into the Address Canvassing universe to help us understand, in clearer detail, which kinds of EDS records are most likely to be valid units, and there is other ongoing research into these units as well. It is important that we continue learning more about the validity rates of certain subcategories of EDS records. If we can identify certain kinds of EDS records that have high invalidity rates, we can fine tune the filtering rules and exclude these problematic records from the ACS and decennial operations.

MAFGOR is the Census Bureau’s main operation for updating address ranges in TIGER, which allows more incoming DSF units to be geocoded, but it is clear that this operation is not working fast enough because the universe of ungeocoded records is growing over time. In 2002, ungeocoded records amounted to 2.9 percent of the full ACS frame; this rose to 3.3 percent in 2003, 3.6 percent in 2004, and 4.3 percent in 2005. As we approach 2010, the universe of ungeocoded records will continue to grow. This has major coverage implications for the MAF and affects both the ACS and decennial census operations. One major result is that, to the extent that existing addresses are ungeocoded on the MAF, the Address Canvassing operation in the 2010 Census will be expected to independently find these records and add them. The operation will be more efficient and accurate if the task of adding ungeocoded units is reduced. If Address Canvassing listers are not successful in finding and adding the ungeocoded units, many of the missed addresses will not be included in later census operations.

Appendix A

Counts of ACS-Eligible Housing Units for Each Frame: U.S. and Regions

Table A1 shows the actual counts of residential housing units that were valid for the ACS in each of the four universes studied in this report. Both regional and national numbers are presented. Some records could be both EDS and ungeocoded so consequently there is some overlap between these two groups; this is shown in Table A2. Table A3 shows a mutually exclusive breakdown of these categories.

Table A1 Counts of ACS-eligible housing units with and without EDS and ungeocoded records: U.S. and regions 2002 through 2005.

	Census Region	ACS Eligible Units	ACS without EDS Records	ACS without Ungeocoded	ACS without Ungeocoded or EDS Records
2002					
	Northeast	23,093,845	22,755,223	22,661,800	22,420,404
	Midwest	28,267,174	27,779,362	27,620,676	27,363,700
	South	45,419,453	44,284,854	43,646,048	43,021,888
	West	25,708,992	25,159,264	25,033,331	24,790,761
	National	**122,489,464**	**119,978,703**	**118,961,855**	**117,596,753**
2003					
	Northeast	23,309,592	22,938,474	22,905,520	22,633,890
	Midwest	28,695,496	28,124,711	27,927,204	27,610,309
	South	46,214,068	44,930,422	44,231,171	43,515,976
	West	26,167,292	25,562,586	25,249,056	24,952,593
	National	**124,386,448**	**121,556,193**	**120,312,951**	**118,712,768**
2004					
	Northeast	23,512,321	23,127,277	23,057,552	22,769,359
	Midwest	29,180,113	28,519,192	28,307,546	27,922,762
	South	47,273,810	45,860,067	45,038,265	44,224,917
	West	26,716,221	26,031,143	25,721,821	25,346,872
	National	**126,682,465**	**123,537,679**	**122,125,184**	**120,263,910**
2005					
	Northeast	23,778,982	23,301,368	23,242,586	22,887,778
	Midwest	29,644,764	28,646,308	28,624,251	27,944,080
	South	48,707,171	46,715,048	45,983,538	44,717,115
	West	27,328,600	26,432,066	26,054,593	25,531,837
	National	**129,459,517**	**125,094,790**	**123,904,968**	**121,080,810**

Counts of EDS and Ungeocoded Records: U.S. and Regions

In Table A1 we showed the counts of residential housing units that were valid for the ACS in each of the four universes. In this section we provide a quick reference of the number of units removed for the last three universes.

Counts of Mutually Exclusive EDS and Ungeocoded Records: U.S. and Regions

In Tables A1 and A2 we showed data for ungeocoded and EDS records where the groups were not mutually exclusive. For example, a record that is ungeocoded will be counted in the ungeocoded tally as well as the "both" tally. In this section we break the data into EDS-only, ungeocoded-only, and those that are both. Thus, the sum of these groups equals the total number of records that are EDS, ungeocoded, or both, which was shown in the last column of Table A2.

Table A2 Counts of EDS/ungeocoded units in the ACS-eligible universe: U.S. and regions 2002 through 2005

	Census Region	EDS	Ungeocoded	EDS and/or Ungeocoded
2002				
	Northeast	338,622	432,045	673,441
	Midwest	487,812	646,498	903,474
	South	1,134,599	1,773,405	2,397,565
	West	549,728	675,661	918,231
	National	**2,510,761**	**3,527,609**	**4,892,711**
2003				
	Northeast	371,118	404,072	675,702
	Midwest	570,785	768,292	1,085,187
	South	1,283,646	1,982,897	2,698,092
	West	604,706	918,236	1,214,699
	National	**2,830,255**	**4,073,497**	**5,673,680**
2004				
	Northeast	385,044	454,769	742,962
	Midwest	660,921	872,567	1,257,351
	South	1,413,743	2,235,545	3,048,893
	West	685,078	994,400	1,369,349
	National	**3,144,786**	**4,557,281**	**6,418,555**
2005				
	Northeast	477,614	536,396	891,204
	Midwest	998,456	1,020,513	1,700,684
	South	1,992,123	2,723,633	3,990,056
	West	896,534	1,274,007	1,796,763
	National	**4,364,727**	**5,554,549**	**8,378,707**

Table A3 ACS eligible housing unit counts for mutually exclusive EDS and ungeocoded categories: U.S. and regions 2002 through 2005.

	Census Region	EDS Only	Ungeocoded Only	EDS AND Ungeocoded	EDS and/or Ungeocoded
2002					
	Northeast	241,396	334,819	97,226	673,441
	Midwest	256,976	415,662	230,836	903,474
	South	624,160	1,262,966	510,439	2,397,565
	West	242,570	368,503	307,158	918,231
	National	**1,365,102**	**2,381,950**	**1,145,659**	**4,892,711**
2003					
	Northeast	271,630	304,584	99,488	675,702
	Midwest	316,895	514,402	253,890	1,085,187
	South	715,195	1,414,446	568,451	2,698,092
	West	296,463	609,993	308,243	1,214,699
	National	**1,600,183**	**2,843,425**	**1,230,072**	**5,673,680**
2004					
	Northeast	288,193	357,918	96,851	742,962
	Midwest	384,784	596,430	276,137	1,257,351
	South	813,348	1,635,150	600,395	3,048,893
	West	374,949	684,271	310,129	1,369,349
	National	**1,861,274**	**3,273,769**	**1,283,512**	**6,418,555**
2005					
	Northeast	354,808	413,590	122,806	891,204
	Midwest	680,171	702,228	318,285	1,700,684
	South	1,266,423	1,997,933	725,700	3,990,056
	West	522,756	900,229	373,778	1,796,763
	National	**2,824,158**	**4,013,980**	**1,540,569**	**8,378,707**

Tracking ACS-Valid EDS and Ungeocoded Units through Time

The tables in this section show either percentages or actual counts. The first two tables show percentages and complement Table 5 in the body of the report. Table A4

Table A4 Status of 2002 ACS-eligible EDS/ungeocoded records in 2003.

			2002 Status		
			Geocoded	**Ungeocoded**	
			EDS	**Not EDS**	**EDS**
2003 Status	Geocoded	Not EDS	32.1%	20.1%	1.6%
		EDS	61.7%	0.2%	1.3%
	Ungeocoded	Not EDS	0.0%	61.1%	38.1%
		EDS	0.0%	1.1%	43.0%
	Not Valid in 2003		6.2%	17.5%	16.1%
	Total Percent		100.0%	100.0%	100.0%
	Total Count		1,365,102	2,381,950	1,145,659

Shading indicates no change in geocoding or EDS status from 2002 to 2003

Table A5 Status of 2002 ACS-eligible EDS/ungeocoded records in 2004.

			2002 Status		
			Geocoded	Ungeocoded	
			EDS	Not EDS	EDS
2004 Status	Geocoded	Not EDS	40.7%	29.9%	13.7%
		EDS	49.9%	0.4%	3.3%
	Ungeocoded	Not EDS	0.0%	49.5%	37.0%
		EDS	0.0%	1.1%	25.9%
	Not Valid in 2004		9.4%	19.0%	20.1%
	Total Percent		100.0%	100.0%	100.0%
	Total Count		1,365,102	2,381,950	1,145,659

Shading indicates no change in geocoding or EDS status from 2002 to 2004

Table A6 Status of 2002 ACS-eligible EDS and ungeocoded records in 2003 – showing counts.

			2002 Status		
			Geocoded	Ungeocoded	
			EDS	Not EDS	EDS
2003 Status	Geocoded	Not EDS	437,992	477,675	17,921
		EDS	842,383	5,747	14,932
	Ungeocoded	Not EDS	0	1,455,496	436,473
		EDS	0	25,467	492,152
	Not Valid in 2003		84,727	417,565	184,181
	Total		1,365,102	2,381,950	1,145,659

Shading indicates no change in geocoding or EDS status from 2002 to 2003

Table A7 Status of 2002 ACS-eligible EDS and ungeocoded records in 2004 – showing counts.

			2002 Status		
			Geocoded	Ungeocoded	
			EDS	Not EDS	EDS
2004 Status	Geocoded	Not EDS	555,130	712,628	157,051
		EDS	681,466	10,714	37,239
	Ungeocoded	Not EDS	0	1,179,835	423,831
		EDS	0	25,071	296,690
	Not Valid in 2004		128,506	453,702	230,848
	Total		1,365,102	2,381,950	1,145,659

Shading indicates no change in geocoding or EDS status from 2002 to 2004

follows EDS and ungeocoded records that were valid for ACS in 2002 through one year.

The last three tables show the actual counts of housing units that are behind the percentages of the first tables and Table 5 above.

Table A8 Status of 2002 ACS-eligible EDS and ungeocoded records in 2005 – showing counts.

			2002 Status		
			Geocoded	Ungeocoded	
			EDS	Not EDS	EDS
2005 Status	Geocoded	Not EDS	612,504	888,139	262,519
		EDS	605,844	28,740	38,980
	Ungeocoded	Not EDS	0	984,000	392,365
		EDS	0	41,454	216,907
	Not Valid in 2005		146,754	439,617	234,888
	Total		1,365,102	2,381,950	1,145,659

Shading indicates no change in geocoding or EDS status from 2002 to 2005

Net Coverage Estimates as Reported in Previous Years

As noted earlier, the baseline estimates that are used in this report to establish our estimates of "truth" use housing unit estimates from the Census Bureau's Population Division. These estimates are updated annually and can modify estimates from previous years. We use the most updated estimates available in this report. However, for the information of the reader, we also restate the previous estimates.

Table A9 Net coverage with and without EDS and ungeocoded records as presented in the national estimate of net coverage: 2002, 2003, and 2004 reports.

	Census Region	ACS Eligible Units	ACS without EDS Records	ACS without Ungeocoded Records	ACS without Ungeocoded or EDS Records
2002					
	Northeast	2.22%	0.64%	0.31%	-0.84%
	Midwest	2.15%	0.34%	-0.19%	-1.17%
	South	2.82%	0.21%	-1.19%	-2.65%
	West	0.98%	-1.23%	-1.68%	-2.67%
	National	**2.05%**	**-0.09%**	**-0.89%**	**-2.08%**
2003					
	Northeast	2.54%	0.72%	0.76%	-0.62%
	Midwest	2.57%	0.42%	-0.18%	-1.42%
	South	2.95%	-0.04%	-1.46%	-3.19%
	West	1.17%	-1.26%	-2.38%	-3.62%
	National	**2.30%**	**-0.16%**	**-1.05%**	**-2.50%**
2004					
	Northeast	3.05%	1.16%	1.06%	-0.41%
	Midwest	2.89%	0.43%	-0.18%	-1.67%
	South	3.21%	-0.05%	-1.67%	-3.62%
	West	1.66%	-1.06%	-2.13%	-3.66%
	National	**2.67%**	**-0.04%**	**-1.03%**	**-2.69%**

Current and Previous Housing Units Estimates from the Population Division

As stated earlier in the report, the Population Division updates its estimates annually, and in the process, estimates from previous years are updated as well. Table A10 shows the current and previous estimates.

Table A10 Current and previous national estimates of housing units from the population division.

Year of Estimates	Year Obtained 2004	2005	2006
2002	119,324,211	119,382,262	119,381,715
2003	120,879,390	120,966,343	120,969,394
2004	N/A	122,671,734	122,676,668
2005	N/A	N/A	124,521,886

N/A indicates Not Applicable

Estimates and Standard Errors from the Census 2000 HUCS

Table A11 shows the percent net undercount of housing units from Census 2000, as estimated in the Census 2000 HUCS report (Barrett et al., 2003). These undercount estimates were used to create the housing unit DSE for the U.S. and regions and are provided here to give the reader some information about the variability of the coverage estimates used in this report (see limitation 3.7).

Table A11 Percent net undercount of housing units from the Census 2000 HUCS report: U.S. and regions.

Census Region	Percent Net Undercount	Standard Error
Northeast	0.47	0.40
Midwest	0.19	0.26
South	0.44	0.28
West	0.86	0.40
National	0.61	0.16

Appendix B

Requirements for Setting the ACS Delivery Flag for the ACS MAF Extract (Singh and Dean, 2005)

The ACS Delivery Flag (ACSDEL) on the July 1, 2005 MAF extracts delivered for ACS should be assigned one of these values:

0	Invalid for ACS
1	Valid for ACS; a ***good Census 2000 address*** that was not deleted by CQR or the surviving member of a linked set of addresses that included at least one good census address.
2	Valid for ACS; a ***CQR add*** or ***CQR reinstatement*** that has not been deleted by DAAL.
3	Valid for ACS; a ***post-census DSF add*** that is inside the blue line or is ungeocoded, is a residential mail delivery point on the DSF, and has not been deleted by DAAL.
4	Valid for ACS; a ***census delete that persists on the DSF*** as a residential mail delivery point.
5	Valid for ACS; a ***DAAL add*** or an address that was previously invalid but has been validated by DAAL.
6	Valid for ACS; a ***test/special census add*** or an address that was previously invalid but has been validated by a Census Test.

Use the following chart to assign the ACSDEL values. Each column – A through F – refers to a set of conditions that must be checked. The conditions are detailed in the table that follows it. A box with a ✓ means *all* the conditions in that set are satisfied, × means they are not all satisfied, and a shaded box means it does not matter.

A	B	C	D	E	F	G	Set ACSDEL to:
✓	✓						1
✓	×	✓					2
✓	×	×	✓				3
✓	×	×	×	✓			4
✓	×	×	×	×	✓		5
✓	×	×	×	×	×	✓	6
All other combinations							0

<table>
<tr><th colspan="2">Sets of conditions for setting ACSDEL (changes from previous year are in bold):</th></tr>
<tr><td>General Requirements (A)</td><td>A-1] The address is:
1) <u>not</u> a duplicate (UNITSTAT is not " 7") <u>and</u>
2) <u>not</u> a physical merge (UNITSTAT is not "29") <u>and</u>
3) not a DSF misdelivery (UNITSTAT is not "16") and
4) <u>not</u> any other type of "retired" record in a linked set of MAFIDs (SURVMAFID is blank)
A-2] The address is residential (RESSTAT="1")</td></tr>
<tr><td>Census 2000 Addresses (B)</td><td>B-1] The address was recognized as a "good" address for Census 2000 (INCENSUS="Y") and was valid for CQR (CQRUSTAT="1")
OR
B-2] The address is the surviving member of a linked set of addresses in which at least one of the retired addresses was a good census address (CENSURV="1")</td></tr>
<tr><td>CQR Adds and Reinstatements (C)</td><td>C-1[The address meets one of these conditions:
1) it was added by CQR (CQRACT="A")
2) it was reinstated by CQR (CQRACT= "R")
3) its HU/GQ status was corrected by CQR (CQRUSTAT="1" <u>and</u> CQRACT is either "G" or "H")</td></tr>
<tr><td>Post-Census DSF Adds (D)</td><td>D-1] The address made its first appearance as a non-commercial address—that is, the DSF Flag is either "1" (residential) or "3" (unknown)—on the DSF in 11/1999 or later
D-2] The address was not delivered on a DMAF for Census 2000 (PREVDEL="N")
D-3] The address meets at least one of these conditions:
1) It is ungeocoded (BTEA is blank) and is <u>not</u> in a county that is entirely outside the "blue line" or geocoded to block with ACT code of MD
2) It is geocoded to a block <u>inside</u> the blue line (BTEA is '1' or '6'-'8')
3) It is the surviving member of a LACS conversion in which both the old and new LACS addresses were found in the MAF (NEWLACSCON is "1", "2", or "3")
4) It is geocoded to a block with one of these ACT codes: C1, C2, C3, Z0, B1, B2, B3, M3, MA, MB, or MC
D-4] The address was neither added by DAAL nor added by a census test (the latest action reflected in the set of action codes DAALACT, DAALLCACT, DAALGQACT, or DAALLCGQACT is not "A" <u>and</u> AC04ACT is not "A")
D-5] The address appears on the most recent DSF with a residential status of "residential" or "unknown" (the most recent DSF Flag is "1" or "3")
D-6] The address is <u>not</u> a business address according to the USPS (Delivery Point Type Flag is <u>not</u> in either of these ranges: "I" through "P"; "1" through "8")
D-7] The address is not an "alternate" address from the DSF (ALTBASE is <u>not</u> "1")
D-8] The address is <u>not</u> a multi-unit placeholder or any other type of DSF address known to be invalid (XTYPE is "0" or "9")
D-9] The address is <u>not</u> a rural address from the DSF (DSFRT is <u>not</u> "R")
D-10] LACS Conversion Flag—New Unit (NEWLACSCON) is neither "4" nor "5"
D-11] The address is not in a "unique" ZIP Code (ZIP Classification — ZIP is not "U")</td></tr>
</table>

Sets of conditions for setting ACSDEL (changes from previous year are in **bold**):	
Census Deletes That Persist on DSF (E)	**E-1]** The address was originally delivered on a DMAF for Census 2000 (PREVDEL="Y") **E-2]** The address was <u>not</u> in the CQR universe (CQRUSTAT="0") **E-3]** The address is a residential mail delivery point for the USPS (Delivery Point Type Flag is in the range "A" through "H") **E-4]** The address appears on the most recent DSF with a residential status of "residential" (the most recent DSF Flag is "1") **E-5]** The address is not an "alternate" address from the DSF (ALTBASE is <u>not</u> "1") **E-6]** The address is <u>not</u> a rural address from the DSF (DSFRT is <u>not</u> "R") **E-7]** LACS Conversion Flag—New Unit (NEWLACSCON) is neither "4" nor "5" **E-8]** The address is not in a "unique" ZIP Code (ZIP Classification — ZIP is not "U")
DAAL Adds (F)	**F-1]** The address was added, verified, moved, or changed by DAAL (the latest action reflected in the set of action codes DAALACT, DAALLCACT, DAALGQACT, or DAALLCGQACT is "A", "V", "M", "C", "G", or "H") **F-2]** LACS Conversion Flag—New Unit (NEWLACSCON) is neither "4" nor "5"
Census Test Adds (G)	**G-1]** The address was added, verified, moved, or changed by a Census Test operation (AC04ACT is "A", "V", "M", or "C") **G-2]** **The address was added, verified, moved, or changed by a Special Census operation (ACSC is "A", "V", "M", or "C")** **G-3]** LACS Conversion Flag—New Unit (NEWLACSCON) is neither "4" nor "5"

Appendix C

Residential Delivery Point Type Codes Excluded from USPS Delivery Statistics (Bureau of the Census 2002)

On the USPS address file, each address has a delivery point type code assigned to it. The codes R through Z refer to residential addresses that are not currently receiving mail from the USPS and are used to determine units classified as EDS in this report. These codes are listed below with a brief description.

R: Residential curbline (a single receiving point at the curb).

S: Residential NDCBU (neighborhood delivery and collection box units). These are records where the delivery point is one that is serviced by residential cluster boxes.

T: Residential central – these are records in buildings with more than one ZIP+4 codes assigned to a bank of boxes.

U: Residential other – these are records where the delivery point is one serviced by other than curb, central, or NDCBU, and include door-to-door and door slot.

V: Residential facility box – these are boxes in a postal facility.

W: Residential contract box – same as V, but the boxes are in a contract facility.

X: No other information provided – Unknown type of delivery point.

Y: Residential detached box – same as W, has more to do with fee collection by the USPS.

Z: Residential non-personnel unit – this is a self-service unit that is not staffed.

Appendix D

Address Characteristic Type (ACT) Code Definitions (Sobel 2005)

The Census 2000 Blue Line was delineated for the 2000 Census to divide areas of city-style and non-city-style addresses. Areas with predominantly city-style addresses were considered to be inside the Blue Line and non-city-style address areas were considered to be outside the Blue Line. The Blue Line was used to determine Type of Enumeration Areas for Census 2000. It is currently still used, but is out of date as many of the addresses outside the Blue Line have been converted to city-style addresses. The Blue Line for Intercensal Master Address File Maintenance Workgroup was therefore established to design a new method for identifying city-style and non-city-style address areas.

The group has decided on the following ACT Codes, which will be determined by block and will indicate whether addresses in the block are city or non-city-style and whether they are supported by the DSF for statewide counties.

Code C1 – city-style, no DSF – Assign a code of C1 if all of the following are true:

a. At least one record in the block is residential
b. All of the records in the block are city-style
c. None of the records in the block have a DSF source

Code C2 – city-style, some DSF – Assign a code of C2 if all of the following are true:

a. At least one record in the block is residential
b. All of the records in the block are city-style
c. At least one record in the block has a DSF source
d. At least one record in the block does not have a DSF source

Code C3 – city-style, all DSF – Assign a code of C3 if all of the following are true:

a. At least one record in the block is residential
b. All of the records in the block are city-style
c. All of the records in the block have a DSF source

Code R1 – Rural Route, no DSF – Assign a code of R1 if all of the following are true:

a. At least one record in the block is residential

b. All of the records in the block are rural route
c. None of the records in the block have a DSF source

Code R2 – Rural Route, some DSF – Assign a code of R2 if all of the following are true:

a. At least one record in the block is residential
b. All of the records in the block are rural route
c. At least one record in the block has a DSF source
d. At least one record in the block does not have a DSF source

Code R3 – Rural Route, all DSF – Assign a code of R3 if all of the following are true:

a. At least one record in the block is residential
b. All of the records in the block are rural route
c. All of the records in the block have a DSF source

Code P1 – P.O. Box, no DSF – Assign a code of P1 if all of the following are true:

a. At least one record in the block is residential
b. All of the records in the block are P.O. Box
c. None of the records in the block have a DSF source

Code P2 – P.O. Box, some DSF – Assign a code of P2 if all of the following are true:

a. At least one record in the block is residential
b. All of the records in the block are P.O. Box
c. At least one record in the block has a DSF source
d. At least one record in the block does not have a DSF source

Code P3 – P.O. Box, all DSF – Assign a code of P3 if all of the following are true:

a. At least one record in the block is residential
b. All of the records in the block are P.O. Box
c. All of the records in the block have a DSF source

Note: There should not be any P2 or P3 blocks at this time. They are reserved for future use.

Code D1 – Location Descriptions and Incomplete Records – Assign a code of D1 if all of the following are true:

a. At least one record in the block is residential
b. None of the records in the block are city-style
c. None of the records in the block are rural route
d. None of the records in the block are P.O. Box

Code M1 – Mixed City-style and Non-city-style, no DSF – Assign a code of M1 if all of the following are true:

a. At least one record in the block is residential
b. At least one record in the block is city-style
c. At least one record in the block is non-city-style
d. None of the records in the block has a DSF source

ACT code "M2" was divided into finer levels by using the percentage of city-style records. The new "M2" ACT codes are assigned as follows:

Code MA – Mixed City-style and Non-city-style, some DSF, where the percentage of city-style is 99.99% to 95%. Assign a code of MA if all of the following are true:

a. At least one record in the block is residential
b. At least one record in the block is city-style
c. At least one record in the block is non-city-style
d. At least one of the records in the block has a DSF source
e. At least one of the records in the block does not have a DSF source
f. The percentage of city-style to non-city-style is 99.99% to 95%

Code MB – Mixed City-style and Non-city-style, some DSF, where the percentage of city-style is 94.99% to 90%. Assign a code of MB if all of the following are true:

a. At least one record in the block is residential
b. At least one record in the block is city-style
c. At least one record in the block is non-city-style
d. At least one of the records in the block has a DSF source
e. At least one of the records in the block does not have a DSF source
f. The percentage of city-style to non-city-style is 94.99% to 90%

Code MC – Mixed City-style and Non-city-style, some DSF, where the percentage of city-style is 89.99% to 85%. Assign a code of MC if all of the following are true:

a. At least one record in the block is residential
b. At least one record in the block is city-style
c. At least one record in the block is non-city-style
d. At least one of the records in the block has a DSF source
e. At least one of the records in the block does not have a DSF source
f. The percentage of city-style to non-city-style is 89.99% to 85%

Code MD – Mixed City-style and Non-city-style, some DSF, where the percentage of city-style is 84.99% to 80%. Assign a code of MD if all of the following are true:

a. At least one record in the block is residential
b. At least one record in the block is city-style
c. At least one record in the block is non-city-style
d. At least one of the records in the block has a DSF source
e. At least one of the records in the block does not have a DSF source
f. The percentage of city-style to non-city-style is 84.99% to 80%

Code ME – Mixed City-style and Non-city-style, some DSF, where the percentage of city-style is 79.99% to 75%. Assign a code of ME if all of the following are true:

a. At least one record in the block is residential
b. At least one record in the block is city-style
c. At least one record in the block is non-city-style
d. At least one of the records in the block has a DSF source
e. At least one of the records in the block does not have a DSF source
f. The percentage of city-style to non-city-style is 79.99% to 75%

Code MF – Mixed City-style and Non-city-style, some DSF, where the percentage of city-style is 74.99% to 70%. Assign a code of MF if all of the following are true:

a. At least one record in the block is residential
b. At least one record in the block is city-style
c. At least one record in the block is non-city-style
d. At least one of the records in the block has a DSF source
e. At least one of the records in the block does not have a DSF source
f. The percentage of city-style to non-city-style is 74.99% to 70%

Code MG – Mixed City-style and Non-city-style, some DSF, where the percentage of city-style is 69.99% to .01%. Assign a code of MG if all of the following are true:

a. At least one record in the block is residential
b. At least one record in the block is city-style
c. At least one record in the block is non-city-style
d. At least one of the records in the block has a DSF source
e. At least one of the records in the block does not have a DSF source
f. The percentage of city-style to non-city-style is 69.99% to .01%

Codes MA, MB, MC, MD, ME, MF, and MG replace the M2 ACT code.

Code M3 – Mixed City-style and Non-city-style, all DSF – Assign a code of M3 if all of the following are true:

a. At least one record in the block is residential
b. At least one record in the block is city-style
c. At least one record in the block is non-city-style
d. All of the records in the block have a DSF source

Code N1 – Non-city-style, assorted, no DSF – Assign a code of N1 if all of the following are true:

a. At least one record in the block is residential
b. None of the records in the block are city-style
c. None of the records in the block have a DSF source

Code N2 – Non-city-style, assorted, some DSF – Assign a code of N2 if all of the following are true:

a. At least one record in the block is residential
b. None of the records in the block are city-style
c. At least one record in the block has a DSF source

d. At least one record in the block does not have a DSF source

Code N3 – Non-city-style, assorted, all DSF – Assign a code of N3 if all of the following are true:

a. At least one record in the block is residential
b. None of the records in the block is city-style
c. All of the records in the block have a DSF source

Code B1 – Nonresidential, no DSF – Assign a code of B1 if all of the following are true:

a. None of the records in the block are residential
b. None of the records in the block have a DSF source

Code B2 – Nonresidential, some DSF – Assign a code of B2 if all of the following are true:

a. None of the records in the block are residential
b. At least one record in the block has a DSF source
c. At least one record in the block does not have a DSF source

Code B3 – Nonresidential, all DSF – Assign a code of M3 if all of the following are true:

a. None of the records in the block are residential
b. All of the records in the block have a DSF source

Code Z0 – No Addresses – There are no records in the block

Appendix E

Definition of Validity Status for ACS – Based on CAPI Final Disposition

Valid

Outcome	Definition
201	Occupied
202	Insufficient partial, case still available
203	Sufficient partial (occupied) - no follow-up
204	Sufficient partial (occupied) - follow-up
213	Language problem
216	No one home
217	Residents temporarily absent
218	Respondent refusal
219	Other, occupied
229	Under construction
241	House or trailer moved
245	Condemned
255	Address converted to group quarters
301	Vacant
305	Vacant insufficient partial, case still available
309	Removed from work load
310	Respondent gives you completed questionnaire
501	Temporarily occupied

Unknown

Outcome	Definition
214	Unable to locate
233	Other

Invalid

Outcome	Definition
243	Converted to permanent business or storage
244	Merged
248	Other
253	Unit non-existent - BSA found
254	Address non-existent

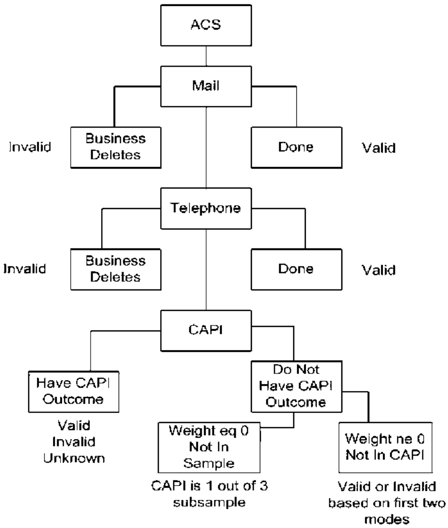

Fig. E1 2004 ACS outcome flow used to record the status for each ACS case in mailing, telephone, or personal interviewing phases.

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Section II

POPULATION ESTIMATES AND PROJECTIONS

Chapter 5
Using Assessor Parcel Data to Maintain Housing Unit Counts for Small Area Population Estimates

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Background and Introduction

The San Diego Association of Governments (SANDAG) has produced small area population estimates for San Diego County since 1984. SANDAG uses the housing unit method of population estimation and controls small area estimates (i.e. census tract level or smaller) to January 1 city and county population totals published by the California Department of Finance (DOF) in May each year. Because the small area estimates are based on housing unit counts, it is important to get the most accurate and timely data available.

Originally SANDAG produced estimates at the census tract level. Later a split-tract geography was introduced so that estimates could be produced for cities, zip codes, school districts, and other political and administrative areas by aggregating estimates for the split tracts. The next progression was to split blocks to allow the compilation of estimates for more customized areas within the county. From split blocks, the natural evolution was to producing estimates at an even smaller geography: the parcel. Parcels are individual house- or business-lots that are tracked by a tax assessor for ownership and taxation purposes. Currently SANDAG produces housing unit and group quarters population estimates at the parcel level. Plans are to develop household population and characteristics estimates at the parcel level using microsimulation techniques.

SANDAG's small-area population estimates are used for a wide variety of purposes. For example, the data provide the backbone for work on infrastructure planning (transit system performance measures), public safety (crime rates), and public health (epidemiological studies). Estimates may be needed for an entire city, a collection of zip codes, or for a buffered area along a transportation corridor. One common use of the estimates is to determine the population within "walking distance" (one quarter mile) of a transit station. Split block-level estimates are too coarse for these calculations and a finer level of geographic detail is required. This issue is not unique to San Diego:

S.H. Murdock and D.A. Swanson (eds.), Applied Demography in the 21st Century, 89–101.

> For many years, population estimates and projections were made primarily at the national and state/provincial levels. In recent decades, they have been carried out at progressively lower levels of geography and are now routinely made for very small areas in the United States – census tracts, block groups, and traffic analysis zones. Methods are already designed for extremely small areas such as blocks and grid cells . . . We also note a growing demand for estimates and projections for even smaller areas such as tax assessor parcels, block faces, and street segments. (Swanson & Pol 2005: 16)

Modeling spatial interactions, for instance for land development projections and transportation forecasts, depends upon a rich dataset with a fine level of spatial detail. In an effort to produce the most detailed data available, SANDAG is migrating to a parcel-based estimates system.

The Housing Unit Method of Population Estimation

The population of any given area can be considered to be the sum of household population (persons living in a housing unit) and non-household population (persons living in group quarters, such as military barracks, college dorms, or convalescent homes). Thus, total population can be represented by the following identity:

$$\text{POPULATION} = \text{HOUSEHOLD POPULATION} + \text{NON-HOUSEHOLD POPULATION}$$

where the household population is represented by:

$$\text{HOUSEHOLD POPULATION} = \text{HOUSEHOLDS} \times \text{PERSONS PER HOUSEHOLD}$$

where the number of households is represented by:

$$\text{HOUSEHOLDS} = \text{HOUSING UNITS} \times \text{OCCUPANCY RATES}$$

In theory, if the number of housing units, occupancy rates, number of persons per household (also referred to as average household size), and non-household populations are known, then the true total population would be known. However, in practice these inputs are rarely known with complete accuracy.

In a 1989 survey, the U.S. Census Bureau found that of the agencies surveyed, 89 percent used the housing unit method (either alone or in conjunction with other methods) to produce population estimates (Byerly 1990: 3). Smith and Mandell found that the housing unit method of population estimation can be at least as good as other methods, if not better, provided that the input data are high-quality and the assumptions are sound (Smith & Mandell 1984: 287). In fact, they found that the housing unit method may hold a strong advantage in subcounty population estimates. Other techniques of small area estimation require data, such as school enrollment, auto registration, and vital events records that are often unavailable at a sub-county level and are delayed by a year or more in cases where the data are available. Therefore the housing unit method has the advantages of availability and timeliness as compared with other data sources.

There are five main sources of data that can be used for the housing unit counts that form the basis of the housing unit method of estimation. Each data source has advantages and disadvantages as outlined in the table and descriptions below.

Source	Spatial Scale	Updates	Other Issues
Utility Records	Parcel (Household)	Annual	May be less accurate than other sources (see details below). May not be available for public release
Census Counts	Block	10 years	Detail by structure type (sample survey) may not sum to 100% count
Aerial Imagery	Parcel	Annual	Costly and time-consuming Unit counts may be ambiguous
Building Permits	Parcel	Annual	Inconsistent reporting Some errors introduced in geocoding
Assessor Records	Parcel	Annual	Sparse data on non-taxable parcels Some tax assessors do not track unit counts for multi-unit dwellings

Utility records may or may not be available to the public. Moreover, meters may be turned on or off without the construction or demolition of a housing unit. Several studies have found the records to be less accurate than other sources. As noted by Rynerson and Tayman, utility records consistently over-estimated increases in housing units in San Diego County (Rynerson & Tayman 1998: 5). Starsinic and Zitter come to a similar conclusion about utility records (Starsinic & Zitter 1968: 477). Census counts are more accurate but are only available every 10 years. Aerial imagery is both precise and frequently updated but is costly and is time- consuming to convert to a small-area unit count. Furthermore, one structure may contain multiple units, and with aerial imagery it is extremely difficult to determine the number of units in a multi-unit structure.

Because of the relative advantages, building permits had been the basis for annual housing unit updates. However, building permits were subject to several inconsistencies, including variations in temporal reporting, data format, and data definition.

For building permits, many jurisdictions provided only hard-copy documents, which required staff time for keying and verification. The data entry process introduces a potential source of error. Even with electronic reporting, an average of 10 percent of permit records are not matched to the appropriate geographic location due to missing data, typographical errors, and other data mismatches. A controlling procedure was implemented to ensure that the totals were consistent with city-level detail reported by DOF, but detail below the city level was subject to error for the reasons noted above.

Moreover, there were inconsistencies in reporting across jurisdictions. Some jurisdictions report only “permits authorized” not “finals.” Permits issued may or may not become final dwelling units, and therefore use of these records led to potential over-estimates of housing units. Some jurisdictions provided a record of multi-unit

Table 1 Example of Unit Count Differences on a Federally-Owned Parcel (2000). *Sources*: U.S. Census Bureau, Census 2000; SanGIS Parcel File (2001, 2006).

U.S. Census Bureau, Census 2000 unit count:

census tract	block	unit count
6600	1004	64
6600	1005	50
6600	1006	81
6600	1007	53
6600	1008	52
6600	1009	0
6600	1010	32
TOTAL		**332**

San Diego County Assessor unit count:

parcel number	ownership	unit count
45046005	United States of America	0
TOTAL		**0**

buildings, but did not provide a unit count for those records. Similarly, structure type was sometimes ambiguous in permit records.

These difficulties provided some of the impetus for switching to a new technique of managing the housing unit estimates.

To produce the most accurate estimates possible, we used three sources to cross check the estimates by parcel: 2000 Assessor records by parcel, 2000 Census block-level housing unit counts, and 2000 aerial imagery. Each of these resources provided advantages in distinct areas. The Assessor data provided parcel level detail for privately owned housing units. The Census block data provided information for areas (e.g. federally owned parcels) where the Assessor unit counts were missing. The aerial imagery provided a resource for visual verification of the unit counts and a cross-check in the event of a mismatch between Census and Assessor data.

Methodology for Improving the Housing Unit Estimates

Initial Steps

As noted above, the switch to a parcel-based housing unit estimate system required an initial reconciliation between 2000 Assessor records and the 2000 Census block data. To begin, we summed the unit counts by parcel to the block level. In cases with a mismatch between the Census and Assessor records at the block level, aerial imagery served as the tie-breaker. Essentially the analysts working on the reconciliation looked for a "preponderance of evidence" and assumed that if two of the three sources matched, that unit count would be carried forward.

One primary reason for using multiple sources is that Assessor records do not account for most units on non-taxable parcels. Thus, Census data and aerial imagery

Image 1 Aerial image of federally-owned parcel #45046005. *Source*: Image Link 2-foot True Color Imagery (2000).

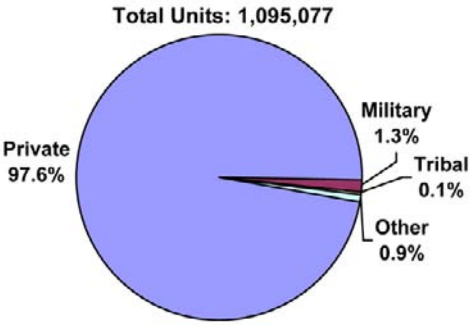

Chart 1 Dwelling unit counts by ownership (2004). *Source*: SANDAG Current Estimates (2004).

were required to identify unit counts on military bases, tribal lands, and other non-taxable property (e.g. federal, state, and city lands). Table 1 includes an example of the unit counts in a federally owned housing development. The Census Bureau counted 332 units in the community in 2000. The San Diego County Assessor, on the other hand, did not note any units at all because the parcel is not on the tax rolls. The aerial imagery clearly shows units on the property (see Image 1). In this case, the evidence supports a unit count of 332 units on the property. This step in the reconciliation identified approximately 14,700 additional units on military bases and 1,600 on tribal lands. Those corrections alone account for nearly 1.5 percent of the region's total housing stock (see Chart 1).

Table 2 Example of unit count differences on an over-counted parcel (2000). *Sources*: U.S. Census Bureau, Census 2000; SanGIS Parcel File (2001, 2006).

U.S. Census Bureau, Census 2000 unit count:

census tract	block	unit count
19107	1074	9
TOTAL		9

San Diego County Assessor unit count:

parcel number	unit count
18918115	0
TOTAL	0

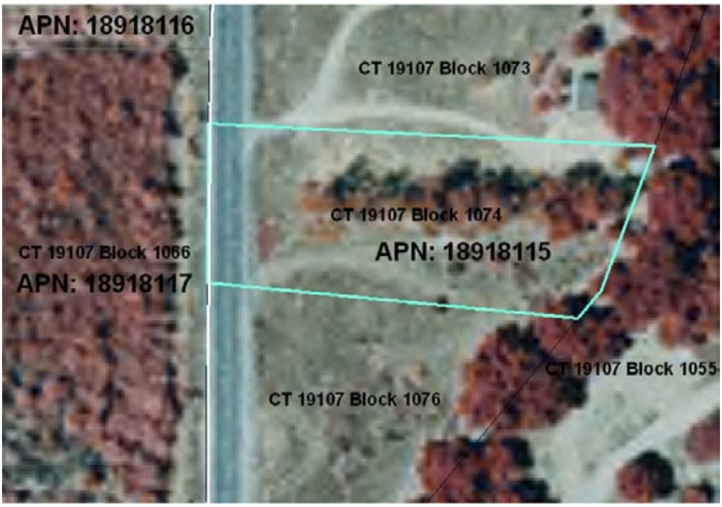

Image 2 Aerial image of over-count parcel #18918115. *Source*: Image Link 2-foot True Color Imagery (2000).

Conversely, there were several areas in which the Census Bureau recorded housing units but the Assessor records and aerial imagery showed no units (see Table 2 and Image 2). In this case, zero units were assigned to the parcel.

Finally, SANDAG has moved away from using Census-defined structure type for housing unit estimates. Census reporting of structure type was based on sample survey results, and therefore provides only an estimate of units by structure type. The move to a parcel-based housing unit system allowed a new approach for determining structure type. Since land use information is available for each parcel, the parcel's land use designation is used to determine whether a structure is single-family, multi-family, or mobile home. (See Appendix A for more details.) This provides 100 percent coverage for the structure type of units within the region.

The reconciliation between the two data sources was completed using an in-house GIS application developed in ArcGIS 8.2 and aerial imagery. The resulting data are stored in a table in an SQL database.

Updates

The database of housing units is updated every quarter with parcel records obtained from the County Assessor's office via an intermediary agency, SanGIS, which maintains geographic data for jurisdictions within the San Diego region. (For a detailed methodology, see Appendix A.) Areas not covered by Assessor records, such as military bases and reservations, are checked for changes using aerial photos.

The completed parcel-level housing unit estimates then serve as the basis for population estimates which are developed using the standard housing unit method of population estimation described above.

Advantages and Disadvantages of the Parcel Data

Advantages

Once the initial conversion is complete, there are several distinct advantages of maintaining housing unit estimates at the parcel level. First and foremost, tax assessor records are often the most consistent and up-to-date information available. As noted above, building permits are subject to several sources of error and differences in reporting across jurisdictions. The San Diego County Assessor uses a consistent technique for storing data, including spatial location, and provides updates on a quarterly basis. Also, because tax assessor records go through an annual review (when owners receive a tax bill), the data are believed to be accurate. Moreover, the GIS update process results in faster updates and easier verification of the housing unit counts.

With verification in mind, parcel-level detail also facilitates the review of estimates and forecast results. Local planners are familiar with reviewing information at the parcel level, and therefore have been better able to provide feedback on the estimates and on forecast results.

The data are also more precise. The parcel system provides a finer level of granularity than any of the prior systems. The level of geographic specificity in the parcel estimates allows more flexibility in developing custom area estimates and in answering policy questions for which data were previously unavailable. For example, as part of a planning project, the parcel-level estimates were used to identify dense residential areas within walking distance of transit stations. Prior to the introduction of parcel-level detail, this analysis would not have been possible.

Difficulties and Disadvantages

The new system resulted in a gap in the comparability of historical data series. For example, structure type definitions in the new system differ from Census Bureau definitions. Also in the new system, unit counts differ from the unit counts reported by the California Department of Finance.

The initial transition to a parcel-level housing unit estimate system is time consuming. At SANDAG, a team of staff took nearly a year to obtain the Assessor's records and to reconcile those records with the 2000 Census using aerial imagery. Switching to an Assessor-only file was not an option because many housing units are non-taxable and therefore do not show up in the Assessor's records. For example, the Census Bureau is more likely to have an accurate count of housing units on state, federal, and tribal lands. The Census Bureau records are also more likely to identify non-standard units, such as unauthorized accessory dwelling units.

Moreover, while San Diego County is fortunate to have detailed information available from the Assessor, other regions may not have this information. In these cases, the records would need to be supplemented with other sources, such as real estate databases or local surveys.

Are the Parcel Level Housing Unit Estimates Better or Worse?

Because of the level of spatial detail, the parcel-level unit counts based on tax assessor data are more precise. Error introduced by keying and geocoding building permits is completely eliminated. Moreover, the fine granularity of the data provides a rich resource to be used in studies such as identifying housing within walking distance of a transit station.

Unfortunately, we do not yet have information on the accuracy of the new method. However, former studies of assessor data suggest that the data are reasonably accurate (Rynerson & Tayman 1998: 8).

In evaluating the new method for the current SANDAG estimates, we compared the Assessor-based unit counts by jurisdiction to those reported by the California Department of Finance (DOF). The overall difference between the SANDAG and DOF housing unit estimates is 0.05 percent for the county in 2006 (see Appendix B). The SANDAG estimates tend to be lower than the DOF estimates, with a mean absolute percent difference of 1.0 percent across the region's 19 jurisdictions. At the jurisdiction-level differences range from −4.0 to 1.4 percent. There are two jurisdictions in which the SANDAG estimate is more than 2 percent lower. Those two, Del Mar and Encinitas, are smaller beach communities that have a high proportion of vacation rental homes, which may account for the lower dwelling unit estimate reported by SANDAG. The jurisdiction in which SANDAG's count is 1.4 percent higher is the unincorporated area.

Next Steps

In addition to being used for the annual population estimates, the parcel-level housing estimates were used as the basis for SANDAG's most current long-range fore-

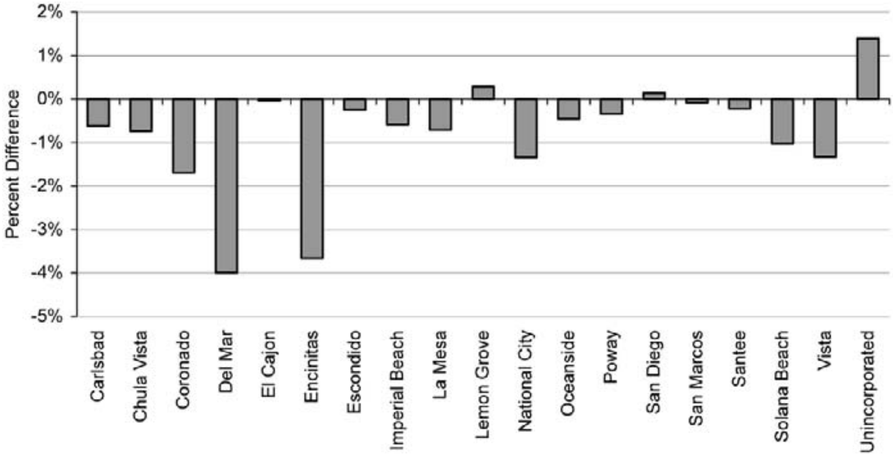

Chart 2 Percent difference by jurisdiction between parcel-based unit counts and state DOF unit counts (2006). *Sources*: SANDAG, Current Estimates (2006); California Department of Finance (DOF), E-5 Population and Housing Estimates for Cities, Counties and the State (2006).

cast. The parcel-level data will also facilitate the development of new forecast and estimates models.

Currently SANDAG produces parcel-level housing unit and group quarters population estimates. The most obvious next step is to produce household population estimates at the parcel level to round out the dataset. We are exploring microsimulation estimation techniques to produce population and characteristics estimates at the household level.

Understandably, microsimulation produces “misleadingly precise” details about every person in a population (Bowman & Rousseau 2006: 1). In fact, at the household level every record is expected to be “incorrect.” However, these records conform to known estimates when aggregated to larger levels of geography (e.g. split tract). Moreover, the household/parcel-level spatial detail is necessary to support next-generation modeling efforts in demographic and economic forecasting and in transportation modeling.

Currently the next-generation models are land-economics based simulation models, such as the PECAS model described above. The PECAS model projects urban development based on economic interactions at the business and household level. The move toward parcel-level housing unit estimates is only the first step in this larger modeling conversion effort. Household-level demographic estimates will be a necessary next step. A detailed inventory of land information (built space, rents, costs, etc.) will also be developed for the PECAS model. The new model is expected to be able to better represent urban spatial interactions, such as residential development and firm locations, and to serve as a tool to analyze the impact of various policy alternatives.

These specific developments represent a larger shift in modeling practices. Longley theorizes that deeper understanding of urban theory is "predicated upon continued ability to measure what is going on in urban areas" and that GIS technology is facilitating the development of ever more complex urban models (Longley 2000: 163). In essence, refinements in the granularity of our data and the ability to track information on a fine spatial scale will improve modeling efforts now and in the future.

Appendix A: Detailed Methodology for Maintaining Parcel Housing Estimates

Three files are combined to create the parcel level housing unit estimates:

1. Parcel File – a digital representation of the most current parcel boundaries, which includes stacked polygons for multi-owner parcels (e.g. condominiums);
2. Master Property Records (MPR) File – a tabular list of selected parcel characteristics including Parcel ID, Assessor's Parcel Number (APN), number of units, and land use; and
3. Property Characteristics – a tabular list of parcel details including Parcel ID, Assessor's Parcel Number (APN), value of improvements, year effective (generally relating to year constructed), and square footage of building (for residential parcels).

The unique identifier for each record is the combined Parcel ID and APN and is used to link the three files.

One of the difficulties of managing the new parcel-based system is that the unique identifier, Parcel ID – APN combination, changes every quarter. This complicates the effort of tracking changes over time. Fortunately parcels with no change keep the same Parcel ID – APN combination. Only those records that have changed, because of a subdivision, merger, or development, change Parcel ID – APN.

Step 1: Managing the Spatial Data
The first step in the update process is to group the stacked polygons from the Parcel File so that the resulting file has only one polygon per parcel. Road right-of-ways are then merged into the file. The resulting file usually has some gaps and overlaps in the polygons, so those are edited to ensure that there are no inconsistencies in the final dataset.

Step 2: Carrying Along Prior Year Counts
The second step in the process is to update dwelling unit counts to account for any changes that have occurred since the last update. Most changes occur on parcels that have been subdivided. Therefore the first step is for records where there has been no change. If a unique Parcel ID – APN record exists in both the current and prior quarter, the unit count is carried along from the prior quarter's file.

Of these cases, which represent well over 90 percent of the processing, records where the current unit count does not match the prior period are flagged for follow-up investigation.

Being able to simply update all records to the current Assessor's unit count would be simplest, but then historical edits to account for units on tribal and federal lands, for example, would be lost.

Step 3: Adding New Units
The third step is to add information for new parcels. New parcels are identified by Parcel ID – APN combinations that did not exist in the prior period. These parcels are assigned the unit count from the MPR. Non-taxed areas are checked for changes using aerial photos.

Step 4: Demolitions
Finally, if a Parcel ID – APN combination existed in the prior period but does not exist now, the units are assumed to have been demolished. Units that still exist and are assigned to a new parcel would be accounted for in step three.

Investigation and Cross-Checking

As with the initial development of the data set, aerial imagery is used to verify the updates. Other sources used to verify the updates include changes to the value of improvements listed on the property record, changes to the land use (e.g. a change from "vacant" to "single family"), listings in the Haines directory, and a small amount of informal field verification.

Finally, the jurisdictions (cities and county) in San Diego and the California Department of Finance provide two independent estimates of housing unit counts by jurisdiction. These estimates are used to determine whether the final unit counts by jurisdiction are reasonable.

Assigning Structure Type

At SANDAG a good deal of staff time is spent in maintaining up-to-date land use information for each parcel. Therefore housing unit structure type is assigned based on parcel land use. For example,

- Units on land coded as a mobile home park are classified to be mobile homes.
- Units on land coded as single family or agricultural/rural residential are classified as single family homes.
- Units on multi-family land are classified as multi-family units.
- Finally, units on non-residential land (e.g. units on commercial property) are classified by the number of units on the parcel. One unit parcels are classified single family while two or more units on a non-residential parcel get a multi-family designation.

While this procedure leads to the potential for some obvious misclassifications (e.g. a mobile home on agricultural land being classified instead as a single family structure) overall the classification system has led to reasonable results. SANDAG currently is exploring the option of moving away from reporting structure type and instead reporting units by density for future estimates.

Appendix B: Reported Housing Unit Counts by Jurisiction (2000, 2004, and 2006)

SANDAG ASSESSOR-BASED ESTIMATES

	2000	2004	2006
Carlsbad	33,798	39,287	41,826
Chula Vista	59,495	70,609	75,078
Coronado	9,494	9,450	9,427
Del Mar	2,557	2,511	2,499
El Cajon	35,188	35,429	35,460
Encinitas	23,843	24,521	24,592
Escondido	45,107	46,467	46,815
Imperial Beach	9,739	9,754	9,792
La Mesa	24,943	24,911	24,921
Lemon Grove	8,722	8,770	8,797
National City	15,422	15,158	15,383
Oceanside	59,581	62,767	63,673
Poway	15,714	16,183	16,281
San Diego	469,689	490,266	498,826
San Marcos	18,888	23,190	25,867
Santee	18,833	18,891	19,182
Solana Beach	6,456	6,473	6,481
Vista	29,813	30,169	30,575
Unincorporated	152,867	160,271	163,224
San Diego County	1,040,149	1,095,077	1,118,699

STATE (DOF) REPORTED ESTIMATES

	2000	2004	2006
Carlsbad	33,798	39,269	42,086
Chula Vista	59,495	70,067	75,640
Coronado	9,494	9,558	9,589
Del Mar	2,557	2,595	2,603
El Cajon	35,188	35,439	35,474
Encinitas	23,843	25,178	25,528
Escondido	45,107	46,374	46,934
Imperial Beach	9,739	9,814	9,850
La Mesa	24,943	24,993	25,099
Lemon Grove	8,722	8,764	8,772
National City	15,422	15,465	15,592
Oceanside	59,581	62,732	63,963
Poway	15,714	16,202	16,337
San Diego	469,689	487,254	498,125
San Marcos	18,888	22,498	25,888
Santee	18,833	18,786	19,223
Solana Beach	6,456	6,533	6,548
Vista	29,813	30,544	30,987
Unincorporated	152,867	159,201	160,986
San Diego County	1,040,149	1,091,266	1,119,224

DIFFERENCE

	2000	2004	2006
Carlsbad	0	18	-260
Chula Vista	0	542	-562
Coronado	0	-108	-162
Del Mar	0	-84	-104
El Cajon	0	-10	-14
Encinitas	0	-657	-936
Escondido	0	93	-119
Imperial Beach	0	-60	-58
La Mesa	0	-82	-178
Lemon Grove	0	6	25
National City	0	-307	-209
Oceanside	0	35	-290
Poway	0	-19	-56
San Diego	0	3,012	701
San Marcos	0	692	-21
Santee	0	105	-41
Solana Beach	0	-60	-67
Vista	0	-375	-412
Unincorporated	0	1,070	2,238
San Diego County	0	3,811	-525

PERCENT DIFFERENCE

	2000	2004	2006
Carlsbad	0.0%	0.0%	-0.6%
Chula Vista	0.0%	0.8%	-0.7%
Coronado	0.0%	-1.1%	-1.7%
Del Mar	0.0%	-3.2%	-4.0%
El Cajon	0.0%	0.0%	0.0%
Encinitas	0.0%	-2.6%	-3.7%
Escondido	0.0%	0.2%	-0.3%
Imperial Beach	0.0%	-0.6%	-0.6%
La Mesa	0.0%	-0.3%	-0.7%
Lemon Grove	0.0%	0.1%	0.3%
National City	0.0%	-2.0%	-1.3%
Oceanside	0.0%	0.1%	-0.5%
Poway	0.0%	-0.1%	-0.3%
San Diego	0.0%	0.6%	0.1%
San Marcos	0.0%	3.1%	-0.1%
Santee	0.0%	0.6%	-0.2%
Solana Beach	0.0%	-0.9%	-1.0%
Vista	0.0%	-1.2%	-1.3%
Unincorporated	0.0%	0.7%	1.4%
San Diego County	0.0%	0.3%	0.0%

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Chapter 6
Aging and Elder Abuse: Projections for Michigan

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Introduction

Demographic changes in the population age structure are outcomes of longer life expectancies, lower birth rates, and an older average age of giving birth (see, e.g., Ram 1998, Chesnais 2001, Vaupel 2001, Becker 2004). It has been recognized that such changes are likely to result in significant increases in elder abuse (see, e.g., Ramsey-Klawsnik 2000, Voelker 2002). Specifically, disproportionate increases in the number of dependent elders relative to working age individuals may result in higher stress levels among caregivers and increase abuse opportunities, and thus may act to increase the rates of elder abuse.

Clinicians have identified a broad array of risk factors typically associated with elder abuse and neglect (for recent surveys, see Lachs and Pillemer 2004, Pillemer and Finkelhor 1989, and Podnieks 2004). Factors such as a caregiver's mental health, substance abuse, dependence on the care recipient, and depression have been described as important indicators of elder abuse and mistreatment. Alternative theories of abuse emphasize the personal problems of the abuser (e.g., alcoholism and personality characteristics) and the personal characteristics of the elderly (e.g., poor health, limitations of daily living, social isolation) as primary factors of abuse.

The literature on elder mistreatment, however, appears to emphasize dependency and stress as two of the most significant factors. For example, a positive relationship between abuse and stressful workplace environment has been emphasized in Pillemer and Finkelhor (1989) and Pillemer and Moore (1989). Specifically, caregiver stress, total hours worked per patient, and staff-to-patient ratio have been associated with elder abuse (see, e.g., Beach et al. 2005, Kleinschmidt 1997, Payne and Cikovic 1995). For example, Pillemer and Brachman-Prehn (1991) found that stressful working conditions and staff burnout were significant risk factors for maltreatment of nursing home residents. Harrington et al. (2000) found a positive rela-

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tionship between nurse staffing hours and nursing home deficiencies. Coyne et al. (1993) compared abusive caregivers to those who were non-abusive and found that the former had provided care for more years and more hours per day and for patients functioning at lower levels. The specific mechanisms that lead to increased levels of abuse, neglect, and exploitation, are not clear; what is consistent among the studies is that a decrease in the qualified workforce is inversely related to abuses.

This study builds on previous elder abuse research in that we factor in caregiver stress. However, our approach goes beyond facility-based results outlined above. We claim that caregiver stress is not restricted to nursing homes and hospitals, but that it is a society wide phenomenon. The fewer younger people there are in a society to take care of a given number of elderly, the higher the aggregate level of caregiver stress in the society, and thus the larger is the potential extent of elder abuse.

Correspondingly, we first construct an aggregate demographic aging measure to approximate for such an aggregate level of society-wide caregiver stress. We use the ratio of the elderly to the working-age adults in Michigan as a proxy. We then project expected abuse based on demographic population projections.

While this study focuses on Michigan, it is important to note that Michigan's population age structure is very similar to that of the entire United States.

Method

To quantify projected changes in the population age structure of Michigan, population pyramids and elder age dependency ratios are calculated out to the year 2030.

Population pyramids provide a graphical display of fluctuations in the age distribution by displaying the relative size of age-defined cohorts. The size of each cohort is calculated using demographic projection data from Woods and Poole (2004).

Elder dependency ratios provide a numerical representation of fluctuations in the age distribution of the population. The Elder Dependency Ratio (*EDR*) is calculated by dividing the number of elderly (those aged 65 and older) by the number of working age individuals (those between 15 and 64 years). We use *EDR* as a proxy for the strain of dependency on working-age individuals attributed to the elderly.

The share of the elder population experiencing abuse is commonly referred to as the prevalence of elder abuse (*PEA*). To project the incidence (future prevalence) of elder abuse relative to changes in the dependent and workforce populations, the baseline *PEA* is multiplied by the change in the *EDR* between time intervals as exemplified in the following equation:

$$PEA_{t+1} = \left(1 + \frac{EDR_{t+1} - EDR_t}{EDR_t}\right) PEA_t, \tag{1}$$

where *PEA* stands for prevalence of elder abuse, *EDR* stands for elder dependency ratio, and the subscripts t and $t+1$ represent the time period.

Equation (1) states that the prevalence of elder abuse at time $t + 1$ is a function of the prevalence at time t and the change in the elder dependency ratio from time t to time $t + 1$. This relationship is based on the assumption that the prevalence of abuse is dependent on caregiver stress and opportunity and that an increase in the elderly dependency ratio will result in an increase in abuse. In the case where there is no change in the *EDR* ($EDR_{t+1} = EDR_t$), there is no change in the *PEA* ($PEA_{t+1} = PEA_t$). For simplicity, Equation (1) is constructed so that a 1 percent increase in the *EDR* causes a 1 percent increase in the *PEA*.

It is worth stressing again that the prevalence of abuse is an aggregate measure of abuse in a specified population. There is a vast literature on individual risk factors for abuse, such as patient aggression (see, e.g., Goodridge et al. 1996), dementia (see, e.g., Anetzberger et al. 2000, Dyer 2000), social isolation (see, e.g., Tarbox 1983), loss of activities of daily living (see, e.g., Beach et al. 2005), family involvement (see, e.g., Pillemer and Finkelhor 1989, Marquis et al. 2004), and sociodemographic characteristics (see, e.g., Payne and Cikovic 1995, Dyer et al. 2000). None of these individual characteristics appear in Equation (1), however some may be correlated with opportunity. Thus, we have implicitly assumed that the prevalence of these individual characteristics in the elderly population does not change over time. For example, this means that we have implicitly assumed that the proportion of elderly who are frail at time $t+1$ is the same as the proportion of elderly who are frail at time t. Given the lack of information about the demographics of frailty, it seems prudent to make the conservative assumption that there will be no change in this proportion. Thus, in an aggregated equation such as (1), we omit these variables as an approximation. Imposing these simplifying assumptions allows us to use a transparent model to investigate the effect of temporal changes in the *EDR* on the *PEA*.

To apply Equation (1), we start with the current *PEA* level and update this according to projected changes in the *EDR*. Woods and Poole (2004) provide projected changes in the population age structure needed for the calculation of *EDR* through 2030. We are particularly interested in the effects of the *EDR* on *PEA* in Michigan and so use projected changes in *EDR* for each of the 83 counties in Michigan. Because of the lack of a single valid estimate for the current *PEA*, we employed a baseline interval of 2 to 10 percent based on the existing literature (see Lachs and Pillemer 2004).

We follow Lachs and Pillemer (2004) in defining elder abuse as (1) physical abuse, which includes acts done with the intention of causing physical pain or injury; (2) psychological abuse, defined as acts done with the intention of causing emotional pain or injury; (3) sexual assault; (4) material exploitation, involving the misappropriation of the older adult's money or property; and (5) neglect, or the failure of a designated caregiver to meet the needs of a dependent older adult.

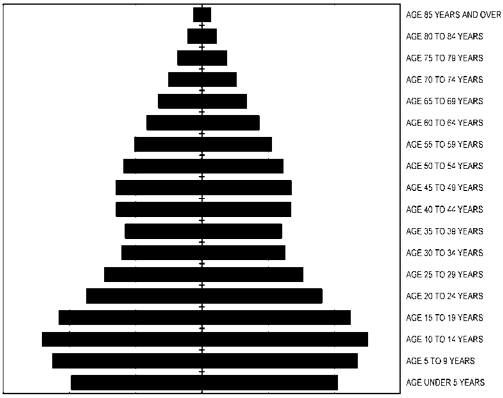

Fig. 1 Michigan population pyramid from 1970. *Source*: Woods and Poole (2004).

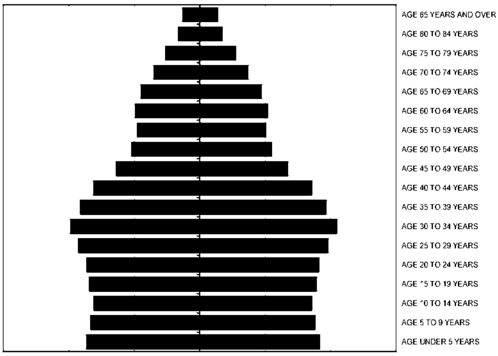

Fig. 2 Michigan population pyramid from 1990. *Source*: Woods and Poole (2004).

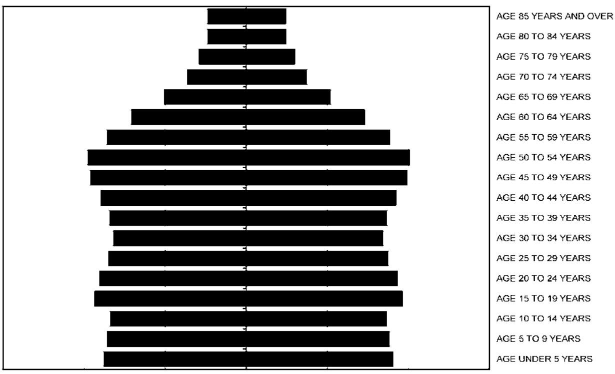

Fig. 3 Michigan population pyramid for 2010. *Source*: Woods and Poole (2004).

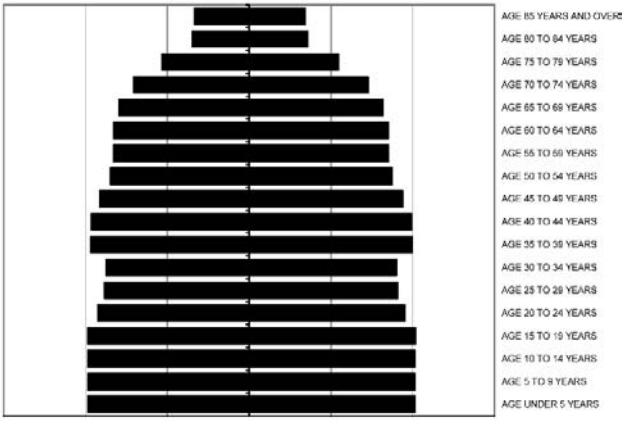

Fig. 4 Michigan population pyramid for 2030. *Source*: Woods and Poole (2004).

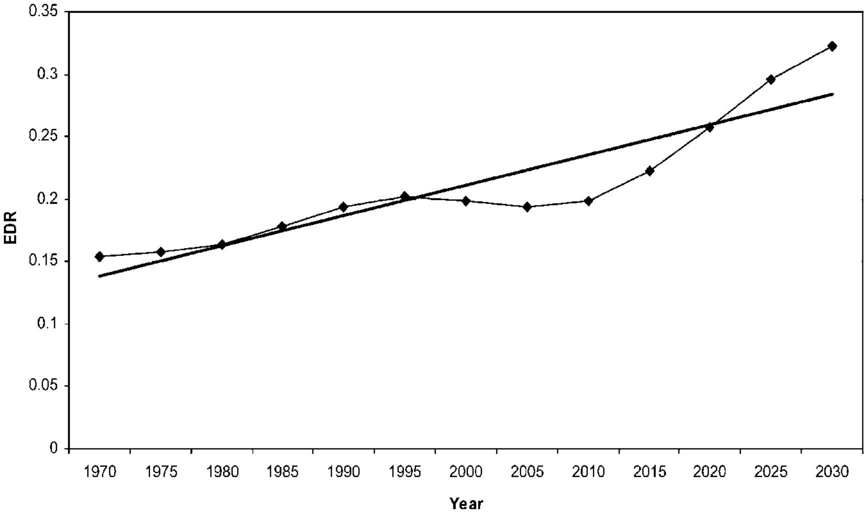

Fig. 5 Elder dependency ratio for Michigan from 1970 to 2030.

Results

The population pyramids provided in Figures 1 through 4 portray the demographic shift towards an increasingly elder society in Michigan from 1970 to 2030. As can be seen from the figures, the population pyramid is projected to become increasingly top heavy because of the significant numbers of elderly relative to working age individuals. However, the most extreme shift in the population age structure is in the number of elderly relative to the number of working-age individuals (*EDR*) depicted in Figure 5. The *EDR* for 2005 is projected to increase by 70 percent by the year

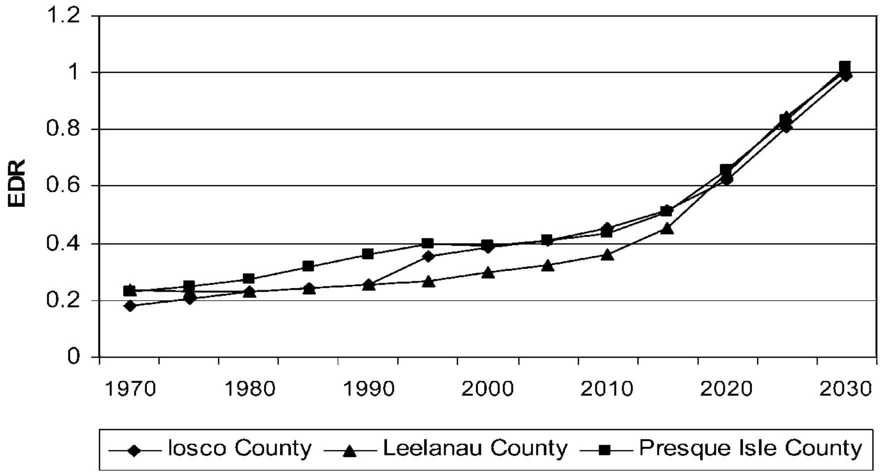

Fig. 6 Counties with the greatest projected growth in elder dependency ratio from 1970 to 2030.

2030. Compared to 1970, the year 2030 is projected to show a 200 percent increase in the *EDR*.

Statewide projections of *PEA* suggest that according to the 10-percent baseline, the abused elder population of Michigan will grow from about 122,000 in 2005 to over 337,000 in 2030.

Many rural counties in Michigan will outpace urban counties in aging population. Counties such as Iosco, Leelanau, and Presque Isle are expected to have high growth in their *EDR* between 2005 and 2030 as shown in Figure 6.

The elder abuse projections demonstrate that 80 out of 83 counties will experience an increase in the proportion of the abused elderly, regardless of the baseline used. The highest growth in prevalence between 2000 and 2030 is predicted in Leelanau, Livingston, and Marquette counties: around 20 percent if the baseline *PEA* of 10 percent is used and around 4 percent if the more conservative 2-percent *PEA* baseline is used. The projected prevalence for these counties based on the 10-percent baseline is presented in Figure 7.

The projected number of abused elderly based on the *PEA* forecasts and population projections reveal that the three counties with the highest projected number of abused elders are Macomb, Oakland, and Livingston. Again, we based our forecast on the worst-case scenario in which the prevalence rate in 2000 is estimated at 10 percent (see Figure 8). Oakland County is estimated to have over 51,000 abused elderly by 2030; Macomb County – over 24,000; and Livingston County – over 17,000. Note, however, that these forecasts are based entirely on the population dynamics and thus are not indicative of the counties' policies toward the elderly or any other county-specific factors.

Interestingly, counties with the greatest expected *PEA* increase and counties with the highest projected number of incidents of abuse are not the same counties. Clearly

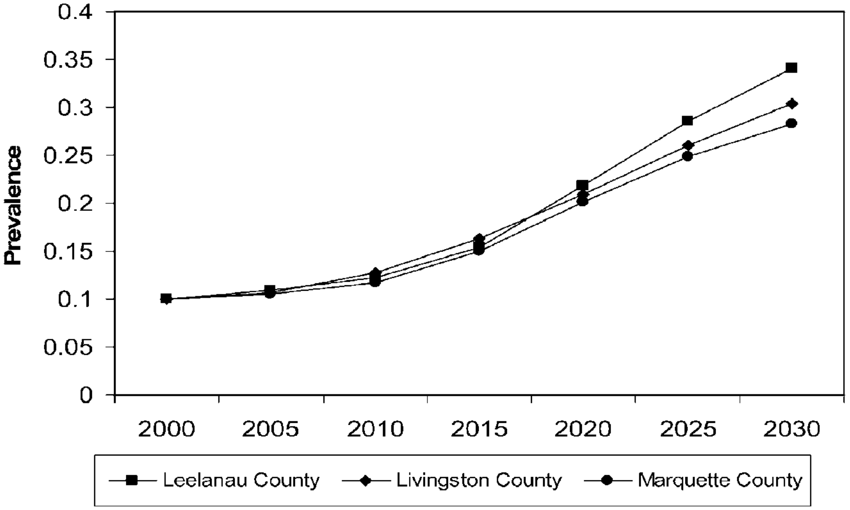

Fig. 7 Counties with the greatest expected increase in prevalence of elder abuse between 2000 and 2030 (based on the 10% current prevalence).

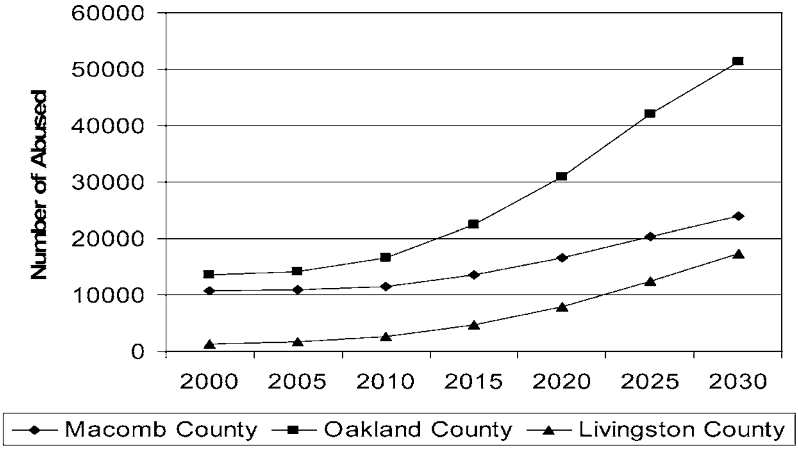

Fig. 8 Counties with the highest expected number of abused elderly between 2000 and 2030 (based on the 10% current prevalence).

this finding is a result of differences in starting conditions. Oakland County, for example, does not have the fastest growing *PEA*, but it does have one of the largest elderly populations in the state of Michigan. This, along with high *PEA* dynamics, brings the number of abuse cases in Oakland County close to that of Livingston County, which has the state's second largest projected *PEA* by 2030, but which will have a much smaller elder population than Oakland.

Discussion

In 1970, individuals aged 65 years or older represented approximately 8.5 percent of Michigan's total population. By 2030, this percentage is expected to triple. In the same period, the proportion of working-age population is expected to grow by only 3 to 4 percent. A disproportionately larger elderly population clearly increases the need for assisted living or service-oriented housing facilities, broad-based health care services, and eligible care personnel. However, such a demographic discrepancy by itself is a weak indicator of the extent of elder abuse. Indeed, elder persons may be much healthier in 2030 than persons in that age group were in 1970 or are now and so will require less care and fewer personnel. Alternatively, the care personnel may become much better qualified and less overworked, and the level of awareness about elder abuse may also increase.

If all other potential factors of abuse (individual-specific, family-specific, facility-specific, county- and state-specific factors) remain the same, however, then based only on population projections, the incidence of elder abuse in Michigan counties may increase in the next three decade by as much as 4 to 20 percentage points. In fact, if anything, the increasing *EDR* shows that there will likely be fewer caregivers per older citizen by 2030.

What can be done to mitigate the negative impact of aging on elder abuse? It has been argued before that maintaining adequate funding aimed at elderly programs is critical. For example, Mueller (2003) reports that Medicaid reductions in health care facility revenues combined with low Medicaid reimbursement rates and declining payments from private entities make it extremely difficult to increase nursing staff. The lack of Medicaid funding is hardly surprising given the disproportionately small working-age population that contributes to Medicaid.

Efficiency of funding will become a priority. Cost-effective ways of increasing workforce capacity may include home health care and home- and community-based services. In addition, community-focused intervention programs may use community resources to address elderly needs (for examples, see Ahn and Kim 2004, Borgenicht et al. 1997).

It is also imperative that caregivers be trained in abuse prevention. Current elder abuse research finds evidence that educational preparation of caregivers is associated with decreasing levels of neglect (see, e.g., Davies et al. 1999, Bond 2004, Woodtli and Breslin 2002). Elders should also be educated about both the definitions of abuse and the proper steps for reporting such experiences. Several educational instruments are available now for these purposes (see, e.g., McCauley et al. 2003, Fulmer et al. 2000).

One important aspect of state policy is how the location of long-term-care facilities influences the prevalence of elder abuse. Locating facilities in counties with relatively low projected levels of elder abuse (e.g., Kalkaska, Lake, or Osceola counties in Michigan) could have an ameliorating effect on the prevalence of abuse in the state. In such counties the demographic situation is more favorable than in other counties and the caregiver stress is less prominent, which may alleviate some of the overall burden in the state.

In addition, locating a number of long-term-care facilities in a relatively small geographic region could result in agglomeration economies.[1] For example, facilities located close to one another could reduce the costs of recruiting new workers since potential health-care employees would naturally look to that region to find a job. In contrast, isolated facilities may have high labor recruitment costs. The costs of the abuse-prevention training programs discussed above could also be reduced if multiple facilities could access the same training at the same time. These considerations suggest that the state may want to provide incentives to facilities that locate in areas projected to have low levels of elder abuse. Such incentives could include tax breaks, state contracts, or other concessions.

Limitations and Suggestions for Future Research

Our projections and subsequent discussion rested on several crucial assumptions. First, the baseline *PEA* is based on a survey by Lachs and Pillemer (2004) and was adjusted assuming that there are no other factors affecting prevalence in Michigan apart from the ratio of elderly to eligible working-age individuals. Clearly, there are other factors that affect prevalence. Personal characteristics of the elder, such as health status and personality traits, personal problems of the abuser, and his or her ethno-cultural background are arguably such factors. The public policies outlined in the previous section may also change *PEA* even if there is no change in *EDR*. Second, if *EDR* is the only factor related to abuse, the assumption that a 1-percent change in the elder dependency ratio corresponds to a 1-percent change in the prevalence of elder abuse may not be feasible.

Existing procedures designed to relax these assumptions and to test them presuppose the existence of time series data on prevalence and prevalence related factors other than *EDR*. In this paper, we are unable to do that because of data limitations, which should be addressed in future studies.

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[1] Agglomeration economies occur when costs of business are reduced by locating near other businesses, often of a similar or related nature.

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Chapter 7
Methods for Measuring the Population after a Disaster

Household Population Surveys in Post-Katrina New Orleans, October 2005–October 2006

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Introduction

In the immediate aftermath of a disaster, estimating population size becomes a uniquely challenging and critically important decision-support function that informs disaster response and recovery. With previous demographic data in question or obsolete, estimates of the size and distribution of the affected population guide all sectors of planning, from the placement of emergency medical and public safety assets to the allocation of temporary housing and reconstruction dollars. In confronting the effects of a significant natural or man-made disaster, planners require flexible demographic tools with which to address the need for fast, accurate, and low resource data collection.

In the weeks and months after Hurricane Katrina, planners from the City of New Orleans (CNO) Emergency Operations Center (EOC) and researchers from the U.S. Centers for Disease Control and Prevention (CDC) developed and implemented a series of rapid household surveys to estimate the size and distribution of New Orleans' returning population. Several months after the last CNO-EOC household survey, the state requested federal assistance to conduct household surveys across 18 parishes, including Orleans Parish, in the 2006 Louisiana Health and Population Survey (LHPS). The methods used in conducting these surveys provided a rapid, reliable, and low resource means for planners to produce demographic estimates in the aftermath of Katrina.

We used three different sampling designs to conduct these household surveys: stratified spatial sampling, stratified random sampling, and stratified cluster sampling. Because no concurrent gold standard estimates or decennial census figures exists against which to assess the accuracy of these survey estimates, we assess the survey methods based on their limitations, the time and resources that went into conducting them, and the usefulness of the estimates that they produced.

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Context

Estimates suggest that Hurricane Katrina (August 29, 2005) initially displaced 373,206 New Orleans residents (Gabe et al. 2005). This initial population disruption was compounded by loss or damage to approximately 71 percent of the city's housing stock and the complete and prolonged collapse of public infrastructure (U.S. Department of Housing and Urban Development 2006). When city neighborhoods began to reopen more than one month after the hurricane, it was clear that all pre-Katrina population and demographics data were completely invalidated (McGovern and Burris 2005, WWLTV 2005).

Within the CNO-EOC, planners made initial efforts to estimate the size of the returning population based on depth of flooding, socioeconomic data from the 2000 Census, and the qualitative observation of city neighborhoods. What confounded these attempts was that no data sources or literature existed articulating the association of these factors with repopulation after a disaster. Consequently, the CNO-EOC planners determined that reliable population estimates could only be produced through the systematic collection of data in the field.

We requested technical assistance with the design and implementation of a survey method from the CDC, which had already deployed a team of epidemiologists with experience conducting population estimates in refugee camps. Through this collaboration, we conducted citywide household population surveys on October 29–30, 2005, November 4–December 11, 2005, and January 28–29, 2006 (City of New Orleans Emergency Operations Center 2005, Stone et al. 2006).

In February 2006 the Louisiana Recovery Authority and the Louisiana Department of Health and Hospitals requested that the CDC provide technical assistance to conduct household surveys in 18 hurricane-affected parishes for the 2006 Louisiana Health and Population Survey (LHPS). In May, the state contracted with a local non-profit organization, the Louisiana Public Health Institute, to conduct the survey, which in turn contracted with several of the CNO-EOC planners to manage the project. The state also requested technical assistance from the U.S. Census Bureau to design the sampling strategy. The Orleans Parish (coextensive with the city of New Orleans) survey was conducted between June and October of 2006 (Louisiana Public Health Institute 2007).

Methods

We designed the four household surveys based upon the housing unit method of population estimation. According to the housing unit method, the population (*P*) is composed of two principle components: the household population, which is the product of the number of households (*HH*) and the average number of persons per household (*PPH*), and the group quarters (*GQ*) population, which refers to all people not living in households (e.g. prisons, assisted living facilities, college dormitories, etc.; see Smith 1986, Smith and Cody 2004):

$$P_t = (HH_t \times PPH_t) + GQ_t.$$

In a standard household survey, a sound sampling design is essential because the characteristics of a relatively small group of households are used to impute the characteristics of all households. In a household *population* survey it becomes additionally important to determine which of the sampled housing units are habitable and, of those, which are occupied (constituting a household). Both habitability and occupancy have a direct impact on the estimation of the number of households.

We made no attempt to estimate the group quarters population during the October 2005 survey because we did not identify any operating facilities at that time, although several tent cities sheltered a large but unknown number of volunteers and first responders. For the three subsequent surveys, we estimated the group quarters population by contacting the management of as many facilities as possible.

Sampling Designs

Stratified Spatial Sample: We conducted the first household population survey over the weekend of October 29–30, 2005, about two months after Katrina made landfall. For this survey, we divided the city into two geographic strata comprising the West Bank of the Mississippi River, which sustained no appreciable flooding, and the East Bank, which was heavily inundated by levee breeches. We used a stratified spatial sampling design and geographic information systems (GIS) to select and locate residences to survey (Noji 2005). GIS was used to randomly produce 82 waypoints within each stratum in census tracts of at least one housing unit according to the 2000 Census. Surveyors used GPS units and paper maps to navigate to each waypoint. At each waypoint, surveyors spun a bottle and selected the housing unit in the direction indicated by the bottle.

Stratified Simple Random Sample: For the November–December 2005 and January 2006 CNO-EOC surveys, we made an additional division of the East Bank stratum to separate flooded from unflooded census tracts. We obtained an address list of the city's 174,227 pre-Katrina water meters, which served as the sampling frame for both surveys. Water meter addresses were geocoded using ArcView 9.1 (Environmental Systems Research Institute, Redlands, CA) and a sample was selected through a stratified simple random sampling design in which each stratum was proportionally sub-stratified at the census tract level based on the number of housing units. This sub-stratification was conducted (1) to produce a representative geographic distribution of sampled housing units, (2) to mitigate potential geographic biases within the sampling frame, and (3) to allow for post-stratification according to the data needs of local, state, and federal planners. In cases where two or more housing units were found to share a water meter, surveyors randomly selected one housing unit to survey.

Stratified Cluster Sample: For the 2006 Louisiana Health and Population Survey, we used a multistage cluster sampling design and enumeration techniques (Hansen 1953, Malilay et al. 1996). The U.S. Census Bureau had created clusters composed of one or more census blocks as part of the 2000 Accuracy and Coverage Evaluation of the 2000 Census (U.S. Census Bureau 2002). In the first stage of sampling, 240 clusters were selected in Orleans Parish. In the second stage of sampling, fieldworkers created a list of all the housing units within each selected cluster and made a habitability determination for each unit based on a standardized definition. Travel trailers on private lots were considered an extension of fixed units, while those in group trailer sites were considered separate units. Once all housing units in the cluster were enumerated, the surveyor used a table of random numbers to select a predetermined number of habitable units to survey.

Survey Methods

For the CNO-EOC surveys, each housing unit was visited three times over the weekend with no less than four hours elapsing between each visit, unless one of the following conditions was met: (1) an encounter with a resident of the sampled housing unit produced a completed survey, (2) an encounter with a resident of the sampled housing unit resulted in a "refusal" to participate, or (3) the sample was declared non-existent or null.

In cases where no response was obtained on the first survey visit, the surveyor left a copy of the questionnaire on the doorknob with a request for participation from the City's Director of Emergency Preparedness and instructions to complete the questionnaire and replace it on the doorknob to be retrieved on the surveyor's next visit. If no household or proxy response was obtained after the three survey visits, we classified the sampled unit as unoccupied during the survey period.

For the LHPS, the fieldworker delivered a survey packet to each sampled housing unit. The survey packet included a uniquely numbered questionnaire and a postage-paid return envelope. All sampled housing units that did not return a completed questionnaire by mail within two to three weeks received a minimum of four (4) follow-up survey visits on weekdays, evenings, and weekends.

For the October 2005 and November–December 2005 CNO-EOC surveys, an overnight resident was defined as someone who occupied the unit during the previous night and a daytime resident was defined as someone who visited the unit during the day with several exceptions. For the January 2006 CNO-EOC survey and the LHPS, a resident was defined as someone who occupied the residence during 15 of the previous 30 nights.

Data Analysis

For the CNO-EOC surveys, we calculated the average persons per household for each stratum. We estimated the number of households by multiplying each stratum's (2000 Census) housing units by its estimated occupancy rate, which was determined from the survey visits. We estimated each stratum's population by multiplying the average persons per household by the estimated number of households.

For the LHPS, we calculated household- and person-level statistical weights as the inverse of the selection probability with adjustments for non-response (Hofler et al. 2005). We estimated the population by multiplying the number of sampled persons by the corresponding person-level statistical weight.

To evaluate the usefulness and efficiency of these methods, we estimated and compared the time and resources used to conduct the January 2006 CNO-EOC survey and the LHPS.

Results

The number of housing units sampled increased considerably with each survey round as additional technical resources and data collectors became available. We sampled 162 units during the October 2005 survey, 409 during the November–December 2005 survey, 902 during the January 2006 survey, and 1,156 during the LHPS. Figure 1 displays the distribution and occupancy status of the 902 sampled housing units from the January 2006 survey.

Survey Results

According to the 2005 American Community Survey conducted by the U.S. Census Bureau, the household population of New Orleans before Hurricane Katrina was 437,186 (U.S. Census Bureau 2005). Including approximately 17,000 people living in group quarters as of the 2000 Census, Orleans was the largest city and parish in the state (U.S. Census Bureau 2000). Two months after Hurricane Katrina made landfall, we estimated the overnight household population of New Orleans at 104,900 with a daytime influx of approximately 93,500 people. One month later, we estimated that the city's population had increased to 135,500 with a daytime influx of 90,000. Five months after Katrina, we estimated that the population of New Orleans had increased to 181,400 with an additional 80,800 during the day. Approximately one year after Hurricane Katrina, we estimated a citywide household population of 191,100 residents (no estimate of daytime influx was made). Table 1 presents the four household population estimates and Figure 2 plots these estimates against the U.S. Census Bureau's modeled estimates for January and July 2006 (U.S. Census Bureau 2006, 2007).

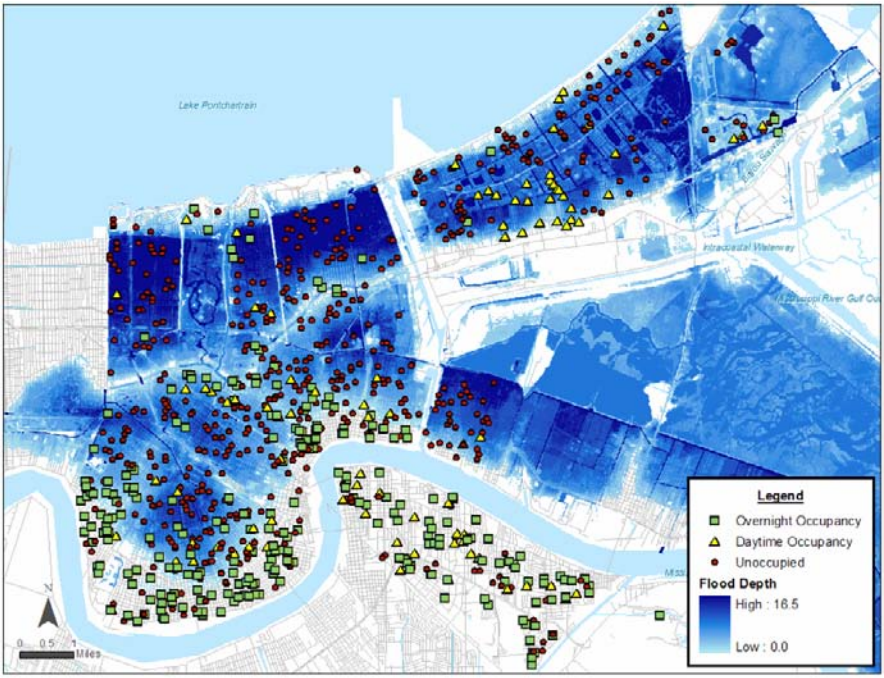

Fig. 1 Housing unit occupancy results from the January 28–29, 2006 survey.

Table 1 Household population estimates of New Orleans after Hurricane Katrina.

Household Survey	Survey Date	Months after Hurricane Katrina	Sampled Housing Units	Household Population Estimate	Margin of Error*	Percent of Pre-Katrina Population**
CNO-EOC 1	Oct 29-30, 2005	2	162	104,900	49.4%	24.0%
CNO-EOC 2	Nov 11-Dec 11, 2005	3	409	135,500	16.5%	31.0%
CNO-EOC 3	Jan 28-29, 2006	5	902	181,400	11.5%	41.5%
LHPS	Jun-Oct 2006	10-14	1,156	208,700	16.4%	47.7%

*Calculated at 95% confidence

**American Community Survey. Washington, D.C.: U.S. Census Bureau; 2005

At the end of November we estimated that approximately 18,000 people, mainly displaced residents, contractors, and first responders, were staying in hotels and 4,500 city workers and first responders were being housed in cruise ships. At the beginning of February 2006 we estimated that approximately 20,000 people were staying in hotels, 2,700 were living on the cruise ships, and 5,900 were occupying student dormitories. In October 2006, we estimated that approximately 9,500 people were living in dormitories, assisted living facilities, and transitional housing.

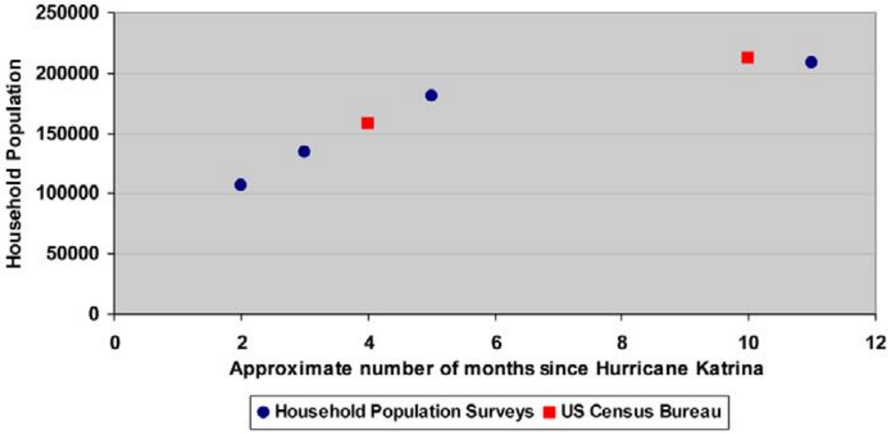

Fig. 2 Plot of population estimates from the four household surveys and the U.S. Census Bureau. *Source*: Special population estimates for impacted counties in the Gulf Coast area, gulfcoast_impact_estimates.xls, 2006, U.S. Census Bureau: Washington, D.C.; County Population Datasets, CO-EST-ALLDATA.csv. 2007, U.S. Census Bureau: Washington, D.C.

Evaluation Results

The January 2006 survey occurred over a six-week period: three weeks for planning, one weekend for data collection, and three weeks for analysis and reporting. Although it was encumbered by concurrent data collection in several parishes, the LHPS occurred over a five and a half month period, which included five weeks for planning, four months for data collection, and several days for analysis and reporting.

We could not obtain an operating budget for the three CNO-EOC surveys so we relied on the City's technical and material resources and the charitable spirit of students, university faculty, and community members. If the volunteer contribution is budgeted, the January 2006 EOC survey would have cost approximately $42,000, or $47 per sampled housing unit, not including some 250 hours of expert consultation from CDC, Census Bureau, and Tulane University faculty. The LHPS cost just over $1 million, or $97 per sampled housing unit, in state and federal support, not including several thousand hours of technical assistance contributed by experts from the CDC and Census Bureau.

Discussion

Limitations

The three survey methods relied on housing unit counts from the 2000 Census to stratify their samples. It is likely that considerable changes occurred in the number and distribution of housing units in the five years since the 2000 Census, irrespective of the effects of Katrina. Although municipal building and demolition permits are commonly used to update housing unit counts from the decennial census, neither time nor resources were available after Katrina to undertake this work (Smith 1996). Of the three methods, only the LHPS accounted for change in housing unit distribution in the calculation of the statistical weights.

The stratified spatial design suffered from significant inefficiency because some GIS waypoints fell in areas with no housing units and sometimes the bottle did not point at a housing unit after spinning. Both scenarios produced null samples that decreased the valid sample size at the cost of precious data collection time.

The use of the water meter address list as a sampling frame for the stratified simple random design eliminated this inefficiency. However, this sampling frame had limitations. First, a water meter address is not a direct substitute for a housing unit because multiunit structures may include only one water meter. With limited time and information about the number of multiunit water meter addresses, we decided to incur the sampling bias rather than formulating complex and uncertain statistical weights.

Second, the distribution of water meter addresses in the sampling frame was not identically proportional to the distribution of housing units at the 2000 Census. This difference could have been due to construction and demolition since the census or to the distribution of more multiunit structures in certain areas. We sub-stratified the sample at the census tract level to mitigate this geographic bias.

Third, approximately 5 percent of the water meter addresses could not be mapped and was excluded from the sample selection. Although we did not detect any systematic bias to account for these errors, it is possible that the excluded addresses shared certain characteristics that may have biased the sample.

The cluster design of the LHPS eliminated these biases but may have introduced new ones. The cluster design assumed that the sampled clusters were representative of all clusters. This assumption might have been violated if changes in the distribution of housing units in the sampled clusters significantly differed from housing unit changes across the rest of the city. In this regard, two points should be considered for further analysis: (1) did the average level of flooding in the sampled clusters approximate the average level of flooding across the city, and (2) did the distribution of travel trailers in sampled clusters approximate the distribution of travel trailers across the city.

Once units were sampled, the data collection process presented numerous challenges. First, it was very difficult to define habitability and to classify sampled units accordingly, particularly since it was reported that many residents were living in substandard conditions. For the CNO-EOC surveys, we decided to consider all units habitable, which occasionally resulted in selecting and surveying slabs. For the LHPS, we adopted a broadly inclusive definition of habitability in order to minimize the population that could be missed living in substandard conditions. Consequently, for the CNO-EOC surveys the estimated occupancy rate referred to the pre-Katrina housing stock, for which we were unable to provide a current estimate. For the LHPS, we likely overestimated the size of the current housing stock and underestimated the occupancy rate.

Devising an appropriate method for determining the occupancy status presented an additional challenge. Under ordinary circumstances, surveyors for the U.S. Census Bureau might make upwards of 10 visits to a sampled unit before deciding whether the unit is unoccupied or occupied but non-responding. Because we had insufficient time and resources to invest in this level of follow up, we placed particular importance on when survey visits were conducted. We had to conduct the CNO-EOC surveys over the weekend because we could not recruit sufficient volunteer surveyors during the workweek. For the LHPS, we devised a visit protocol which ensured that sampled units were visited on weekdays, evenings, and weekends.

It is possible that the size and distribution of New Orleans' weekend population differed considerably from the weekday population after Katrina. If so, the CNO-EOC estimates might considerably misrepresent weekday demographics and would not be comparable to the LHPS and Census Bureau estimates. We believe that by defining a resident as someone who spent 15 of the previous 30 nights at the sampled unit, we have mitigated this potential bias.

Information from proxy respondents was also a critical factor in determining between vacancy and non-response. The quality of proxy information is particularly uncertain after a disaster when neighborhoods are disrupted and residents lose contact with each other. Contradictions between proxy information and surveyor observations occurred very infrequently. In these cases we erred on the side of non-response over vacancy.

The granularity of the survey data presents a final but very important point of discussion. Recovery planners were adamant about the importance of understanding the distribution of the population in addition to the citywide estimate. Of the three methods, only the stratified simple random sampling design provided us with the flexibility and statistical power to provide estimates for groups of neighborhoods that approached the level of geographic detail requested by recovery planners. Although the stratified cluster design was the most sophisticated of the three methods, it did not allow for this critical degree of flexibility.

Conclusion

The most challenging aspect of any research endeavor is found in negotiating the relationship between the time, expense, and robustness of the methods. After a disaster, limited time and resources profoundly strain this uneasy dynamic. In post-

Katrina New Orleans, we found that constantly changing conditions, immediate data needs, and severe resource constraints created a complex and challenging research environment. The limitations and assumptions of our methods and the margins of error of the estimates reflect these challenges and the creative problem-solving that was required to address them.

Under these circumstances, our approach to selecting and refining methods was guided principally by the availability of time, resources, and expertise. We adopted a spatial sampling design for the first CNO-EOC survey because we could not obtain an adequate sampling frame and did not have sufficient time or fieldworkers to create and enumerate clusters. Similarly, with greater time and resources available for the LHPS, we selected a sample size based on statistical considerations, while for the CNO-EOC surveys, we had selected samples based on the expected number of volunteer surveyors. Also, as we were able to recruit more surveyors and devote more time to planning and analysis, we increased the questionnaire length for each survey to capture additional demographic and health data.

Our experience navigating these challenges highlights the importance of planning for demographic research before a disaster strikes. We suggest preparing for disaster research by designating personnel, allocating resources, and forming relationships with federal and academic experts as part of a state or municipality's comprehensive disaster response plan. In the certain event of future disasters, the survey methods used in New Orleans after Hurricane Katrina provide a launching point for researchers who will have to conduct demographic research under similar conditions.

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Chapter 8
An Evaluation of Population Estimates for Counties and Places in Texas for 2000

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Introduction

Population estimate is one of the most widely used products of demographic analyses (Murdock and Ellis 1991). Population estimates for the state, counties, and places are essential for planning of different types of services, such as health care, schools, highways, water, and sewer. Planning for health services requires accurate information on the number of older people (aged 60 and over), their age, sex, marital status, distribution in different areas, and rural or urban residence. Population estimates provide a basis for allocation of resources between areas in relation to population size. The federal government uses the Census Bureau's national and subnational population estimates in calculating the distribution of many billions of dollars in the form of block grants each year to the states and jurisdictions within them. Some state governments use State Data Center (SDC) population estimates to administer the state revenue sharing program. For example, the State of Florida uses its population estimates to distribute more than $1.5 billion each year to local governments (Smith and Cody 2004). Population estimates are also necessary to provide denominators to compute many types of rates and ratios, such as birth rates, death rates, labor force participation rates, school enrollment rates, dependency ratios, and sex ratios in non-census years. Population estimates play an important role in market analysis, public facility, and environmental planning and form a major basis for determining the present and future markets for a variety of goods and services and for other aspects of private-sector planning and marketing efforts (Murdock and Ellis 1991). They are often critical elements in the analyses leading to decisions of whether or not to build a new school, fire station, library, hospital, a shopping mall, or highway (Siegel 2002). Thus, population estimates make an important contribution to the activities of governments, organizations, and businesses in non-census years. Intercensal estimates provide data for years between two existing censuses, such as 1990 and 2000, while postcensal estimates provide data for years since the last census (Rowland 2003).

S.H. Murdock and D.A. Swanson (eds.), Applied Demography in the 21st Century, 125–148.

Census data are normally used for reapportionment purposes. However, for some cases when census data were obsolete, estimate data were used for reapportionment. For example, in 1988 intercensal population estimates were used for redistricting Palm Beach County, Florida and in 1991 Los Angeles County, California, used population estimates for redistricting purposes (for detailed discussion, see Serow et al. 1997, Bolton 1997).

Population estimates are difficult to complete with accuracy for small areas because small areas can grow or decline rapidly, or even may undergo substantial changes in age, sex, and race/ethnicity, and other demographic characteristics. All these factors raise the difficulty for making accurate estimates. As a result, it is essential that any ongoing program of population estimation periodically evaluate the results of past estimation against actual census counts of the population (Murdock and Ellis 1991). Only by assessing the accuracy of past efforts is it possible to know the nature of errors made and to take steps to improve future estimates. This paper presents the results of the evaluation of the Texas Population Estimates and Projections Program's population estimates for 2000 compared to the 2000 Census counts for counties and places in Texas. The Component Method II, Ratio-correlation Method, and Housing Unit Method were evaluated.

In the remainder of this paper, several basic principles of population estimation and projection, the historical context of population growth from which the Texas program's estimates and projections were made, and the methods used in the evaluation are described. We also present an evaluation of 2000 county and place-level estimates produced by the Texas Population Estimates Program.

Component Method II depends on the use of three characteristics of population that directly determine population change: births, deaths and net migration. Thus, for any given year, the population can be determined using the following equation (Guseman and Murdock 1983):

$$P_t = P_0 + B - D + NM,$$

where P_t = population for the estimate year, P_0 = population at the base year, B = births between P_t and P_0, D = deaths between P_t and P_0, NM = net migration between P_t and P_0.

A population estimate is developed with Component Method II by updating the base population as enumerated in the most recent census, by adding to it the natural increase (births minus deaths) that occurred between the census and the estimate date, and estimating the amount of net migration in the area (Raymondo 1992). Component Method II typically takes direct account of natural increase through actual data on births and deaths while using symptomatic data for assessing net migration. Component Method II assumes that the rate of migration of school-age population can be used to assess the migration rate for the population 64 years of age and younger and that Medicare data can be used to estimate the migration rate for the population 65 years of age and older. There is some variation in terms of school-age population. Some prefer to use the elementary enrollment for grades 1 to 8, while others prefer to use the elementary enrollment for grades 2 to 8. Texas

State Data Centers' Population Estimates Program uses the elementary enrollment for grades 1 to 8 (both public and private schools).

Component Method II provides reliable results at the county level assuming that actual births and deaths data are available at the county level. However, it is difficult to obtain births and deaths data at the place level (particularly small places). It is also difficult to collect private school enrollment data for grades 1 to 8. Another concern is the implicit assumption that migration patterns of the elementary school-age population may be generalized for the population age 64 and under.

The Ratio-correlation Method is a multiple regression-based technique which compares change in one areal unit to change occurring in a parent area. Such estimates are developed using the following multiple regression equation (Guseman and Murdock 1983):

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_n X_n + e,$$

where Y = the dependent variable to be estimated (e.g., population), α = the intercept to be estimated, β_i = the coefficient to be estimated, X_i = independent variables, such as births, deaths, voter registration, etc., e = error term.

This model uses variables of births, deaths, elementary school enrollment, vehicle registration, and voter registration. The dependent and independent variables are expressed in the form of a ratio. For example, to obtain the estimate of population for a county in 2001, where the state population is known, the following equation could be applied:

$$\begin{aligned}
&\left(\frac{\text{County Pop., 2001/State Pop., 2001}}{\text{County Pop., 2000/State Pop., 2000}}\right)\\
&\quad = \alpha_0 + \beta_1 \left(\frac{\text{County Births, 2001/State Births, 2001}}{\text{County Births, 2000/State Births, 2000}}\right)\\
&\quad + \beta_2 \left(\frac{\text{County Deaths, 2001/State Deaths, 2001}}{\text{County Deaths, 2000/State Deaths, 2000}}\right)\\
&\quad + \beta_3 \left(\frac{\text{County School Enrollment, 2001/State School Enrollment, 2001}}{\text{County School Enrollment, 2000/State School Enrollment, 2000}}\right) + \cdots
\end{aligned}$$

In the equation above, all of the indicator values are known except county population. In order to obtain the intercept and coefficients to use in solving the equation, estimates of the values must be obtained. This is done by solving the equation for past periods for which all the values are known. For example, the coefficients obtained by solving the equation for the past periods (e.g., 1990–2000) can be used in the above formula for a 2001 estimate. Thus, 1990–2000 intercept and coefficients can be obtained by solving the equation for 1990–2000 period such as:

$$\alpha_0 = \left(\frac{\text{County Pop., 2000/State Pop., 2000}}{\text{County Pop., 1990/State Pop., 1990}}\right),$$

$$\beta_1 = \left(\frac{\text{County Births, 2000/State Births, 2000}}{\text{County Births, 1990/State Births, 1990}}\right),$$

$$\beta_2 = \left(\frac{\text{County Deaths, 2000/State Deaths, 2000}}{\text{County Deaths, 1990/State Deaths, 1990}}\right),$$

$$\beta_3 = \left(\frac{\text{County School Enrollment, 2000/State School Enrollment, 2000}}{\text{County School Enrollment, 1990/State School Enrollment, 1990}}\right).$$

The dependent variables used in the Ratio-correlation Method for population estimates for Texas are births, deaths, school enrollment, voter registration, and vehicle registration.

The Housing Unit Method is regarded as one of the most reliable methods for making population estimates for small areas and is one of the easiest to apply. The Census Bureau uses the Housing Unit Method for population estimates for counties and places, and some state agencies including ones in Florida and Texas use it for population estimations. The logic of the Housing Unit Method is that everyone lives in some type of household (Smith and Cody 2004). The Housing Unit Method produces population estimates by taking into account the number of occupied households times the average number of persons per household. In terms of equation it can be expressed as:

$$P_t = (OHU_t \times PPH_t) + GQ_t,$$

where P_t = total population at time of estimate, OHU_t = occupied housing units on the estimate date, PPH_t = household size or population per household on the estimates date, GQ_t = the group quarters population at the time of estimate.

Each of the components of the Housing Unit Method can be estimated using a variety of data sources, such as building permit and demolition data, or utility data based on electric utility meters (for a detailed discussion, see Smith and Lewis 1980). The form of Housing Unit Method used in Texas population estimate is:

$$P_t = (HU_t + BP_t - DU_t) \times OCC_t + GQ_t,$$

where P_t = total population at time of estimate, HU_t = occupied housing units counted in the most recent census (by type, e.g. single family, multifamily, mobile home), BP_t = building permits issued by type between the most recent census and time t (adjusted for time lag), DU_t = units reported demolished by type between the most recent census and time t, OCC_t = occupancy rate by type at time t, GQ_t = group quarters population at time t.

Building permits data can be obtained from the U.S. Department of Commerce, which collects the data directly from counties and cities throughout the United States. The Texas State Data Center also collects building permit data, as well as data on vacancy rates and mobile homes, from the counties and cities in Texas. Texas State Data Center also collects data on vacancy rates and mobile homes, since the U.S. Department of Commerce does not collect data for either.

There are some problems with the Housing Unit Method. First, some counties and places neither issue building permits nor provide data to the U.S. Department of Commerce or Texas State Data Center. (In 2005, 13 counties did not provide building permit data to the U.S. Department of Commerce and the Texas State Data Center.) Second, the U.S. Department of Commerce stopped collecting data on demolition permits. Third, most of the counties and places do not provide data on vacancy rates to the Texas State Data Center.

Principles of Population Estimation and Projection

The history of population estimates and projections suggests certain basic findings from past analyses that merit recognition in an evaluation of any estimation or projection. These basic findings or principles, as outlined by Shryock and Siegel (1980), Raymondo (1992), Murdock and Hoque (1992), Smith et al. (2001), and Murdock et al. (2006) show that no single method has been found to consistently produce more accurate estimates and projections than any other method, and that population estimates and projections are generally more accurate:

1. For geographic areas with larger populations than for those with smaller populations. For example, population estimates tend to be more accurate for an entire country rather than for subareas within the country. Data from larger areas are generally stable and superior than those from smaller areas. Natural disasters in local areas may have a major impact on the population in the immediate areas but will have virtually no impact on the national population. For example, the impact of Hurricane Katrina will be pronounced on the population at New Orleans and also at Louisiana but not at the national level. All of the dispersed population will be absorbed by the neighboring states. However, a military base closing would have almost no impact on the population size at the state or national level but it definitely would reduce the population of a small county or place significantly. On the other hand, a newly established industrial base may increase the population significantly for a small county or place but not for the population at state or national level.
2. For total populations rather than for population subgroups because estimates of such characteristics involve additional assumptions that may prove to be in error. Population estimates that bear greater level of detail such as age, sex, race and ethnicity also produce greater levels of error.
3. For short rather than long periods of time past the reference date for the base data used in the estimates (i.e. last census.) Population estimates that bear a longer duration between the base population and the estimation date, result in a greater degree of error.
4. For areas that show consistency in the direction of change during the estimation period compared to the period from which the base data are derived. If the direction of change is from growth to decline or from decline to growth then accurate estimates of the population are difficult.
5. For areas that experience slow rather than rapid change. A period of dramatic population growth makes population estimates more difficult.

6. If completed with data that directly determine population change (such as data on births, deaths, and migration) rather than with data that employ indirect or symptomatic indicators of population change.
7. No single method of population estimation will always be the best choice. The average of methods may be employed as a basis for improving the accuracy of population estimates. Using multiple techniques will provide a means of checking the validity of the estimates since similar results obtained from a variety of different methods tend to suggest the overall accuracy of the result.

In sum, an estimate or projection is likely to be most accurate if it is based on direct birth, death, and migration data and is for the total population of a large area that is showing slow change that is in the same direction and form as the change in the recent past. In general, the greater an area's departure from these conditions, the greater the error in estimates or projections.

Population Change in Texas in the 1990s

Texas' population has undergone dramatic change in the last 30 years. After rapid population growth during the 1970s and early 1980s, the rate of population growth fell to its lowest level in the years during the mid-1980s before beginning to show patterns of renewed growth during the late 1980s and the 1990s. Such a dramatic pattern of change in population makes it difficult to do accurate estimates of population. The population of Texas increased from 16,986,510 in 1990 to 20,851,820 in 2000. This increase of 3,865,310 persons or 22.8 percent was the largest of any decade in state's history and was the second largest numerical increase of any state in the nation. Only California, which increased its population by 4,111,627, showed a larger numerical increase. However, the growth was not the same everywhere in the Texas. During the 1990s, 68 (26.8 percent) of the state's 254 counties and 334 (26.1 percent) of the 1,279 places lost population. During 1980s, 98 (38.6 percent) of the 254 counties and 557 (46.1 percent) of the 1,208 places lost population.

Overall, during the 1990s the State of Texas and its component areas showed not only extensive population growth but also dramatic changes in rates of growth from 3.5 percent per year in the early 1980s to 0.5 percent per year during the later part of the decade. The patterns of population change in many counties and places changed from growth to decline or from decline to growth during the 1990s. These changes make accurate estimates of the population for the state and for counties and places within Texas very difficult.

Methods for Evaluation

Given the patterns and principles noted above, several widely used procedures were selected to evaluate the population estimates and projections for Texas (Murdock

$$(1)\ \text{Mean Percent Error (MPE)} = \frac{\sum_{i=1}^{n}\left(\frac{\text{Estimated Value - Census Count}}{\text{Census Count}}\right)}{n} \times 100$$

$$(2)\ \text{Mean Absolute Percent Error (MAPE)} = \frac{\sum_{i=1}^{n}\left|\frac{\text{Estimated Value - Census Count}}{\text{Census Count}}\right|}{n} \times 100$$

$$(3)\ \text{Mean Percent Absolute Difference (MPAD)} = \frac{\sum_{i=1}^{n}|\ \text{Estimated Value - Census Count}\ |}{\sum_{i=1}^{n}\text{Census Count}} \times 100$$

where n = number of areas (counties, places)

Fig. 1 Error measures used in the evaluation of Texas State Population Estimates and Projections Program's population estimates and projections.

and Ellis 1991, Siegel 2002). These methods generally rely on comparisons of values for error measures for the estimates, or projections being evaluated relative to expected patterns and relative to those for estimates or projections from other sources. The estimates and projections were evaluated relative to the expected patterns of increased rates of error with decreased population size and increased rates of error with increased rates of population change. They were also evaluated relative to their tendency to underestimate or overestimate the population of different types of areas. Comparison of estimates and projections to those from other sources assists in identifying which factors may be impacting the accuracy of estimates or projections, because the assumptions can be compared to those used by other sources. Such a comparison often helps to determine which of the assumptions are increasing or decreasing the accuracy of the estimates or projections.

Several error measures are used to assess the accuracy of estimates. The error of an estimate or projection is determined by subtracting the estimated or projected population value for an area from the census count (for purposes of this report, the 2000 census count) and dividing the difference by the census count. This proportion is then multiplied by 100 to produce a percentage rate of error.

Three error measures are commonly used in such assessments. The formulas for these measures are shown in Figure 1. They include the Mean Percent Error (MPE), the Mean Absolute Percent Error (MAPE), and the Mean Percent Absolute Difference (MPAD). This later measure is also referred to as the weighted mean absolute percent error.

The Mean Percent Error (MPE) is simply the arithmetic average of the percent errors for each area (county, place, etc.). This value is useful, but because positive and negative values cancel out one another in computation, it may provide somewhat misleading estimates of error. For example, if the population of one area were to be underestimated by 50 percent and the population of the second area were to be overestimated by 50 percent, the MPE would be 0.0 percent, suggesting that the estimates were perfect when in fact the two component estimates were quite inaccurate.

The Mean Absolute Percent Error (MAPE) is the mean of the absolute values of the errors, that is, ignoring the sign of the value. Given that the magnitude, rather than direction of the error is usually the major concern, the MAPE provides a more useful overall estimate of total error and is the most widely used measure of error in evaluations of population estimates and projections. Both MPE and MAPE, however, share a common weakness, in that errors for all places contribute equally to the overall error rate computed. Suppose the estimate for an area with 1 million people fell within two percent of the actual count, and the estimate for an area of 100 people fell within 18 percent. The MAPE for the two areas would be 10 percent (2 plus 18 divided by 2), although the estimate for the area with most of the population was quite good. The problem is that neither MPE nor MAPE take the size of the areas in the computation into account.

The Mean Percent Absolute Difference (MPAD) or weighted mean absolute percent takes the size of areas into account by weighting the values of areas proportionally to their size (population size of the area as a proportion of the sum of the populations of all the areas of interest). The MPAD is thus also widely used in evaluations of estimates and projections.

For this report, the values of these three error measures are presented for each type of area (i.e., Texas counties and/or places) and for the areas grouped by population size in 2000 and rate of population change from 1990 to 2000. Data are also shown for the number of overestimated and underestimated areas to indicate the extent to which the estimates tend to be biased either upward or downward. The number of areas estimated within certain ranges of error is also provided to indicate how many areas are estimated within specified levels of error. Finally, the errors in the estimates are compared to those from other sources.

Evaluation of Texas County and Place Estimates for 2000

Evaluation Procedures

During the 1990s, county-level estimates produced by the Texas Population Estimates and Projection Programs were computed as an average of the Housing Unit Method, Ratio-correlation Method, and Component Method II. Place-level estimates were made using the average of Housing Unit Method and Component Method II. In this section, the results of the evaluation of these population estimates are presented first for the counties and then for the places for each individual method and for an average of combined methods.

Table 1 and Figure 2 present the three error measures for different estimation methods for counties in Texas. The results in this table show an overall mean percent error of 1.84 percent, a mean absolute percent error of 8.04 percent, and a

Table 1 Mean Percent Error (MPE), Mean Absolute Percent Error (MAPE), and Mean Percent Absolute Difference (MPAD) between 2000 census counts and Texas Population Estimates and Projections Program's estimated population for counties by population size.

Population Size 2000	No. of Counties	MPE	MAPE	MPAD
Panel I: Component Method II				
Under 1,000	7	15.97	20.61	19.24
1,000- 2,499	15	19.27	22.94	25.34
2,500- 4,999	29	7.07	14.56	14.08
5,000- 9,999	38	1.91	6.95	6.80
10,000-24,999	69	0.19	5.60	5.57
25,000-49,999	42	-2.06	5.45	5.42
50,000-99,999	20	-3.46	5.67	5.65
100,000+	34	-2.03	4.07	4.07
All Counties	254	1.84	8.04	4.48
Panel II: Ratio-correlation Method				
Under 1,000	7	0.79	13.17	11.60
1,000- 2,499	15	-5.68	7.67	7.53
2,500- 4,999	29	-6.04	7.70	7.56
5,000- 9,999	38	-5.17	6.70	6.99
10,000-24,999	69	-4.86	6.38	6.25
25,000-49,999	42	-3.14	4.00	3.87
50,000-99,999	20	-2.51	3.47	3.29
100,000+	34	-2.33	2.80	2.91
All Counties	254	-4.13	5.74	3.28
Panel III: Housing Unit Method				
Under 1,000	3	20.17	20.17	23.12
1,000- 2,499	10	14.40	14.94	12.96
2,500- 4,999	28	14.36	16.55	16.78
5,000- 9,999	36	6.74	10.58	10.57
10,000-24,999	68	4.04	8.61	8.18
25,000-49,999	42	-3.84	5.78	5.85
50,000-99,999	20	-3.54	6.33	6.20
100,000+	34	-2.12	4.30	4.42
All Counties	241	3.40	8.94	5.01
Panel IV: Average of Component Method II, Ratio-correlation Method, and Housing Unit Methods				
Under 1,000	7	4.07	9.15	6.32
1,000- 2,499	15	3.98	9.63	9.76
2,500- 4,999	29	0.33	7.88	7.95
5,000- 9,999	38	-0.11	5.09	5.02
10,000-24,999	69	-1.62	4.85	4.62
25,000-49,999	42	-3.06	4.07	4.06
50,000-99,999	20	-2.76	3.95	3.97
100,000	34	-2.05	2.96	3.55
All Counties	254	-1.07	5.18	3.73

*For counties for which housing data were not available to implement the Housing Unit Method, only the Component Method II estimate was employed.

mean percent absolute difference of 4.48 for Component Method II (Table 1, Panel I). The MPE, MAPE, and MPAD for counties with population less than 1,000 are 15.97, 20.61, and 19.24, respectively. The highest MPE, MAPE, and MPAD are for counties with population greater than 1,000 and less than 2,500 and are 19.27, 22.94, and 25.34, respectively. The MPE, MAPE, and MPAD for counties with population more than 2,500 and less than 5,000 are 7.07, 14.56, and 14.08, respectively. The MPE, MAPE, and MPAD for counties with population more than 5,000 and less than 10,000 are 1.91, 6.95, and 6.80, respectively. The MPE, MAPE and MPAD are for counties with population more than 10,000 and less than 25,000 and are 0.19, 5.60, and 5.57, respectively. The MPE, MAPE and MPAD for counties with population of 100,000 or more are 1.91, 6.95, and 6.80, respectively. The MPE are negative for counties with population of 25,000 or more. The lowest MPE is for counties with population greater that 10,000 and less than 25,000. The MAPE and MPAD is lowest for the counties with a population 100,000 or more.

For the Ratio-correlation Method, the overall mean percent error is −4.13, and mean absolute percent error is 5.74, and the mean percent absolute difference is 3.28 (Table 1, Panel II). The MPE, MAPE and MPAD for counties with population less than 1,000 are 0.79, 13.17, and 11.60, respectively. The MPE, MAPE, and MPAD for counties with population more than 1,000 and less than 2,500 are −5.68, 7.67, and 7.53, respectively. The MPE, MAPE, and MPAD for counties with population more than 2,500 and less than 5,000 are −6.04, 7.70, and 7.56, respectively. The MPE, MAPE, and MPAD for counties with population more than 5,000 and less than 10,000 are −5.17, 6.70, and 6.99, respectively. The lowest MPE, MAPE, and MPAD are for counties with population of 100,000 or more and are −2.33, 2.80, and 2.91, respectively.

For the Housing Unit Method, the overall mean percent error is 3.40, the mean percent absolute error is 8.94, and the mean percent absolute difference is 5.01 (Table 1, Panel III). The highest MPE, MAPE and MPAD, 20.17, 20.17, and 23.12, respectively, are for counties with population less than 1,000. The MPE, MAPE, and MPAD for counties with population more than 1,000 and less than 2,500 are 14.40, 14.94, and 12.96, respectively. The second highest MAPE and MPAD are for counties with population more than 2,500 and less than 5,000 and are 16.55, and 16.78, respectively. The MPE, MAPE, and MPAD for counties with population more than 5,000 and less than 10,000 are 6.74, 10.58, and 10.57, respectively. The lowest MPE, MAPE, and MPAD are for counties with population of 100,000 or more and are −2.12, 4.30, and 4.42, respectively.

Averaging the Component Method II, Ratio-correlation Method, and Housing Unit Method produced an overall mean percent error of −1.07, a mean percent absolute error of 5.18 percent, and a mean percent absolute difference of 3.73 percent (Table 1, Panel IV). The MPE, MAPE, and MPAD for counties with population of 1,000 or more and less than 2,500 are 3.98, 9.63, and 9.76, respectively. The MPE, MAPE, and MPAD for counties with population of 2,500 or more and less than 5,000 are 0.33, 7.88, and 7.95, respectively. The MPE, MAPE, and MPAD for counties with population of 5,000 or more and less than 10,000 are −0.11, 5.09, and 5.02, respectively. The MPE, MAPE, and MPAD for counties with population

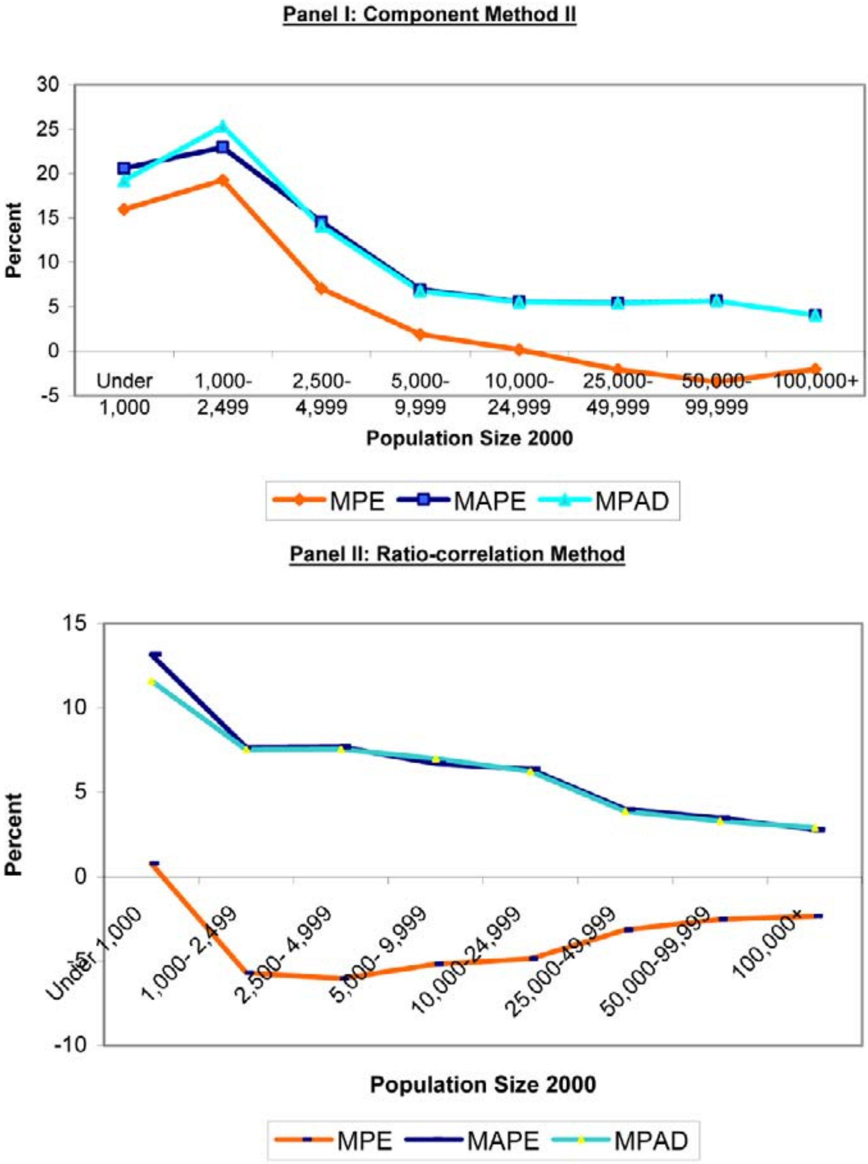
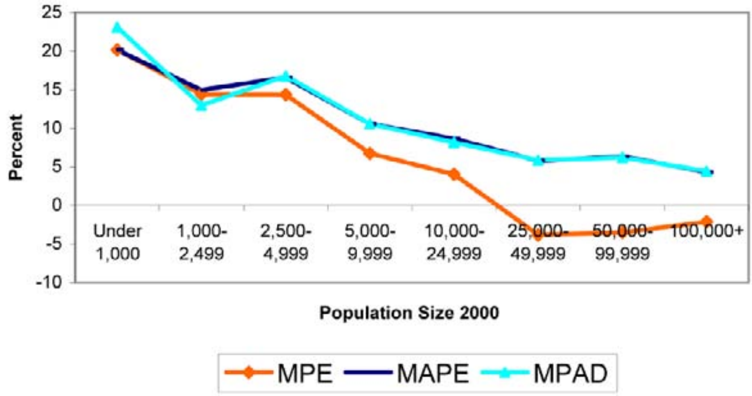


Fig. 2 Plot of MPE, MAPE, and MAPD for counties by population size, 2000.

of 10,000 or more and less than 25,000 are −1.62, 4.85, and 4.62, respectively. The MPE, MAPE, and MPAD for counties with population of 25,000 or more and less than 50,000 are −3.06, 4.07, and 4.06, respectively. The MPE, MAPE, and MPAD for counties with population of 50,000 or more and less than 100,000 are −2.76, 3.95, and 3.97, respectively. The MPE, MAPE, and MPAD for counties with pop-

Panel III: Housing Unit Method



Panel IV: Average of All Three Methods

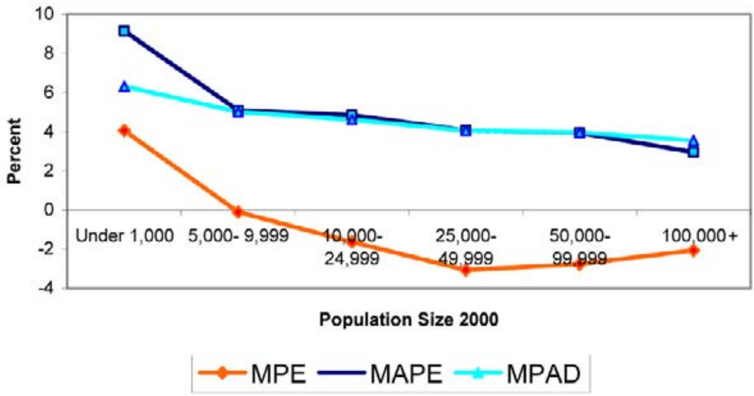


Fig. 2 Continued.

ulation of 100,000 or more are −2.05, 2.96, and 3.55, respectively. In general, the data in Table 1 and Figure 2 suggest the expected patterns, with error measures being larger for counties with smaller population and smaller for counties with larger populations. The data in Table 1 and Figure 2 also suggest that using the average of the three methods is superior to the use of any single method of estimation.

Table 2 and Figure 3 present the same error measures by the rate of population change from 1990 to 2000. Panel I presents error measures for Component Method II, Panel II presents error measures for the Ratio-correlation Method, Panel III presents error measures for Housing Unit Method, and Panel IV presents error measures for the average of all three methods. As can be seen from Table 2, mean percent error was largest for counties with declining population. The mean percent error was 27.06 for Housing Unit Method, 11.66 for Component Method II, and −1.46 for Ratio-correlation Method for counties with declining population of

Table 2 Mean Percent Error (MPE), Mean Absolute Percent Error (MAPE), and Mean Percent Absolute Difference (MPAD) between the Texas Population Estimates and Projections Program's population estimates and the 2000 census counts by percent population.

Percent Population Change, 1990-2000	No. of Counties	MPE	MAPE	MPAD
Panel I: Component Method II				
< - 10.00	22	11.66	13.67	13.09
-10.0 - 00.00	46	10.77	12.45	7.13
00.00 - 09.99	61	-0.20	5.76	3.49
10.00 - 19.99	54	0.40	6.36	4.09
20.00 - 29.99	34	-3.53	6.18	3.65
30.00 - 39.99	15	-6.24	7.98	6.73
40.00 - 49.99	10	-7.38	8.31	8.72
50.00 +	12	-0.59	5.08	3.97
All Counties	254	1.84	8.04	4.48
Panel II: Ratio-correlation Method				
< - 10.00	22	-1.46	5.66	4.68
-10.0 - 00.00	46	-3.27	5.75	3.98
00.00 - 09.99	61	-4.49	5.83	3.73
10.00 - 19.99	54	-2.87	4.03	1.74
20.00 - 29.99	34	-7.62	8.55	3.89
30.00 - 39.99	15	-6.08	6.57	3.53
40.00 - 49.99	10	-5.11	5.29	6.21
50.00 +	12	-2.89	4.43	2.75
All Counties	254	-4.13	5.74	3.28
Panel III: Housing Unit Method				
< - 10.00	21	27.06	27.06	26.62
-10.0 - 00.00	40	13.38	13.38	12.28
00.00 - 09.99	58	4.26	4.59	3.49
10.00 - 19.99	52	-0.43	3.52	3.35
20.00 - 29.99	33	-3.48	5.31	3.70
30.00 - 39.99	15	-9.92	11.09	9.02
40.00 - 49.99	10	-9.92	11.19	7.14
50.00 +	12	-12.10	12.43	10.34
All Counties	241	3.40	8.94	5.01
Panel IV: Average of Component Method II, Ratio-correlation Method, and Housing Unit Method				
< - 10.00	22	9.35	10.29	10.43
-10.0 - 00.00	46	2.66	5.17	4.28
00.00 - 09.99	61	-1.82	3.76	2.53
10.00 - 19.99	54	-2.33	3.81	3.76
20.00 - 29.99	34	-5.96	6.38	3.53
30.00 - 39.99	15	-5.05	6.26	3.83
40.00 - 49.99	10	-6.11	6.73	6.56
50.00 +	12	-1.97	3.23	2.71
All Counties	254	-1.07	5.18	3.73

*For counties for which housing data were not available to implement the Housing Unit Method only the Component Method II and Ratio-correlation estimate was employed.

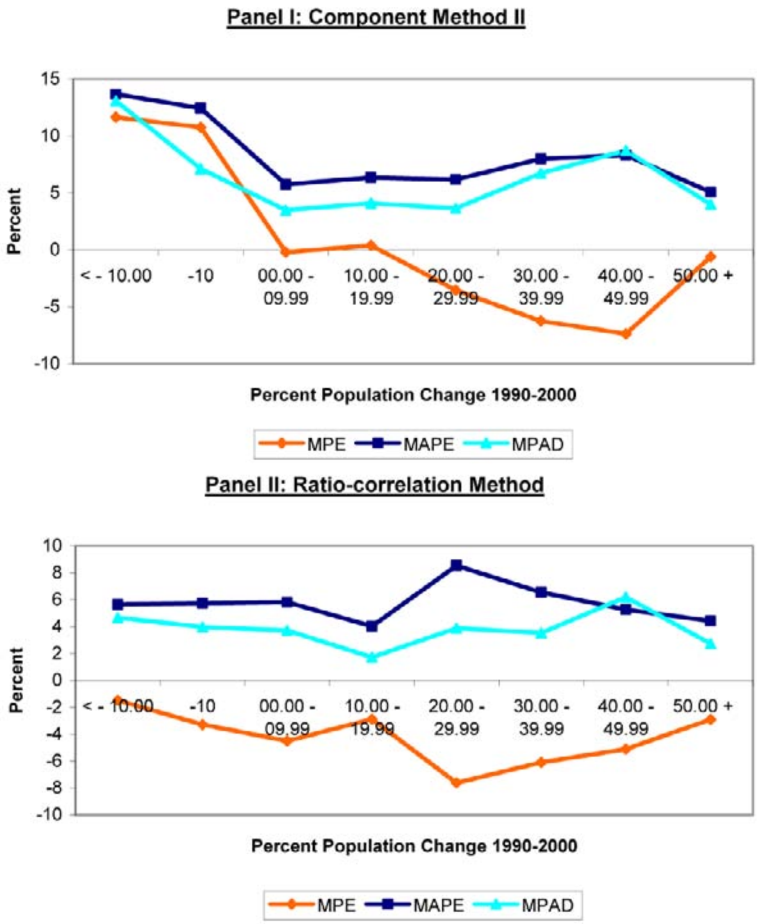


Fig. 3 Plot of MPE, MAPE, and MAPD for counties by percent population change, 1990–2000.

10.0 percent or more. The MPE, MAPE, and MPAD were lowest for counties with growth rates of 10.0 to 20.0 percent. The mean percent error was 0.40 for Component Method II and -0.43 for Housing Unit Method. As can be seen from Panel IV, the overall mean percent error for counties with declining population of 10.0 percent or more is 9.35 and MAPE of 10.29 and MPAD of 10.43. The MPE, MAPE, and MPAD for counties with increasing population of 40.0 to 50.0 percent are −6.11, 6.73, and 6.56, respectively. Overall, Table 2 and Figure 3 suggest that the error measures are higher for the fastest declining and fastest growing countries; the error measures are smaller for moderate growing counties.

The ranges of error for the estimates are presented in Table 3. The data in Table 3 also provide general support for the relative accuracy of the methods with almost 75 percent of all county estimates calculated using the Component Method II, almost

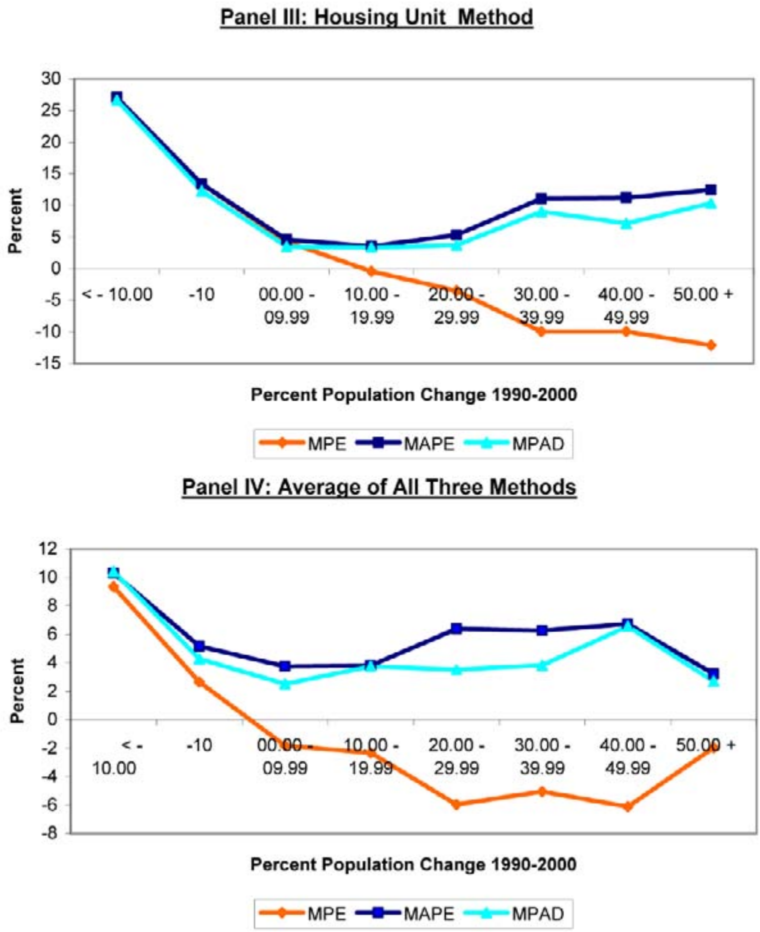


Fig. 3 Continued.

84 percent of all county estimates calculated using the Ratio-correlation Method, and 65 percent of all county estimates calculated using the Housing Unit Method being estimated within 10 percent of the actual 2000 Census counts. Using the average of three methods (Component Method II, Ratio-correlation Method, and Housing Unit Method), 87.40 percent of all counties are being estimated within 10 percent of actual counts, and overall, only 5 of the 254 counties have a 20 percent or more error from the actual 2000 Census counts.

The results in Table 4 show that the Ratio-correlation Method tended to be biased downward with 74.80 of the counties being underestimated, while the Component Method and the Housing Unit Method produced estimates that tended to overestimate the population of the counties with 51.18 and 58.09 percent of the counties, respectively being overestimated. An average of the three methods produced estim-

Table 3 Range of percentage error for differences between the Texas Population Estimates and Projections Program's population estimates for counties for 2000 and 2000 census counts.

Range of Error	Component Method II		Ratio-correlation		Housing Unit Method		Average of Component Method II, Ratio-correlation and Housing Unit Method	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
00.0-04.9	118	46.46	147	57.87	103	42.74	149	58.66
05.0-09.9	72	28.35	66	25.98	53	21.99	73	28.74
10.0-14.9	31	12.20	26	10.24	46	19.09	20	7.87
15.0-19.9	19	7.48	7	2.76	18	7.47	7	2.76
20.0-24.9	9	3.54	4	1.57	4	1.66	3	1.18
25.0-29.9	1	0.39	3	1.18	8	3.32	.	.
30.0+	4	1.57	1	0.39	9	3.73	2	0.79

Table 4 Number and percent of counties, Mean Percent Error (MPE) and Mean Percent Absolute Difference (MPAD) for counties with estimates above and below the 2000 census counts for the 2000 Texas Population Estimates and Projection Program's population estimates for counties by alternative method.

	Component Method II		Ratio-correlation		Housing Unit Method		Average of Component Method II, Ratio-correlation and Housing Unit Method*	
	Below	Above	Below	Above	Below	Above	Below	Above
Number	124	130	190	64	101	140	158	95
Percentage	48.82	51.18	74.80	25.20	41.91	58.09	62.20	37.40
MPE	-6.35	9.65	-6.59	3.95	-6.61	10.63	-5.02	3.98
MPAD	4.61	3.99	3.20	0.97	5.10	4.73	5.49	2.52

*One county's 2000 estimated population (average of three methods) was exactly the same as the 2000 census count and therefore it is not included in the computation shown here.

ates that tended to underestimate the population of the counties with 62.20 percent of the counties being underestimated and 37.40 percent being overestimated.

The Results of the Evaluation of Place-Level Estimates

Table 5 and Figure 4 present error measures for place estimates for Component Method II, Housing Unit Method, and the average of Component Method II and the

Table 5 Mean Percent Error (MPE), Mean Absolute Percent Error (MAPE), and Mean Percent Absolute Difference (MPAD) between Texas Population Estimates and Projections Program's estimates for places for 2000 and 2000 census counts by population size.

Population Size 2000	No. of Places	MPE	MAPE	MPAD
Panel I: Housing Unit Method				
Under 1,000	406	7.61	18.57	15.34
1,000 - 2,499	320	2.53	11.42	11.40
2,500 - 4,999	186	-2.62	13.49	14.10
5,000 - 9,999	132	-0.49	11.66	11.83
10,000 - 24,999	104	-3.02	9.30	8.84
25,000 - 49,999	50	-2.92	7.01	6.86
50,000 - 99,999	24	-4.00	7.92	7.37
100,000 and over	24	-2.47	5.40	6.72
All Places	1246	2.19	13.55	7.85
Panel II: Component Method II				
Under 1,000	425	19.60	29.08	24.15
1,000 - 2,499	324	6.81	17.71	17.32
2,500 - 4,999	187	-0.21	18.13	18.62
5,000 - 9,999	132	1.13	16.14	16.35
10,000 - 24,999	104	-0.49	15.57	15.17
25,000 - 49,999	50	-7.61	16.94	16.88
50,000 - 99,999	24	-1.67	11.47	10.47
100,000 and over	24	-0.73	6.67	7.09
All Places	1270	8.00	20.88	10.80
Panel III: Average of Housing Unit Method and Component Method II				
Under 1,000	432	10.86	21.01	17.51
1,000 - 2,499	326	4.92	13.39	13.23
2,500 - 4,999	187	-0.82	12.80	13.35
5,000 - 9,999	132	2.47	11.93	12.00
10,000 - 24,999	104	1.53	9.57	9.35
25,000 - 49,999	50	2.00	6.80	6.51
50,000 - 99,999	24	2.18	6.22	5.64
100,000 and over	24	-1.86	4.82	4.46
All Places	1279	5.26	14.86	6.52

Housing Unit Method. For the Housing Unit Method the overall mean percent error was 2.19, the mean percent absolute error was 13.55, and the mean percent absolute difference was 7.85 (Table 5, Panel I).

For the Component Method II, the overall mean percent error was 8.00, the mean percent absolute error was 20.88, and the mean percent absolute difference was 10.80 (Table 5, Panel II). The average of Housing Unit Method and Component Method II produced the mean percent error of 5.26, mean absolute percent error of 14.86 and mean percent absolute difference of 6.52.

The overall levels of error shown in this table are within the higher end of the expected range of 10 to 15 percent error, when estimates for a relatively large number of places with small population size are involved; however, they are higher than

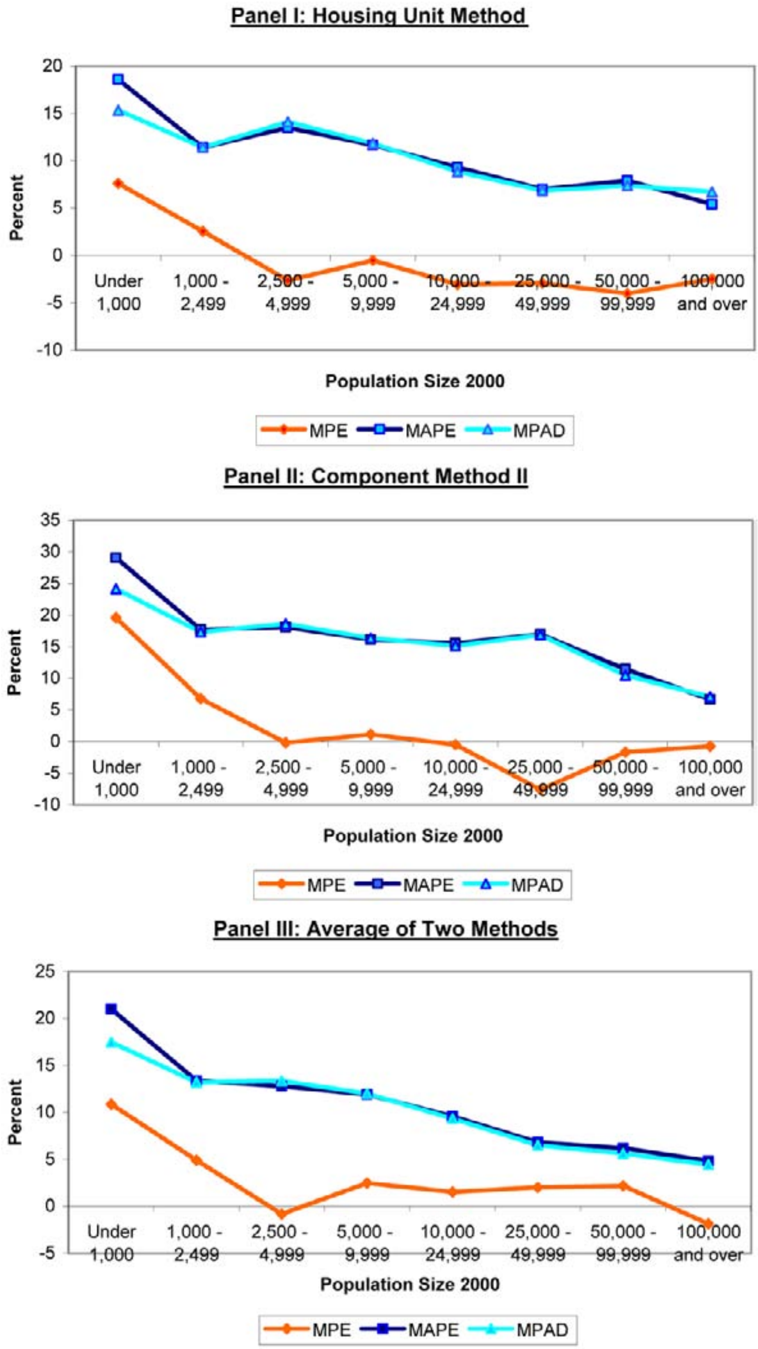


Fig. 4 Plot of MPE, MAPE, and MPAD for places by population size, 2000.

Table 6 Mean Percent Error (MPE), Mean Absolute Percent Error (MAPE), and Mean Percent Absolute Difference (MPAD) between Texas Population Estimate and Projections Program's population estimates for places for 2000 and 2000 census counts by population change.

Percent Population Change, 1990-2000	No. of Counties	MPE	MAPE	MPAD
Panel I: Housing Unit Method				
<-10.00	109	40.10	40.10	31.87
-10.00 - 00.00	214	12.99	13.00	8.43
00.00 - 09.99	284	3.97	5.98	4.66
10.00 - 19.99	221	-1.42	5.45	6.10
20.00 - 29.99	126	-3.33	7.36	6.35
30.00 - 30.99	83	-5.97	12.21	7.56
40.00 - 49.99	53	-12.19	12.96	11.94
50.00 +	156	-23.50	26.89	17.04
All Places	1246	2.19	13.55	7.85
Panel II: Component Method II				
<-10.00	114	49.98	51.07	28.33
-10.00 - 00.00	218	15.13	18.09	11.52
00.00 - 09.99	290	9.30	15.79	7.83
10.00 - 19.99	225	7.95	16.45	10.66
20.00 - 29.99	130	6.92	15.33	9.35
30.00 - 30.99	84	-1.19	14.12	10.72
40.00 - 49.99	53	-6.14	16.26	4.93
50.00 +	156	-24.36	28.42	22.03
All Places	1270	8.00	20.88	10.80
Panel III: Average of Housing Unit Method and Component Method II				
<-10.00	114	37.91	38.09	24.47
-10.00 - 00.00	218	11.68	13.31	7.65
00.00 - 09.99	290	6.66	10.17	5.84
10.00 - 19.99	227	3.77	9.68	5.43
20.00 - 29.99	133	3.74	11.31	4.73
30.00 - 30.99	83	-3.09	11.14	8.85
40.00 - 49.99	53	-3.59	9.94	6.15
50.00 +	161	-18.48	22.79	11.89
All Places	1279	5.26	14.86	6.52

is desirable. For example, the mean percent absolute difference (MPAD) for the average of the Housing Unit Method and the Component Method II for places with population of under 10,000 varies from 12.0 to 17.51, while for places with population over 10,000, it varies from 4.46 to 9.35 (Table 5, Panel III). In general, the data in Table 5 and Figure 4 suggest the expected patterns, with error measures being larger for places with smaller population and smaller for places with larger populations.

Table 6 and Figure 5 present the same error measures by the rate of population change from 1990 to 2000. Differences in population growth rates had the same impact on errors for places as for counties (i.e., fastest declining and growing places have higher error rates than slowest declining or growing places), but the patterns were more clearly visible for the places than the counties. As can be seen from

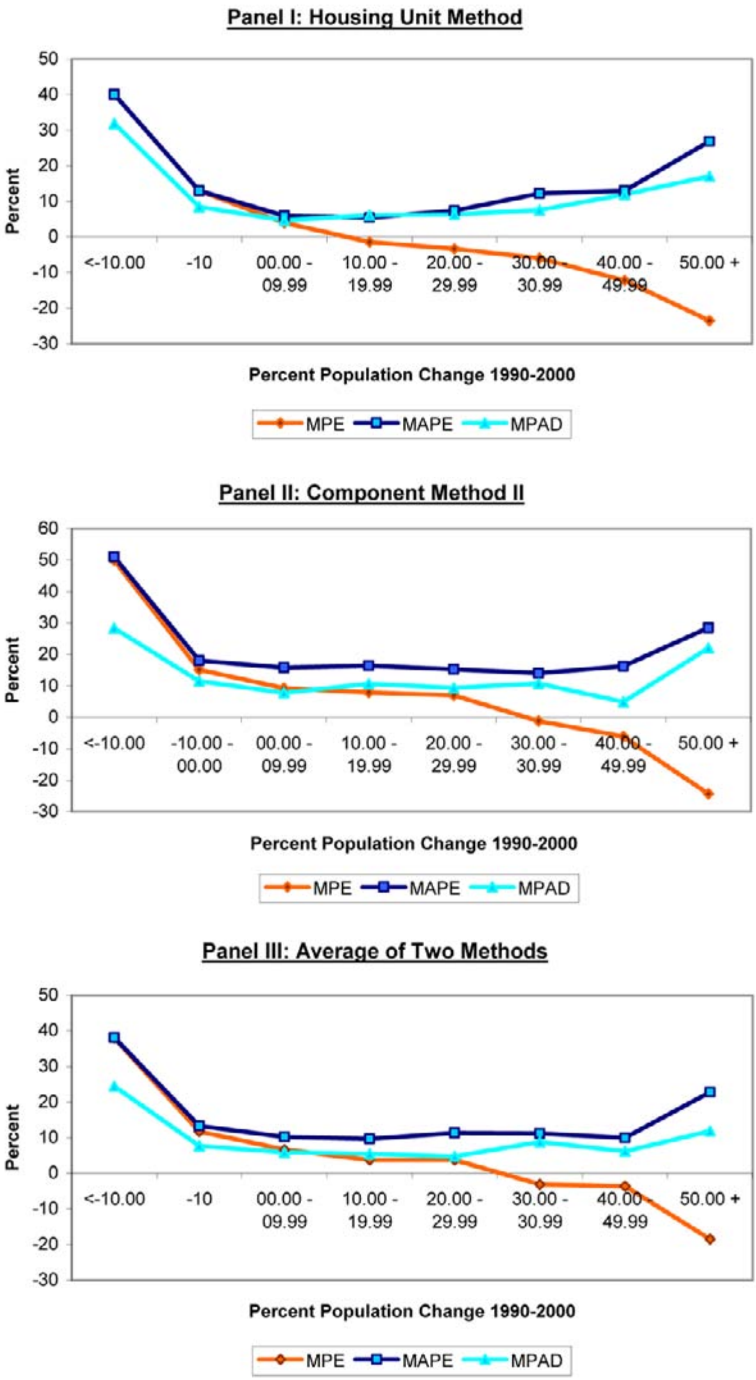


Fig. 5 Plot of MPE, MAPE, and MPAD for places by percent population change, 1990–2000.

Table 7 Range of percentage error for differences between Texas Population Estimates and Projections Program's population estimate for places for 2000 and the 2000 census counts.

	Housing Unit Method		Component Method II		Average of Housing Unit Method and Component Method II	
Range of Error	Number	Percent	Number	Percent	Number	Percent
00.0-04.9	400	32.10	241	8.98	373	29.16
05.0-09.9	314	25.20	231	18.19	286	22.36
10.0-14.9	176	14.13	196	15.43	188	14.70
15.0-19.9	98	7.87	142	11.18	136	10.63
20.0-24.9	80	6.42	97	7.64	92	7.19
25.0-29.9	41	3.29	84	6.61	55	4.30
30.0+	137	11.00	279	21.97	149	11.65

*One county's 2000 population was exactly estimated by the base estimates and so is not included in the comparisons shown here.

Table 6 and Figure 5, there was a tendency to overestimate the fastest declining places and underestimate the fastest growing places. The mean percent error was 40.10 for Housing Unit Method and 49.98 for Component Method II for counties with declining population of 10.0 percent or more. The mean percent absolute difference was 31.87 for Housing Unit Method and 28.33 for Component Method II for counties with declining population of 10.0 percent or more. The MPE, MAPE, and MPAD were higher for the fastest growing counties as well. This was evident from both Housing Unit Method and Component Method II. There was an obvious U-shaped pattern for MAPE and MPAD by rate of population change, 1990–2000 (Figure 5).

Table 7 shows results of the evaluation of estimates in terms of range of errors. Overall (average of the Housing Unit Method and the Component Method II) 51.52 percent of the places (compared to 76 percent of the counties) were estimated within 10 percent, 25.33 percent within 10 to 20 percent, and another 23.14 percent more than 20 percent of 2000 population count. For the Housing Unit Method 57.30 percent of the places were estimated within 10.00 percent while for Component Method II only 27.17 percent of the places were estimated within the 10.00 percent of the actual census count.

The results in Table 8 point to a tendency for the population of places to be underestimated when averaging the Housing Unit and Component Method II. This underestimation may be due to the undercount in the 1990 census, and the base population was lower than it should have been. Murdock and Hoque (1995) evaluated the impact of undercount on the accuracy of small-area population estimates and found significant differences in using adjusted and non-adjusted population for 1990 (for a detailed discussion, see Murdock and Hoque 1995). Another possible explanation is that there might have been an overestimation of population in small places in 2000. There was no study that I know of that has looked into the adjustment of the 2000 census.

Table 8 Number and percent of places, Mean Percent Error (MPE) and Mean Percent Absolute Difference (MPAD) for places with estimates above and below the 2000 census counts for the 2000 Texas Population Estimates and Projection Program's Population Estimates by alternative method.

	Component Method II		Housing Unit Method		Average of Component Method II, Ratio-correlation and Housing Unit Method	
	Below	Above	Below	Above	Below	Above
Number*	515	754	546	698	794	482
Percentage	40.58	59.42	43.89	56.11	62.08	37.69
MPE	-15.89	24.32	-12.95	14.05	16.21	-12.74
MPAD	9.70	12.01	8.41	6.70	7.26	6.64

*2000 population was exactly estimated by the base estimates and so is not included in the comparisons shown here.

The data in Tables 6 through 8 also suggest that in nearly all cases, the use of the Housing Unit Method improves the accuracy of the estimates obtained. During the 1980s, the Texas State Data Center did the population estimates for places based on Component Method II only. The results of the Housing Unit Method averaged with Component Method II appear to lead to a reduction in the error of estimate for places in Texas.

In review, the data for places suggest that the estimates for places are less accurate than those for counties. They suggest that the use of the Housing Unit Method averaged with estimates from the Component Method II may provide one with the means of moving toward improvement of the estimates. As a result, the Housing Unit Method was added to the base procedures for the Texas Population Estimates and Projections Program for the 1990s.

Conclusion

Accurate estimates are difficult for small areas and for areas showing inconsistency in the direction of change during the estimation period. Most of the places in Texas experienced rather rapid change making it more difficult to do accurate estimates of population. Texas is one of the few states that has produced population estimates for the counties and places since the mid-1980s. Texas Population Estimates and Projections Program's population estimates are calculated using an average of the Component Method II, the Ratio-correlation Method, and the Housing Unit Method. For this paper, population estimates calculated using the Component Method II, the Ratio-correlation Method, and the Housing Unit Method separately as well as estimates calculated using an average of the three methods were evaluated against actual 2000 census counts.

Three error measures are used to assess the accuracy of population estimates of Texas for 2000. They are the Mean Percent Error, the Mean Absolute Percent Error, and the Mean Percent Absolute Difference. At the county level, Component Method II did better than the Housing Unit Method and Ratio-correlation Method. At the place level, the Housing Unit Method did better than the Component Method II. However, as mentioned earlier, some counties and places in Texas neither issue building permits nor provide data to the U.S. Department of Commerce or Texas State Data Center. Recent data on vacancy rate is also unavailable.

The evaluation of the Texas Population Estimates and Projections Program's population estimates presented here suggest that the average of two or three methods performed better than single method. The estimates also show the expected patterns of error by population size and population change. That is, population estimates are more accurate for large counties and places than small counties and places. Of the several methods tested, no single method produced more accurate estimates than the averages of two or three methods. The assessment of the accuracy of the place-level estimates showed substantially higher levels of errors than the levels found for county-level estimates. This higher error rate results because of the large number of places with small population size and the inconsistency in the direction of change during the estimation period.

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Chapter 9
Using Demographic Estimates and Projections to Improve Statistical Forecasting

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Introduction

Much of statistical forecasting is done for large organizations, such as the federal government, state governments, or other large entities (e.g., corporations or non-profit organizations). These organizations usually need monthly forecast estimates to manage their workloads and to accomplish their budgeting and revenue estimates. That is, to produce their operating budgets, these organizations need to have detailed estimates (e.g., measures of monthly activity) because their business activities within a year are not uniform across the months but can vary substantially by month, controlled by such phenomena as multi-year business cycles or by seasonality. For example, many businesses have slow months and busy months (such as the months that precede holidays), and most government agencies have busy months (such as the IRS approaching April 15th) and slow months caused by the demand structure of their work.

In order to produce monthly forecast estimates, analytically detailed models (i.e., models with substantial and intricate seasonality) are often needed. When the forecast time horizon is longer-term (e.g., beyond 2 years), the forecasting models usually become statistically "exhausted," meaning that they degrade noticeably in characteristic problematic ways. They might generate values that exceed known population limits, or a model component such as the trend might fade even though other components continue, or the model might eventually collapse entirely into a constant value after having earlier produced sensible seasonal forecasted values. When the project requirements exceed what the typical forecasting methods can provide, demographic estimates and projections can be used to give forecasters the methods that they need to prevent the collapse of their forecasting models.

Before discussing these methods, I will (a) review a too-seldom-discussed distinction between projections and forecasts and (b) describe a one-way disconnection between statisticians and demographers. The review of the distinction between projections and forecasts is necessary because demographers regularly make projec-

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tions of up to 30 years (e.g., Tayman et al. 2007: 12), up to 40 years (e.g., Murdock et al. 2003: 24) or even up to 50 years (cited in George et al. 2004: 576), making it confusing to some readers as to why someone would mention the statistical collapse of forecasting models after about two years. The review of this distinction is integral to clearing up this confusion.

The description of the disconnection between statisticians and demographers is necessary because statisticians could be working collaboratively with demographers, but they do not seem to be. The statisticians' turf is the nearer-term forecast horizon, usually two years or less; the demographers' turf is the further-term projection horizon, usually 10 years or more. This article addresses the nearer-side, and joins other researchers in trying to close this gap.

Distinction between Projections and Forecasts

The words "projection" and "forecast" are usually used as synonyms when researchers are talking or writing about future values. However, some scholars have pointed out important conceptual and practical differences between these terms. For example, Murdock and Ellis (1991: 177), while discussing the production of future population values, write that "projections … refer to determinations of future populations …. A population forecast also refers to an attempt to determine future population levels. Unlike a projection, however, the term 'forecast' has a connotation of certainty and judgment that many demographers wish to avoid." Keyfitz (1977: 222, italics in the original) states this distinction,

> All projection consists of such statements as the following: '*If* (which we do not assert) the population grows at 33 percent in 30 years, then by the year 2000 it will have increased to $203 \times 1.33 = 270$ million'. … Forecasting is where the 33 percent is taken as the real prospective increase: 'The population *will* grow 33 percent in 30 years.'

In short, projections describe what *would happen* if stated conditions were to occur, while forecasts assert unconditionally what *will happen*.

To lessen the confusion mentioned above, demographic projections might reasonably have multiple decade time horizons, but the applied quantitative forecasting models (e.g., analytically-detailed ARIMA models) do not usually have reasonable time horizons past about two years. To support this assertion, Makridakis and Wheelwright (1989: 27, 29) state the following:

> Time horizons generally can be divided into immediate term (less than one month), short term (one to three months), medium term (three months to two years), and long term (two years or more). … Generally speaking, qualitative methods of forecasting are used more for longer term forecasts, whereas quantitative methods are used more with intermediate and shorter term situations.

In further support of this assertion, Pack (1987: 217) states that "ARIMA model time series forecasting is particularly suited to short-term forecasting and to forecasting highly seasonal variables."

A One-Way Disconnection between Statisticians and Demographers

Most applied quantitative researchers (in this case, demographers) seem to be familiar with the forecasting methods of statisticians. For example, Tayman et al. (in press) used non-seasonal ARIMA models to make up to 30-year population projections. However, many statisticians do not seem to be familiar with the projection methods of applied quantitative researchers. (For an article with a similar theme but one that discusses different statistical methods, see Clogg 1992.)

As an example of statisticians, I use the Makridakis and Wheelwright book cited above. For longer-term forecasts of two years or more, they prescribe *qualitative* methods of forecasting, a category within which they include "population or demographic forecasting" (Makridakis and Wheelwright 1989: 318). These qualitative methods (Makridakis and Wheelwright 1989: 321–336) include "adjusting long-term trends using expert judgment"; "time-independent analogies" (e.g., using increases over time in the maximum speed of military aircraft to forecast corresponding increases for commercial aircraft); "the Delphi method"; the "relevance tree method … using panels of experts"; "cross-impact matrices … closely related to the Delphi method"; "role playing"; and "futuristics" that "advocates active participation in the creation of the future."

In contrast, over more than a century, demographers (see Alho and Spencer 2005, and reviews by George et al. 2004; Murdock and Ellis 1991) have developed a range of innovative *quantitative* projection methods, such as the cohort-component method, and extrapolation methods and structural models that are tailored toward demographic issues or uses. These demographic methods, typically using annual historical data, have been used to produce multi-decade quantitative projections, as mentioned above.

On the part of demographers, I can only speculate as to their inadvertent involvement in this disconnection: there are (relative to statisticians) fewer full-time demographers, they are less numerous or less conspicuous in the national statistical bureaus, and they are less visible professionally because they are often components of other academic departments instead of having their own.

On the part of statisticians, I would partially speculate as to their involvement (using the complements of the reasons above) but I can also cite published reasons:

> [Statistical analysts using] forecasting models have typically ignored demographic factors for several reasons. First, the [demographic] changes have manifested themselves slowly. In contrast, most time series models incorporate a relatively short history. Second, the improvement in forecasting performance from incorporating demographic factors is small for reasons related to the first point. Third, models already disaggregated by age class or geographic region are not common. (Beckenstein 1987: 286)

As statisticians become more familiar with the demographic literature, these reasons will apply less often. First, although demographic changes manifest themselves relatively slowly, some forecasting models incorporate a longer history. Second, the performance improvement will no longer be expected to be small, both because

Beckenstein's first point often no longer applies and because of the purely statistical reasons that I explore in this article. The third point above no longer applies for several reasons: (a) researchers working with aggregate forecasting models can (as inputs) use corresponding aggregate demographic estimates and projections; and (b) the statistical interplay between aggregated and disaggregated forecasting models is now more common (e.g., Fildes and Stekler 2002; Clark 2000).

Thus, the purposes of this article are the following: (1) to demonstrate the use of demographic estimates and projections to successfully extend the useful time horizon of applied forecasting models from about two years to at least four years; and more generally (2) to encourage the use of methods to extend forecasting models to time horizons that are beyond the customary two-year end-point of forecasting statisticians.

The importance of having forecasting methods for use with horizons beyond two years is that, in my experience, these horizons are the ones most frequently needed for forecasts for the large organizations mentioned above. Later in this article, I describe the 3.5-year forecast horizon needed for the Texas Legislature. In addition, the USDA's World Agricultural Outlook Board specifies, along with shorter-term forecasts, five-year commodity forecasts (GAO 1991a: 18) and 10-year meat forecasts (GAO 1991b: 19).

An Example of a Longer-Term Applied Forecasting Project

To provide a concrete example of this type of forecasting setting, I will use my experiences with the Texas Legislature. It meets in regular session starting in January of odd-numbered years for about five months. Their most-recent session started in January 2007.

State agency analysts must submit their biennial forecasts by about March of the year that precedes the session or, to follow the running example, the first of March 2006. During the next few months, the agencies use their forecasts to estimate the operating expenses that their forecasts would require for the next biennium, and then use their estimated operating expenses to prepare their legislative appropriation requests in time for a round of pre-session legislative committee hearings during the fall of 2006, at which the agencies defend their appropriation requests. By the start of the legislative session, in this example January 2007, the eventual pre-session revisions of legislative appropriation requests are aggregated into an appropriations bill that is introduced into the legislative process.

By the middle of June 2007, the appropriations bill was signed into law, giving the state agencies about three months to prepare operating budgets before their appropriations took effect in September 2007, the start of the next biennium.

In short (as shown in Table 1), these agency forecasters must use an initial forecasting time horizon of about 42 months (or about 3.5 years).

Table 1 Schedule of major events in legislative forecasting calendar.

Event	Due date or end date	Months before next event
Forecasters submit forecasts for agency budget preparation	Mar 2006	3
Agencies prepare budgets for pre-session committee hearings	Jun 2006	1
Agencies defend budgets at pre-session committee hearings	Jul 2006	6
Start of legislative session	Jan 2007	5
End of legislative session	May 2007	3
Agencies prepare operating budgets by the start of the biennium	Sep 2007	24
End of biennium	Aug 2009	
Total number of months		42

The Typical Applied Forecasting Setting

As introduced above, the problem with using a relatively long time horizon for an ARIMA model is that it will lead to the overextension of most of the models that are used in the applied forecasting setting. This setting usually involves statistically intricate ARIMA models, monthly data series, and the requirement of monthly forecasts with time horizons that are unreasonably long for these standard methods.

This setting is populated with people who play two separate roles: the clients and the consulting forecasters. The forecasting requirements are established by the demands on (and thus the cascaded demands of) the clients and not on the skill and judgment of the forecasters. When the clients are confronted with the cautions of the forecasters, the usual approach of the clients is (a) to decide to overextend the forecasting model anyway and (b) to cover the dubiousness of this by issuing a blanket caveat that they hope will protect them and their organizations, and that they suspect the readers of their forecasting reports will either miss, ignore, or quickly forget.

This behavior on the part of the clients is predicated on the following two erroneous beliefs: (a) that an overextended forecasting model will continue to function as intended (e.g., the forecasts will continue a reasonable trend and the prediction intervals will continue their characteristic funnel shape in that they progressively widen as they move away from the historical values); and (b) that even if the prediction intervals become too wide, there is no alternative to the overextension of the model.

In contrast, the consulting forecasters know that an overextended model may stop functioning as designed. The forecasted values may *not* continue a reasonable trend, either (a) by exceeding the limit of the respective population (a fatal error that surprisingly often goes undiscovered in the wider public forum) or (b) by producing forecasts (or their components) that falter by, for example, losing their trend or seasonal components or by reverting to a constant. In addition, the prediction intervals may also become useless by becoming too wide or by reverting to a constant.

When forecasters attempt to explain these problems to their clients, the forecasters' explanations often consist of diffuse anxiety mixed with abstract statistical theory and are, as a result, singularly unpersuasive to clients who are less concerned about the anxiety of their collaborators than on the demands on themselves, and who seldom understand statistical theory or its implications. Thus, the forecasters are confronted with what they perceive as an ethical dilemma: they are either coerced into silence or, if they respond assertively, they run the risk of attenuated employment.

Instead, they need to understand that they can often escape this dilemma by developing alternatives that will allow them both to deliver the forecasts that their clients need and, at the same time, to not overextend their forecasting models. That is, they need to move beyond their accustomed methods by learning to use demographic estimates and projections as forecasting regressors.

Demographic Complements to Forecasted Data Series

There is a broad category of forecasted data series the values of which relate closely to people, either in a one-to-one manner or in a manner that has a well defined statistical translation. For example, in forecasting the use of (or need for) health insurance, an individual insurance policy relates to either a single adult, a couple, or a (one or two adult) family, each occurring at a known probability. Because of its known structure, the number of potential health insurance policies relates well to demographic categories. Other examples in this category of data series with near one-to-one linkages to demographic estimates and projections are pension funds, labor estimates, housing starts, public assistance programs, and transportation.

Thus, forecasters can use the estimates and projections of the corresponding demographic categories both to extend the usefulness of their forecasting models beyond their usual time-horizon, and to perform validity checks such as making sure that their forecasted values do not exceed (or really even approach) their population limits.

An Over-Extended ARIMA Model

As introduced, a frequent problem with forecasting models is that they produce reasonable forecasted values early in the time horizon but will not do so throughout the rest of the needed time horizon. This section reports a worst-case example of such a model.

The 96 monthly values of an historical data series, relabeled as a caseload for the purposes of this article, is graphed in Figure 1. Its model (see the top section of Table 2) is estimated well, showing statistically significant parameters that would

Table 2 Results and diagnostics for the ARIMA model.

<table>
<tr><td colspan="10">Parameter Estimates: Conditional Least Squares Estimation</td></tr>
<tr><td></td><td></td><td>Parameter</td><td>Estimate</td><td>SE</td><td>t</td><td>Pr > |t|</td><td>Lag</td><td></td><td></td></tr>
<tr><td></td><td></td><td>MU</td><td>6057.1</td><td>233.0</td><td>26.00</td><td><.0001</td><td>0</td><td></td><td></td></tr>
<tr><td></td><td></td><td>AR1,1</td><td>0.5423</td><td>0.0990</td><td>5.48</td><td><.0001</td><td>2</td><td></td><td></td></tr>
<tr><td></td><td></td><td>AR2,1</td><td>0.6480</td><td>0.0939</td><td>6.90</td><td><.0001</td><td>12</td><td></td><td></td></tr>
<tr><td></td><td></td><td>MA1,1</td><td>-0.5551</td><td>0.0802</td><td>-6.92</td><td><.0001</td><td>1</td><td></td><td></td></tr>
<tr><td></td><td></td><td>MA1,2</td><td>-0.4369</td><td>0.0794</td><td>-5.51</td><td><.0001</td><td>3</td><td></td><td></td></tr>
<tr><td></td><td></td><td>BIC</td><td>1,417.8</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="10">Augmented Dickey-Fuller Unit Root Tests</td></tr>
<tr><td></td><td>Type</td><td>Lag</td><td>Rho</td><td>Pr < Rho</td><td>Tau</td><td>Pr < Tau</td><td>F</td><td>Pr > F</td><td></td></tr>
<tr><td></td><td>Single</td><td>0</td><td>-33.400</td><td>0.0009</td><td>-4.47</td><td>0.0005</td><td>9.970</td><td>0.0010</td><td></td></tr>
<tr><td></td><td>mean</td><td>1</td><td>-14.573</td><td>0.0375</td><td>-2.67</td><td>0.0831</td><td>3.570</td><td>0.1736</td><td></td></tr>
<tr><td></td><td></td><td>2</td><td>-9.959</td><td>0.1258</td><td>-2.13</td><td>0.2318</td><td>2.290</td><td>0.4940</td><td></td></tr>
<tr><td></td><td>Trend</td><td>0</td><td>-44.912</td><td>0.0003</td><td>-5.22</td><td>0.0002</td><td>13.680</td><td>0.0010</td><td></td></tr>
<tr><td></td><td></td><td>1</td><td>-21.120</td><td>0.0424</td><td>-3.04</td><td>0.1276</td><td>4.700</td><td>0.2516</td><td></td></tr>
<tr><td></td><td></td><td>2</td><td>-17.280</td><td>0.1000</td><td>-2.78</td><td>0.2081</td><td>3.870</td><td>0.4130</td><td></td></tr>
<tr><td colspan="10">Portmanteau Tests (Autocorrelation Check of Residuals)</td></tr>
<tr><td>To Lag</td><td>Chi-Square</td><td>DF</td><td>Pr > ChiSq</td><td colspan="6">Autocorrelations</td></tr>
<tr><td>6</td><td>2.42</td><td>2</td><td>0.2979</td><td>-0.009</td><td>-0.051</td><td>0.071</td><td>0.070</td><td>0.104</td><td>0.018</td></tr>
<tr><td>12</td><td>3.63</td><td>8</td><td>0.8891</td><td>-0.084</td><td>0.032</td><td>-0.024</td><td>0.013</td><td>-0.033</td><td>-0.035</td></tr>
<tr><td>18</td><td>11.86</td><td>14</td><td>0.6176</td><td>-0.082</td><td>0.168</td><td>0.014</td><td>-0.137</td><td>0.107</td><td>0.073</td></tr>
<tr><td>24</td><td>16.16</td><td>20</td><td>0.7066</td><td>0.023</td><td>0.019</td><td>-0.010</td><td>-0.047</td><td>0.174</td><td>0.000</td></tr>
<tr><td colspan="10">Average and Half-Width (HW) of Prediction Interval (PI) by Calendar Year (CY)</td></tr>
<tr><td></td><td></td><td></td><td></td><td>CY</td><td colspan="2">95% PI Width</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Avg.</td><td>HW</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>1992</td><td>2,014</td><td>0.159</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>1993</td><td>2,595</td><td>0.208</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>1994</td><td>2,805</td><td>0.227</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>1995</td><td>2,889</td><td>0.236</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>1996</td><td>2,923</td><td>0.239</td><td></td><td></td><td></td></tr>
</table>

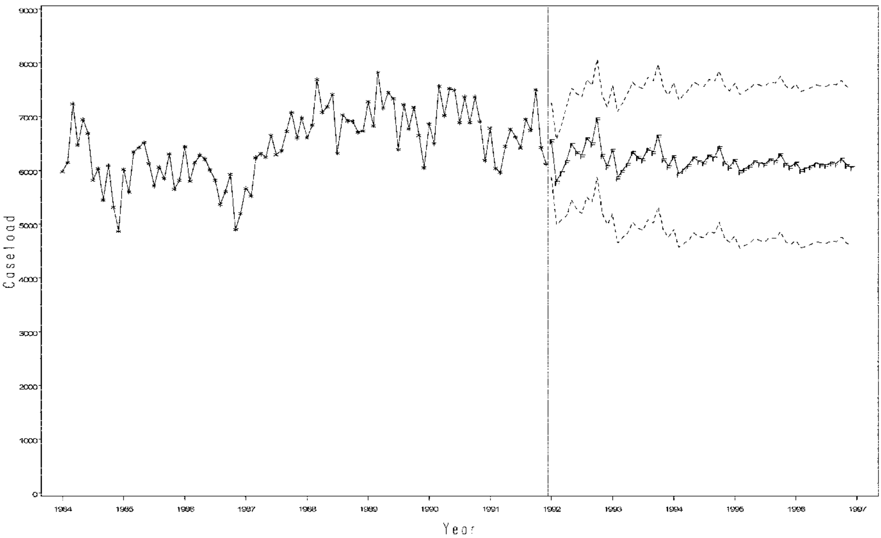

Fig. 1 ARIMA forecast (without demographic assistance).

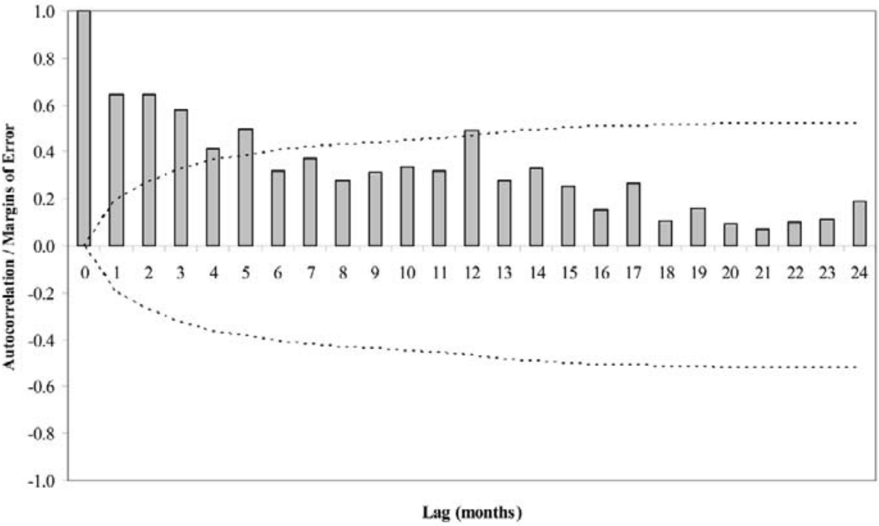

Fig. 2 Autocorrelation plot: ARIMA.

be expected to forecast reasonably through the shorter time horizon of 12 months (SAS Institute Inc. 2006).

Inspection of the visual plots of the caseload time series (e.g., see Figure 1) show stationarity in the variance (i.e., no clear fluctuation in the variance over time) and stationarity in the mean (i.e., no clear change in the level of the mean over time).

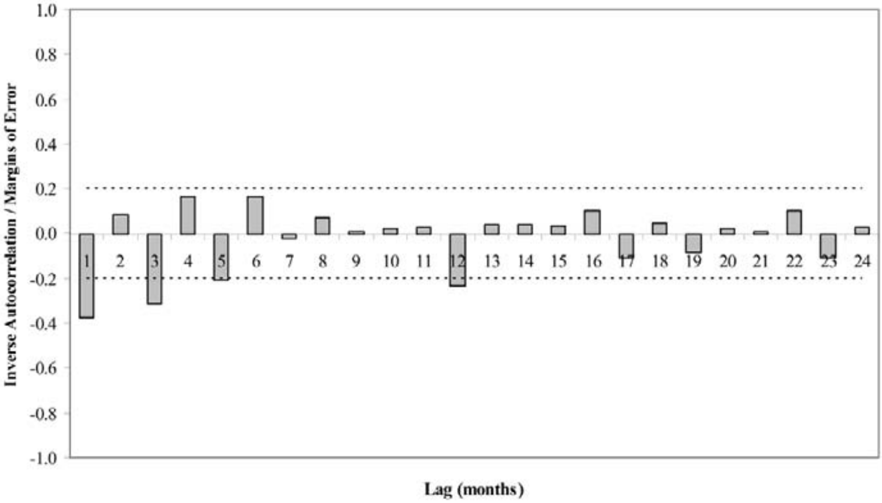

Fig. 3 Inverse autocorrelation plot: ARIMA.

Consistent with stationarity in the mean, the autocorrelation plot (see Figure 2) drops relatively quickly and the partial autocorrelation at lag one has a value that is substantially less than 1, in this case 0.646. The augmented Dickey–Fuller test (see Table 2) rejects the null hypothesis that the forecasted variable is non-stationary, indicating that no differencing is needed.

To further assess the fit of this ARMA model, a combination of an autocorrelation plot with an inverse autocorrelation plot was used (see Figures 2 and 3). Although a different combination of autocorrelation plots with partial autocorrelation plots are typically used for ARIMA model identification, for ARMA models Chatfield (2004: 255) writes that the inverse autocorrelation function "often contains more information than the partial autocorrelation function." Also, Granger and Newbold (1977: 75; cited in Chatfield 1979: 370) write that the partial autocorrelation function for ARMA models "will die out though not according to any clearly recognizable pattern." In addition, "the inverse autocorrelation function … generally indicates … seasonal autoregressive models better than the [partial autocorrelation function]" (SAS Institute Inc. 2004: 409).

In the autocorrelation function (see Figure 2), values associated with the smaller lags were significant statistically because they extended beyond the curved dashed line drawn at the margin of error (= 1.96 standard errors) of the individual lags; the optimal non-seasonal autoregressive model component was at lag 2 where this function "cuts off"; this parameter was ultimately chosen because it contributed to a model that was stable and parsimonious and that produced statistically significant parameters. The value of the autocorrelation at lag 12 was also significant statistically; this indicated that the series had, as a model component, seasonal autocorrelation at that lag. In the inverse autocorrelation function (see Figure 3), optimal

Table 3 Results and diagnostics for the ARIMAX model.

Parameter Estimates: Conditional Least Squares Estimation									
		Parameter	Estimate	SE	t	Pr > |t|	Lag		
		MU	3449.0	392.3	8.79	<.0001	0		
		AR1,1	0.4099	0.1128	3.63	0.0005	2		
		AR2,1	0.4757	0.1051	4.53	<.0001	12		
		MA1,1	-0.3933	0.1038	-3.79	0.0003	1		
		MA1,2	-0.2708	0.0977	-2.77	0.0068	3		
		POP	0.1271	0.0168	7.56	<.0001	0		
		BIC	1,381.9						
Augmented Dickey-Fuller Unit Root Tests									
	Type	Lag	Rho	Pr < Rho	Tau	Pr < Tau	F	Pr > F	
	Single mean	0	-33.400	0.0009	-4.47	0.0005	9.970	0.0010	
		1	-14.573	0.0375	-2.67	0.0831	3.570	0.1736	
		2	-9.959	0.1258	-2.13	0.2318	2.290	0.4940	
	Trend	0	-44.912	0.0003	-5.22	0.0002	13.680	0.0010	
		1	-21.120	0.0424	-3.04	0.1276	4.700	0.2516	
		2	-17.280	0.1000	-2.78	0.2081	3.870	0.4130	
Portmanteau Tests (Autocorrelation Check of Residuals)									
To Lag	Chi-Square	DF	Pr > ChiSq	Autocorrelations					
6	5.53	2	0.0630	-0.040	-0.034	0.006	0.063	0.206	0.067
12	7.10	8	0.5255	-0.066	-0.024	0.021	-0.024	0.068	-0.063
18	10.52	14	0.7229	0.104	0.115	-0.029	-0.065	0.000	-0.024
24	17.67	20	0.6089	0.175	-0.074	-0.068	-0.052	0.057	0.102
Average and Half-Width (HW) of Prediction Interval (PI) by Calendar Year (CY)									
				CY	95% PI Width				
					Avg.	HW			
				1992	1,371	0.108			
				1993	1,575	0.119			
				1994	1,617	0.113			
				1995	1,626	0.115			

non-seasonal moving average parameters at lags 1 and 3 were included because of the significant inverse autocorrelation values at those lags; estimation indicated that their corresponding terms were of this type.

The non-significance of the chi-square values in the Portmanteau tests (see Table 2) further supported the fit of the model. These tests were aggregated into sets of lags, and they test whether the overall residual autocorrelation functions for the sets are nothing more than white noise or random error. The lack of statistical significance supports the idea that there is nothing of substance left to model statistically.

For the purpose of illustration, this time horizon was extended beyond 12 months to show that the forecasts degrade thereafter, eventually reverting to a constant value. In addition, the 95-percent prediction interval of the forecasted values itself reverts to a constant value. (The time horizon for this graph was extended to 60 months to more clearly demonstrate these reversions to constants.) At the bottom of Table 2, note for the prediction intervals their steadily-increasing average widths and their half-widths, defined as half of the difference between the upper and lower endpoints of the interval divided by the point estimate (Tayman 2007). The eventual collapse of this particular subset of ARIMA models is not merely possible or even likely but is inevitable (Enders 2004: 79–86).

A Demographically Assisted ARIMAX Alternative

I use the customary label ARIMAX to identify forecasting models that use additional data series (exogenous variables) as input variables. Examples of the usual additional input variables that are in the forecasting literature (see Makridakis et al. 1998: 393–403) are (a) a time trend to help forecast auto production, (b) chemical sales, auto sales, and coal production to help forecast petroleum sales, (c) rainfall to help forecast stream flow, (d) advertising expenditures to help forecast monthly sales, (e) the number of letters mailed at a post office to help forecast the number of letters delivered, and (f) the acquisition of new breeding stock to help forecast the size of the herd.

The same historical data series that is shown in Figure 1 (with its same tendency to collapse during a 48-month horizon) is shown in Figure 4. To facilitate comparison with the previous ARIMA model, this improved ARIMAX model was kept to the same model specification as the previous ARIMA model (and produced similar corresponding parameter values) except that it incorporated a hypothetical contemporaneous demographic series (identified in Table 3 as “POP”). The values of this demographic series represent the population limits for that caseload as well as function statistically as a regression-style predictor variable (the series could also function as a dynamic regressor, etc.). Note that all model parameters are statistically significant. Another finding was that the cross-correlation function peaked at lag 0. The cross-correlation function is, in this case, the correlation between the caseload

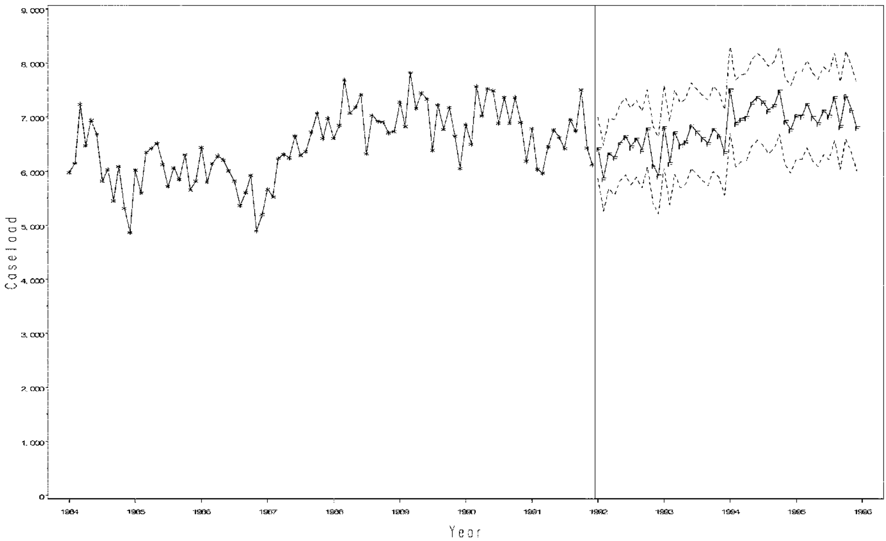

Fig. 4 The more robust ARIMAX alternative (with demographic assistance).

variable and individual negative, zero, and positive lags of the population variable that show at which lag the correlation is strongest.

The main results of this demographic assist are as follows: (a) the BIC statistic for the ARIMAX model is substantially improved over (i.e., is less than) the BIC for the ARIMA model. A main strategy of choosing between alternative forecasting models is to pick the model that minimizes the BIC statistic; (b) the forecasted values of the ARIMAX model show diagnostically reasonable values through the full 48-month time horizon; and (c) the 95-percent prediction interval for the ARIMAX model continued the usual funnel shape (see the bottom section of Table 3). However, please note that the prediction interval is too narrow because it does not include the additional prediction error attributable to the projection of the demographic series, a statistical term that would amplify this funnel shape. The unavailability of the additional prediction error is a common occurrence for demographic projections because they are seldom published because they are seldom readily calculable (however for a potential improvement in this situation, see Tayman et al. 2007).

Thus, the assistance provided by the demographic series to the forecasting model resulted in a better model on utilitarian grounds by statistically maintaining the model through a forecast horizon that would otherwise have contained the inevitable reversion to constants of both its forecasted values and its prediction interval. However, the width of the prediction interval for the ARIMAX model, even though at the same confidence level, is not comparable to the width of the prediction interval for the ARIMA model for the reason explained above.

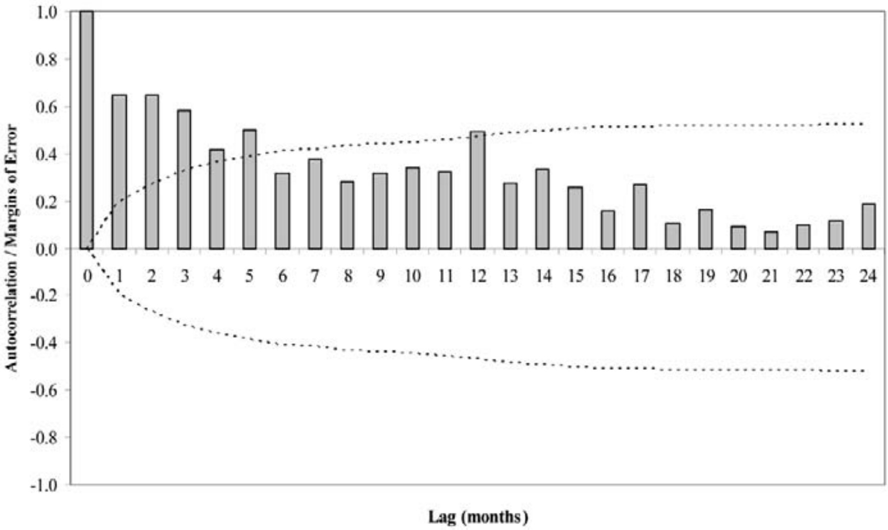

Fig. 5 Autocorrelation plot: ARIMAX.

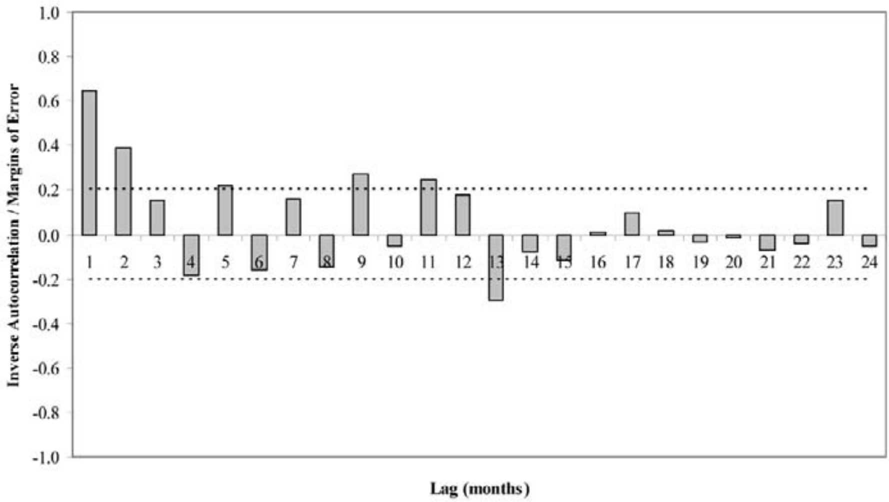

Fig. 6 Inverse autocorrelation plot: ARIMAX.

Conclusions

The usual applied forecasting setting involves statistically intricate ARIMA models, monthly data series, and the requirement of monthly forecasts with time horizons that are usually excessive for these standard methods. For assistance, the applied forecaster usually turns to the forecasting literature, the standard concepts of which are theoretical models, internal model-evaluation diagnostics, and various strategies for the assessment of forecasting errors; these concepts do not customarily include demographic concepts.

Thus, in addition to the forecasting literature, applied forecasters should also turn to the demography literature for estimates and projections that correspond to the data series that they are forecasting. Estimates and projections could be used as both validity checks of the level of their forecasts as well as important statistical assists to their forecasting models. However, they seldom use this demographic assistance, presumably because it is seldom discussed in the forecasting literature. An additional purpose of this article is to provide forecasters with concrete examples of these problems to improve communication with their clients.

Finally, forecasting statisticians and projecting demographers could benefit by working together more often to address common methodological problems.

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Chapter 10
Measuring Uncertainty in Population Data Generated by the Cohort-Component Method: A Report on Research in Progress*

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Introduction

Building on work by Kintner and Swanson (1990, 1993a, 1993b), and Swanson et al. (1993), Swanson et al. (1994) describe a procedure for generating a formal measure of uncertainty (in the form of confidence intervals) for short-term population projections made using the cohort-component method. Swanson et al. (1994) also provide an empirical example of this procedure by showing a set of age-sex projections for a small area (Nye County, Nevada) to 2000 using a 1990 launch date. However, Swanson et al. (1994) give no assessment against a census benchmark because the 2000 census results were not available when the initial work was done and other limitations precluded doing projections from earlier launch dates that could be assessed against 1990 and other existing census results. In this paper, I provide such an assessment by doing an ex post facto comparison of the confidence intervals generated for age-sex projections of this small-area population against actual 2000 census counts.

As some background, I again note what was stated by Swanson et al. (1994) in regard to Nathan Keyfitz's (1987: 236) observation that forecasting is a task that is "... unavoidable yet impossible." It is unavoidable in that forecasts must be done in the modern world and impossible in that the forecasted numbers turn out to be different than what actually occurs. Swanson and Tayman (1995) describe this irony as the "rock" and the "hard place." As noted by Swanson and Tayman (1995), demographers have developed several strategies for dealing with the "irony" of forecasting. They include the use of the term "projection" rather than "forecast," (Keyfitz 1972, Pittenger 1978, Smith and Bayya 1992, Smith et al. 2001), "normative"

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forecasting (Moen 1984), and providing measures of forecast uncertainty, ranging from the familiar informal approach of "high-medium-low" (Cheeseman-Day 1992) to more formal approaches such as empirically-based confidence intervals (Smith 1987; Smith and Sincich 1988, 1990, 1992, Stoto 1983), statistically-based confidence intervals (Kintner and Swanson 1990, Swanson and Beck 1994, Swanson et al. 1995, Tayman et al. 2007), stochastic models (Alho and Spencer 1990, 2005; Cohen 1986, Lee and Tuljapurkar 1994, Sykes 1969) and mixtures of judgment and formal approaches (Alho 1984, Alho and Spencer 1985). As a last resort, particularly if a forecast is found to be highly inaccurate, the strategy of distancing oneself from it may be employed (Swanson and Tayman 1995).

The formal measure of uncertainty developed by Swanson et al. (1994) takes the form of a "mean square error confidence interval" (*MSECI*), which I later describe in more detail. This interval places an upper and lower limit around the projected number in a given age (race-sex) group such that the limits can be given a probabilistic interpretation concerning the accuracy of the projection, given qualifications involving the assumptions underlying the projections. What is meant by these "qualifications involving assumptions?" Simply that the procedure is, like most procedures, subject to a set of limiting conditions. If the procedure gains acceptance and the limitations are better understood then it may be the case that some of them will be relaxed.

In presenting this procedure, it is useful to discuss its limitations in terms that were used by Swanson et al. (1994) and Kintner and Swanson (1993a, 1993b) in discussing the limitations of *MSECI* for intercensal net migration estimates. This discussion is based on an observation by Pittenger (1978: 276) regarding the role of assumptions in assessments of uncertainty in population forecasting:

> Essentially, the confidence intervals are valid only if all of the assumptions in the model application are valid; since the assumptions are judgmental, it follows that the confidence intervals are also judgmental.

Pittenger (1978: 272) suggests that classifying assumptions into three broad categories is useful for purposes of population forecasting. These are: (1) strategic; (2) logistical; and (3) tactical. Strategic assumptions involve issues such as what one believes will be the nature of population change in the future and the methods that can transform these ideas into numbers. They include, for example, whether or not a current life table will apply to future mortality and, if not, how this mortality schedule can be changed and applied to the population in question.

Logistical assumptions involve the selection of specific techniques within a given methodological framework and include, for example, the decision to use the forward life table survival method to develop initial net migration data instead of the reverse life table survival method. They also involve the selection and use of data. For example, should one use MARS population counts as the base population or adjust MARS data to take into account net undercount error?[2]

[2] Based on the 1990 census, the U.S. Census Bureau created a "Modified Age-Race-Sex" (MARS) file in which race categories were made comparable to those used by state and local agencies.

The third classification covers the set of assumptions falling under the rubric of "tactical." They involve the specification of specific values within a given technique. Given that one has decided to use the Forward Life Table Survival Method to develop initial net migration data should these be turned into age-specific rates or proportions by age? This is a tactical assumption.

For the most part, the level of forecast uncertainty associated with assumptions is determined by the strategic set rather than the logistical and tactical sets. Thus, for our purposes, the relationship between the *MSECI* system and logistical and tactical assumptions is discussed neither by Swanson et al. (1994) nor by me in this paper. However, the relationship between strategic assumptions and the *MSECI* system is important and requires clarification.

The *MSECI* system described by Swanson et al. (1994) is not meant to measure the uncertainty associated with a given set of strategic assumptions. Rather, it should be viewed as a set of boundaries incorporating the effects of random and other sources of noise within a given set of strategic assumptions. That is, given a set of strategic assumptions, what kind of uncertainty can one expect due to random error (variation in mortality, fertility, and migration) and systematic error (net undercount error in census counts underlying both the base populations from which the projections are made and the denominators used to develop the initial mortality, fertility, and net migration data specific to this population). Here it also is important to note that strategic, logistical, and tactical assumptions should be viewed as boundary conditions not subject to the measurement of uncertainty provided by the *MSECI*. These assumptions, particularly the strategic ones, form the scenarios that would be analogous to "groups" in an Analysis of Variance (ANOVA). Because I take, for purposes of this exposition, the strategic assumptions as given, there is no "Between-Scenario" uncertainty. That is, the *MSECI* is designed to examine "Within-Scenario" uncertainty. This interpretation is phrased differently, but it appears to be consistent with observations made by Alho and Spencer (1985: 306), Pollard (1973) and Sykes (1969) in regard to uncertainty.

Before describing the *MSECI* system, it is useful to recall that any quantitative approach to forecasting is constrained to satisfy various mathematical identities (Land 1986). The Cohort-Component Approach must satisfy demographic accounting identities, the most fundamental of which is the identity known as the balancing equation:

$$P_t = P_0 + \text{Births} - \text{Deaths} + \text{In-migrants} - \text{Out-migrants}.$$

That is, the population at some time in the future, P_t, must be equal to the population at an earlier time, P_0, plus the births and in-migrants and less the deaths and out-migrants that occur between time $= 0$ and time $= t$. In virtually all applications of the Cohort-Component Method, the balancing equation is applied to specific age-sex groups of the population (George et al. 2004, Smith et al. 2001, Murdock and Ellis 1991, Pittenger 1976) so that the potential errors associated with hidden heterogeneity (Vaupel and Yashin 1985) can be avoided.

Mean Square Error Confidence Intervals

The *MSECI* proposed by Swanson et al. (1994) is closely related to that found in introductory courses on inferential statistics, particularly in its interpretation. However, there is an important difference in the type of error that is measured. The type of confidence interval found in a typical introductory course is based solely on the standard error (*se*). That is, on the error stemming from the random variation inherent in scientific sampling. For purposes of this paper, this is referred to as an "se-based" confidence interval.

The *MSECI*, on the other hand, is based on two types of error: (1) the random variation inherent in mortality (which in this system is equivalent to the random variation inherent in sampling); and (2) measurement error, which in this system is based on the relative magnitude of systematic error occurring in successive decennial census counts for given birth cohorts as measured by "Demographic Analysis" (DA). Thus, the *MSECI* system is based on the statistical concept of a biased estimator (Kish 1965: 11). It is biased because of the differential net undercount errors that are found from census to census (Kintner and Swanson 1993b; Robinson et al. 1991, 1993, 2002; Smith 1987; Swanson et al. 1994) and the fact that these census counts are not directly adjusted for these errors. The Appendix contains a discussion on these issues taken from Swanson et al. (1994).

In a system that uses a five-year projection cycle, for any given population age group P_i (where $i = 5$–9 to 80–84) at time t, then

$$(P_i)_t = \{[(P_{i-5})_{t-5}] * ({}_5S_{i-5})\} + (NM_i)_t,$$

where $(P_i)_t$ = population in age group i at time t; $(P_{i-5})_{t-5}$ = population in age group $i-5$ at time $t-5$; $({}_5S_{i-5})$ = five-year survivorship for age $i-5$ from time $t-5$ to time t; $(NMi)_t$ = net number of migrants for age group i at time t; and the lower and upper bounds, respectively, around $(P_i)_t$ are given by

$$\text{Lower limit} = \{[[((P_{i-5})_{t-5}) * ({}_5S_{i-5}))] - (T * se_i)] + [(NM_i)_t - (T * RMSE_i)]\},$$

$$\text{Upper limit} = \{[[((P_{i-5})_{t-5}) * ({}_5S_{i-5}))] + (T * se_i)] + [(NM_i)_t + (T * RMSE_i)]\},$$

where $(P_i)_t$ = population in age group i at time t; $(P_{i-5})_{t-5}$ = population in age group $i-5$ at time $t-5$; $({}_5S_{i-5})$ = five-year survivorship for age $i-5$ from time $t-5$ to time t; $(NM_i)_t$ = net number of migrants for age i at time t; $T = T$ value for given level of confidence (2-sided) (e.g., 1 = 66%, 1.96 = 95%, 4.00 = 99.99%); se_i = mortality standard error for age i:

$$i = \{[P_{i-5})_{t-5}] * ({}_5S_{i-5}) * [1 - ({}_5S_{i-5})]\}^{0.5};$$

$$RMSE_i = [V(NMF)_i + (B)_i^2]^{0.5},$$

where

$$V(NMF)_i = [C_i(O)) * (1 - {}_{10}S_i)]$$

and $C_i(O))$ = number in age group i counted in the 1980 census; ${}_{10}S_i$ = 10 year survivorship for age group i in 1980,

$$B_i = \{[({}_{10}S_i) * ((U_i)_t)] - ((U_{i+10})_{t+10})]\}$$

and ${}_{10}S_{i-10}$ = 10 year survivorship for age group i in 1980; $(U_i)_t$ = net undercount for age group i in 1980 census; $((U_{i+10})_{t+10})$ = net undercount error for age group $i+10$ in 1990 census; and the lower and upper bounds, respectively, around $(P_{0-4})_t$ are given by

$$\text{Lower limit} = P_{0-4} - [{}_5\text{births}_{t-5}) * (S_{\text{births}})(1 - S_{\text{births}})]^{0.5},$$

$$\text{Upper limit} = P_{0-4} + [{}_5\text{births}_{t-5}) * (S_{\text{births}})(1 - S_{\text{births}})]^{0.5},$$

where S_{births} = averaged survivorship to time t of all births occurring between time $t-5$ and t and the lower and upper bounds, respectively, around $(P_{85+})_t$ are given by

$$\text{Lower limit} = \{[[((P_{80+})_{t-5})*({}_5S_{80+}))]-(T*se_{85+})]+[(NM_{85+})_t-(T*MSE_{85+})^{0.5}]\},$$

$$\text{Upper limit} = \{[[((P_{80+})_{t-5})*({}_5S_{80+}))]+(T*se_{85+})]+[(NM_{85+})_t+(T*MSE_{85+})^{0.5}]\}.$$

Data

There are two primary reasons why I chose the population of Nye County, Nevada during the period from 1980 to 2000 as the case study for this paper: (1) it qualifies as a small area population and, as such, it is subject to a high level of uncertainty in regard to population estimates and projections; and (2) it is a population with which I have experience due to my involvement with the demographic aspects of the site characterization activities associated with the U.S. High Level Nuclear Waste Repository at Yucca Mountain, Nevada, which is located in Nye County (Roe et al. 1992, Swanson 1997a, 1997b, 1998a, 1998b, Swanson et al. 1995).

Figure 1 provides a portrait of the geography of the County. As this exhibit suggests, the county is large in area and sparsely populated. Its growth in the 1990s was largely due to the fact that its major community, Pahrump, which is not too far from Las Vegas, had much more available land, and substantially lower housing prices than Las Vegas. Not surprisingly, the overwhelming majority of growth in Nye County was in Pahrump.

What kind of growth has Nye County experienced? Between 1980 and 1990 the county nearly doubled and it grew by 83 percent between 1990 and 2000. Specifically, the population of Nye County was reported as follows from 1980 to 2000: 9,048 in the 1980 census; 17,778 in the 1990 census; 23,050 via an official Nevada estimate in 1995; and 32,485 by the 2000 Census. Thus, this population represents a

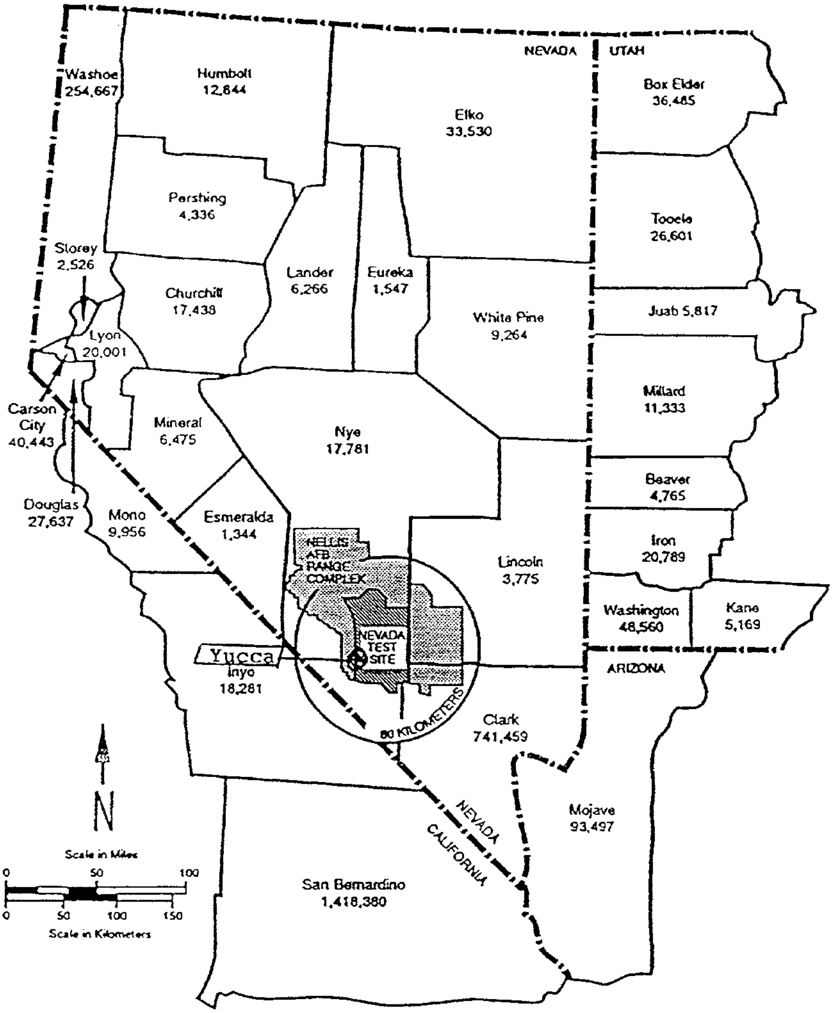

Fig. 1 Map of counties in Nevada showing the Yucca Mountain Project and the Nevada test site.

good example of the populations that are the most difficult to forecast (and estimate) accurately (Smith et al. 2001: 292).

Table 1 provides the 1980, 1990, and 2000 census count for Nye County, while Table 5 provides the county's 1995 "official" estimate, as done by the Nevada State Demographer.

Table 1 Population of Nye County, Nevada, by age and sex, 1980, 1990, and 2000.*

	1980		1990		2000	
Age	Female	Male	Female	Male	Female	Male
0–4	323	389	649	641	938	999
5–9	296	336	644	622	1071	1123
10–14	348	374	570	634	1094	1210
15–19	396	436	489	510	905	975
20–24	332	396	420	430	574	569
25–29	337	365	566	756	651	684
30–34	292	343	718	832	887	863
35–39	282	334	632	742	1153	1153
40–44	251	297	567	643	1154	1252
45–49	200	267	509	709	1130	1138
50–54	252	323	510	648	1162	1136
55–59	257	272	478	638	1109	1248
60–64	235	297	470	573	1117	1206
65–69	170	191	445	513	1055	1179
70–74	109	131	308	335	766	964
75–79	62	66	169	181	604	551
80–84	25	21	94	66	290	276
85+	28	15	43	24	175	124
Total	4195	4853	8281	9497	15835	16650

*Taken from U.S. Census Bureau reports (1982, 1992). For 1980 data, see, e.g., http://webapp.icpsr.umich.edu/cocoon/ICPSR-STUDY/09055.xml; for 1990 and 2000 data, see e.g., http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=DEC&_submenuId=datasets_1&_lang=en&_ts=

Methods

The context for the empirical assessment of the MSE-confidence intervals is provided by the development of three projection scenarios for Nye County – the classic and judgmentally formed low, medium and high scenarios (Smith et al. 2001: 331–334). These represent, respectively, the strategic assumptions described earlier. The only source of difference among the three scenarios is due to migration (see Tables 4a through 4c). The jump-off populations, fertility, and mortality input data and assumptions are the same in all three scenarios, as shown in Tables 1, 2 and 3, respectively. I believe that holding fertility and mortality constant across the three scenarios is a valid approach, given my experience with this county and the intent of this paper.

Because this assessment is *ex post facto*, I have consciously tried to avoid contaminating the results by "fudging" any of the results such that the system I am proposing looks better than it is. The three scenarios represent a reasonable set of assumptions that I would have been made in 1990 when I launched the projections

Table 2 Age-specific fertility rates used in the Nye County projections under all three scenarios, low, medium, and high.*

Age	ASFR
15–19**	0.0720
20–24	0.1490
25–29	0.1280
30–34	0.0770
35–39	0.0305
40–44***	0.0053
TFR =	2.309

*Taken from Swanson (1999).
**Births to females less than 15 years of age are included in the numerator for this age group.
***Births to females aged 45 years and over are included in the numerator for this age group.

Table 3 Five-year survivorship rates used in the Nye County projection (1990 Nevada five-year survivorship by sex) under all three scenarios, low, medium, and high.*

	${}_5S_x$	
Age-Group	Female	Male
0–4	0.997595	0.996676
5–9	0.998835	0.998190
10–14	0.997456	0.994673
15–19	0.996211	0.990249
20–24	0.995900	0.989335
25–29	0.995460	0.987012
30–34	0.993933	0.983450
35–39	0.991445	0.980560
40–44	0.985946	0.974329
45–49	0.977599	0.961173
50–54	0.967041	0.941224
55–59	0.949964	0.909753
60–64	0.921800	0.868595
65–69	0.880513	0.816199
70–74	0.821616	0.736112
75–79	0.741723	0.617891
80+	0.484162	0.442836

*The values are derived from the "Years Lived Column" in the Nevada Life Tables for 1989–1991 produced by the U.S. National Center for Health Statistics (1998).

to the year 2000 and subsequently examined in 1995 against a current population estimate.

The low scenario is so labeled because it reduced the overall rate of net migration to one third of the level observed between 1980 and 1990. Again, this was an assumption that was reasonable in 1995 because Nye County was starting to experi-

Table 4a Five year net migration rate* used in the low scenario projection.

	1990–1995		1995–2000	
Age-Group	Female	Male	Female	Male
0–4	0.0932	0.0995	0.0932	0.0995
5–9	0.1300	0.1325	0.1300	0.1325
10–14	0.1150	0.1496	0.1150	0.1496
15–19	0.0678	0.0965	0.0678	0.0965
20–24	0.0016	(0.0444)	0.0016	(0.0444)
25–29	0.0561	0.0615	0.0561	0.0615
30–34	0.1868	0.1759	0.1868	0.1759
35–39	0.1744	0.0952	0.1744	0.0952
40–44	0.1028	0.0934	0.1028	0.0934
45–49	0.1339	0.1009	0.1339	0.1009
50–54	0.1798	0.1478	0.1798	0.1478
55–59	0.2048	0.1576	0.2048	0.1576
60–64	0.2108	0.1956	0.2108	0.1956
65–69	0.2206	0.2231	0.2206	0.2231
70–74	0.1280	0.2288	0.1280	0.2288
75–79	0.0902	0.1313	0.0902	0.1313
80+	(0.0391)	0.0752	(0.0391)	0.0752

*The Net Migration Rate is taken from 1980–1990 net migration for Nye County as found by the Forward Life Table Survival Method. The denominator is the survived population from 1980. The 1980–1990 rate is divided by 2 to obtain a five-year rate. The set of low scenario rates was found by dividing by three the five-year rates taken directly from the 1980–1990 rates using the Forward Life Table Survival Method.

ence infrastructure issues that suggested the level of growth seen between 1990 and 1995 could lead to dramatically lower population growth. The major infrastructure issue was the fact that the road between Pahrump and Las Vegas was only two-lane over much of the distance and was subject to the traffic slow-downs and accidents associated with such roads when they are heavily traveled, especially with the idea of moving at high rates of speed. The net migration rates for the low scenario are shown in Table 4a.

The medium assumption is also reasonable in that it represents an adjustment made to a forecast when the jump-off date is superseded by a population estimate that is viewed as accurate. In this case, the 1995 population estimate for Nye County (shown in Table 5) was viewed as sufficiently accurate to justify controlling to it the population projection launched from 1990. Because fertility and mortality are viewed as fixed over the period, 1990 to 2000, this means that the controlling was done exclusively through the adjustment of the initial net migration rates used in the projection. This was accomplished as follows.

First, the net migration rates derived from 1980–1990 for males in age groups 0–4 to 10–14 were viewed as reasonable for the period 1990–1995, given evidence about fertility and the number of people in these age groups in 1995.

Table 4b Five-year net migration rates* used in the medium scenario projection.

	1990–1995		1995–2000	
Age-Group	Female	Male	Female	Male
0–4	0.2985	0.2985	0.2795	0.2985
5–9	0.3976	0.3976	0.3901	0.3976
10–14	0.4487	0.4487	0.3449	0.4487
15–19	0.0963	0.1370	0.2035	0.1385
20–24	0.0023	(0.0444)	0.0048	(0.0444)
25–29	0.0796	0.0873	0.1682	0.1845
30–34	0.2652	0.2498	0.5603	0.5277
35–39	0.2477	0.1352	0.5232	0.2856
40–44	0.1460	0.1326	0.3085	0.2802
45–49	0.1901	0.1433	0.4017	0.3027
50–54	0.2553	0.2098	0.5393	0.4433
55–59	0.2908	0.2238	0.6144	0.4728
60–64	0.2993	0.2777	0.6324	0.5867
65–69	0.3132	0.3168	0.6617	0.6693
70–74	0.1818	0.3250	0.3840	0.6865
75–79	0.1282	0.1864	0.2707	0.3938
80+	(0.0391)	0.1068	(0.0391)	0.2256

*The Net Migration Rates are derived from 1980–1990 net migration for Nye County as found by the Forward Life Table Survival Method. The 1990–1995 rates were found by forcing the 1995 population projection for Nye County (under the High Scenario) to agree to the State of Nevada's official 1995 estimate using constant rates for age groups 15–19 to 80+ while retaining the male net migration rtes for age groups 0–4 to 10–14. For the period 1995–2000 the same age-sex specific migration rates found in the high scenario are used. The denominator is the survived population from 1980.

Second, these rates were applied to both males and females for the period 1990 to 1995 and the period 1995 to 2000.

Third, the net migration rates for the remaining age groups (15–19 to 80+), were found as follows: (a) an arithmetic average was taken of the net migration value for the low and high scenarios of each age group by sex (above age group 10–14) and the resulting 1995 population was generated, 24,149; (b) this value (24,149) was compared to the 2005 estimate of the total population (23,050) and the difference (1,099) was assumed to reflect net migration; and (c) using an iterative process, a constant scaling factor was applied to each age group by sex with positive migration until the net number of migrants was lowered to the point that the population projected from 1990 matched the estimated population in 1995 (the estimated population was 23,050). The final factor was found to be 0.71. This yielded a projected 1995 population of 23,056, which was judged to be sufficiently close to the independently estimated number of 23,050 to stop the iteration process.

Fourth, the age-sex specific net migration rates for the period 1995–2000 were then returned to those initially calculated by the FLTSM for the period 1990–1995.

Table 4c Five-year net migration rates* used in the high scenario projection.

	1990–1995		1995–2000	
Age-Group	Female	Male	Female	Male
0–4	0.2795	0.2985	0.2795	0.2985
5–9	0.3901	0.3976	0.3901	0.3976
10–14	0.3449	0.4487	0.3449	0.4487
15–19	0.2035	0.2894	0.2035	0.2894
20–24	0.0048	(0.0444)	0.0048	(0.0444)
25–29	0.1682	0.1845	0.1682	0.1845
30–34	0.5603	0.5277	0.5603	0.5277
35–39	0.5232	0.2856	0.5232	0.2856
40–44	0.3085	0.2802	0.3085	0.2802
45–49	0.4017	0.3027	0.4017	0.3027
50–54	0.5393	0.4433	0.5393	0.4433
55–59	0.6144	0.4728	0.6144	0.4728
60–64	0.6324	0.5867	0.6324	0.5867
65–69	0.6617	0.6693	0.6617	0.6693
70–74	0.3840	0.6865	0.3840	0.6865
75–79	0.2707	0.3938	0.2707	0.3938
80+	(0.0391)	0.2256	(0.0391)	0.2256

*For the derivation of these rates see note on Table 4b.

This procedure, while effecting the desired adjustment, is sufficiently crude that the results of this examination are not likely to be contaminated by either conscious or unconscious fudging. The net migration rates for the medium scenario are shown in Table 4b.

The high scenario is so labeled because it generated a 1995 population value for Nye County that was well in excess of the official state of Nevada estimate for 1995 – an estimate that when initially released I considered to be very reasonable and still do (see Table 5). However, the high scenario was reasonable because it used the actual rates of net migration observed between 1980 and 1990 and, as such, basically continued the high level of growth that was observed during this same period. The net migration rates for the high scenario are shown in Table 4c.

In terms of uncertainty, I provide here three sets of confidence intervals for each of the three scenarios, 66%, 95%, and 99.99%. The 66% level was selected because of the findings of Stoto (1983), which, in turn, led to the results for this level of confidence reported by Swanson and Beck (1994) and Swanson et al. (1995). The 95% level was selected because of its ubiquity in statistical inference, while the 99.99% level was selected because if this level of confidence intervals does not encompass a given value (e.g., a parameter), it would suggest that the process generating the intervals is not providing useful guidance about “within-group” uncertainty.

Table 5 Comparison of official 1995 total population estimate of Nye County, Nevada, with the projected total projected total population from the three scenarios.*

1995	1995 Projection by Scenario		
Official Nevada Estimate*	Low Scenario	Medium Scenario**	High Scenario
23,050	21,278	23,056	25,935

*Available online from the Nevada Division of Water Planning (1997).
**The Medium Scenario was forced to agree to the official estimate for 1995 as closely as possible using a set of fixed age-sex specific migration rates.

Table 6a Low scenario projection of the 2000 population of Nye County, Nevada, by age and sex: 66% MSE Confidence Interval and 2000 census count.

	FEMALE			**MALE**			**TOTAL**		
Age	**projected lower bound**	**2000 Census**	**projected upper bound**	**projected Lower Bound**	**2000 Census**	**projected upper bound**	**projected lower bound**	**2000 Census**	**projected upper bound**
0-4	694	938	711	727	999	742	1,421	1,937	1,453
5-9	716	1,071	740	748	1,123	770	1,464	2,194	1,510
10-14	732	1,094	738	788	1,210	795	1,521	2,304	1,532
15-19	722	905	745	763	975	796	1,485	1,880	1,541
20-24	718	574	724	693	569	703	1,411	1,143	1,426
25-29	693	651	729	665	**684***	759	1,358	1,335	1,488
30-34	654	887	670	659	863	729	1,313	1,750	1,399
35-39	595	1,153	603	560	1,153	593	1,155	2,306	1,196
40-44	586	1,154	595	613	1,252	633	1,199	2,406	1,228
45-49	778	1,130	792	876	1,138	914	1,654	2,268	1,706
50-54	883	1,162	898	957	1,136	995	1,840	2,298	1,892
55-59	807	1,109	821	846	1,248	889	1,654	2,357	1,710
60-64	738	1,117	756	804	1,206	842	1,542	2,323	1,598
65-69	676	1,055	701	831	1,179	864	1,507	2,234	1,565
70-74	592	766	618	740	964	775	1,332	1,730	1,393
75-79	507	604	533	606	551	637	1,113	**1,155**	1,170
80+	369	465	392	453	400	480	821	**865**	873
Total	11,459	15,835	11,765	12,330	16,650	12,915	23,789	32,485	24,680

*See note below Table 6c.

Results[2]

I will not spend much time discussing the results of the low and high scenario projections. As expected, given the earlier discussion about the fact that the *MSECI* is not designed to accommodate the uncertainty associated with strategic (between group) assumptions, the *MSECI*'s intervals for these scenarios do not do a good job of encompassing the 2000 census counts (see Tables 6a through 6c for the low assumption results and Tables 8a through 8c for the results of the high scenario).

[2] The input data and calculations used in this analysis are in a documented excel spreadsheet (NYE COUNTY_1990_2000_5_YR_V5.xls), which is available upon request from the author.

Table 6b Low scenario projection of the 2000 population of Nye County, Nevada, by age and sex: 95% MSE Confidence Interval and 2000 census count.

	FEMALE			MALE			TOTAL		
Age	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound
0-4	686	938	719	720	999	749	1,406	1,937	1,468
5-9	704	1,071	752	738	1,123	780	1,441	2,194	1,533
10-14	730	1,094	740	786	1,210	798	1,515	2,304	1,538
15-19	711	905	757	747	975	812	1,458	1,880	1,568
20-24	715	574	726	688	569	707	1,403	1,143	1,434
25-29	676	651	746	620	**684***	804	1,296	**1,335**	1,550
30-34	646	887	678	626	863	762	1,272	1,750	1,440
35-39	592	1,153	606	544	1,153	609	1,136	2,306	1,215
40-44	581	1,154	600	604	1,252	642	1,185	2,406	1,242
45-49	771	1,130	799	858	1,138	932	1,629	2,268	1,731
50-54	876	1,162	904	938	1,136	1,013	1,815	2,298	1,917
55-59	801	1,109	827	826	1,248	910	1,627	2,357	1,737
60-64	730	1,117	764	786	1,206	860	1,515	2,323	1,624
65-69	663	1,055	713	815	1,179	880	1,479	2,234	1,593
70-74	580	766	630	723	964	792	1,303	1,730	1,422
75-79	495	604	545	591	551	652	1,086	**1,155**	1,197
80+	357	465	404	440	400	493	797	**865**	897
Total	11,312	15,835	11,911	12,050	16,650	13,196	23,362	32,485	25,107

*See note below Table 6c.

Table 6c Low scenario projection of the 2000 population of Nye County, Nevada, by age and sex: 99.99% NSE Confidence Interval and 2000 census count.

	FEMALE			MALE			TOTAL		
Age	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound
0-4	669	938	736	705	999	764	1,373	1,937	1,501
5-9	678	1,071	778	715	1,123	803	1,394	2,194	1,580
10-14	724	1,094	746	779	1,210	804	1,503	2,304	1,550
15-19	687	905	780	713	975	846	1,400	1,880	1,626
20-24	709	574	732	678	569	717	1,387	1,143	1,450
25-29	640	**651***	782	525	**684***	900	1,164	**1,335**	1,682
30-34	629	887	695	555	863	833	1,184	1,750	1,528
35-39	584	1,153	614	510	1,153	643	1,094	2,306	1,257
40-44	572	1,154	609	584	1,252	662	1,156	2,406	1,271
45-49	756	1,130	813	820	1,138	970	1,576	2,268	1,784
50-54	862	1,162	919	900	1,136	1,052	1,762	2,298	1,971
55-59	787	1,109	841	782	1,248	954	1,569	2,357	1,795
60-64	711	1,117	783	747	1,206	898	1,459	2,323	1,681
65-69	637	1,055	740	782	1,179	913	1,419	2,234	1,653
70-74	554	766	656	686	964	829	1,241	**1,730**	1,484
75-79	469	604	571	560	551	684	1,029	**1,155**	1,254
80+	333	465	428	412	400	521	745	**865**	949
Total	11,001	15,835	12,223	11,453	16,650	13,792	22,454	32,485	26,015

*The census number is within the confidence interval for a specific age-sex group. Technically, confidence intervals are not generated for summations of age-sex groups. However, the summed values are provided to get an idea of the utility of the procedure and where the census value falls within the summed values, the census number is boldfaced.

However, given the fact that the medium scenario is viewed as the most likely (and, as such, serves as a forecast), the results for it are discussed.

In terms of the 66% *MSECI* (Table 7a), the 2000 census count is encompassed for two male age groups. When the numbers serving as the high and low confidence

Table 7a Medium scenario projection of the 2000 Population of Nye County, Nevada, by age and sex: 66% MSC Confidence Interval and 2000 census count.

	FEMALE			MALE			TOTAL		
Age	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected Upper bound
0-4	837	938	854	885	999	900	1,723	1,937	1,754
5-9	953	1,071	978	998	1,123	1,020	1,951	2,194	1,998
10-14	1,073	1,094	1,078	1,200	1,210	1,207	2,273	2,304	2,285
15-19	1,036	905	1,060	988	975	1,021	2,024	1,880	2,081
20-24	934	574	940	877	569	886	1,811	1,143	1,826
25-29	773	651	809	765	684	858	1,537	1,335	1,667
30-34	849	887	866	849	**863***	919	1,699	**1,750**	1,785
35-39	810	1,153	817	690	1,153	724	1,500	2,306	1,541
40-44	786	1,154	795	827	1,252	847	1,613	2,406	1,642
45-49	1,046	1,130	1,060	1,091	1,138	1,129	2,137	2,268	2,189
50-54	1,173	1,162	1,187	1,220	1,136	1,258	2,394	2,298	2,446
55-59	1,117	1,109	1,131	1,107	1,248	1,150	2,224	2,357	2,280
60-64	1,040	1,117	1,057	1,142	1,206	1,180	2,182	2,323	2,237
65-69	980	1,055	1,005	1,176	**1,179***	1,209	2,156	2,234	2,214
70-74	767	766	792	1,066	964	1,101	1,832	1,730	1,893
75-79	619	604	644	771	551	802	1,389	1,155	1,446
80+	386	465	409	544	400	571	930	865	981
Total	15,177	15,835	15,483	16,196	**16,650**	16,781	31,374	32,485	32,264

*See note below Table 7c.

Table 7b Medium scenario projection of the 2000 Population of Nye County, Nevada, by age and sex: 95% MSC Confidence Interval and 2000 census count.

	FEMALE			MALE			TOTAL		
Age	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound
0-4	829	938	863	878	999	907	1,707	1,937	1,770
5-9	941	1,071	989	988	1,123	1,031	1,929	2,194	2,020
10-14	1,070	1,094	1,081	1,198	1,210	1,210	2,267	2,304	2,290
15-19	1,025	905	1,071	972	**975***	1,037	1,997	1,880	2,108
20-24	931	574	943	872	569	891	1,803	1,143	1,834
25-29	756	651	826	720	684	903	1,475	1,335	1,729
30-34	841	887	874	816	**863***	952	1,657	**1,750**	1,826
35-39	806	1,153	821	675	1,153	739	1,480	2,306	1,560
40-44	781	1,154	800	818	1,252	856	1,600	2,406	1,656
45-49	1,039	1,130	1,067	1,073	**1,138***	1,147	2,112	2,268	2,213
50-54	1,166	1,162	1,194	1,202	1,136	1,277	2,368	2,298	2,471
55-59	1,111	1,109	1,137	1,086	1,248	1,170	2,197	2,357	2,307
60-64	1,031	1,117	1,066	1,124	1,206	1,198	2,155	2,323	2,264
65-69	968	1,055	1,018	1,160	**1,179***	1,225	2,128	**2,234**	2,242
70-74	754	**766***	804	1,049	964	1,118	1,803	1,730	1,922
75-79	607	604	656	756	551	817	1,362	1,155	1,473
80+	374	465	421	531	400	584	905	865	1,005
Total	15,031	15,835	15,630	15,916	**16,650**	17,062	30,946	**32,485**	32,691

*See note below Table 7c.

levels for age- specific groups are summed, respectively, we find that only one age group (30-34) is encompassed for both sexes combined. Of the three “total” populations (male, female, and both sexes combined), only the 2000 census count for total males is encompassed by the 66% intervals. Considering the 95% level of confidence shown in Table 7b, five sex-specific age groups are encompassed, as are two

Table 7c Medium scenario projection of the 2000 Population of Nye County, Nevada, by age and sex: 99.99% MSC Confidence Interval and 2000 census count.

	FEMALE			MALE			TOTAL		
Age	**projected lower bound**	**2000 Census**	**projected upper bound**	**projected lower bound**	**2000 Census**	**projected upper bound**	**projected lower bound**	**2000 Census**	**projected upper bound**
0-4	812	938	880	863	999	922	1,675	1,937	1,802
5-9	916	1,071	1,015	966	1,123	1,053	1,881	2,194	2,068
10-14	1,064	1,094	1,086	1,191	**1,210***	1,216	2,256	2,304	2,302
15-19	1,001	905	1,095	938	**975***	1,071	1,939	1,880	2,165
20-24	925	574	949	862	569	901	1,787	1,143	1,850
25-29	719	651	862	624	**684***	999	1,343	1,335	1,861
30-34	825	**887***	891	745	**863***	1,023	1,570	**1,750**	1,914
35-39	798	1,153	828	641	1,153	773	1,439	2,306	1,602
40-44	772	1,154	810	798	1,252	876	1,570	2,406	1,685
45-49	1,024	1,130	1,081	1,035	**1,138***	1,185	2,059	2,268	2,266
50-54	1,152	**1,162***	1,209	1,163	1,136	1,316	2,315	2,298	2,524
55-59	1,097	**1,109***	1,151	1,042	1,248	1,214	2,139	**2,357**	2,365
60-64	1,013	1,117	1,084	1,085	**1,206***	1,236	2,098	2,323	2,320
65-69	941	1,055	1,044	1,127	**1,179***	1,258	2,068	**2,234**	2,302
70-74	729	**766***	830	1,012	964	1,154	1,741	1,730	1,985
75-79	581	**604***	682	724	551	848	1,305	1,155	1,531
80+	350	465	445	503	400	612	853	**865**	1,057
Total	14,719	**15,835**	15,942	15,319	**16,650**	17,658	30,038	**32,485**	33,599

*The census number is within the confidence interval for a specific age-sex group. Technically, confidence intervals are not generated for summations of age-sex groups. However, the summed values are provided to get an idea of the utility of the procedure and where the census value falls within the summed values, the census number is boldfaced.

combined-sex age groups, and those for both total males and the total of both sexes combined.

In examining the results for the 99.99% *MSECI* of the medium scenario (Table 7c), 12 of 34 sex-specific groups are encompassed, as are four combined-sex age groups, and the totals for males, females, and both sexes combined. The interval widths range from an absolute value of around 1.02 percent (age group 10-14 for females) to a high of 30.05 percent for males aged 25–39. The arithmetic average of the absolute confidence interval width across the specific age groups for males is 8.4 percent; for females, it is 4.8 percent; and for the sum of the high and low boundaries for both sexes combined, it is 6.5 percent. This average appears to be neither too narrow nor too wide (see, e.g., Swanson and Beck 1994, Swanson et al. 1994). However, the average width for the 66% confidence intervals for this same scenario does appear to be too narrow in that for males, it is only 1.9 percent, for females, 1.1 percent, and for both sexes combined, it is 1.5 percent. Similarly, the average width of the 95% intervals also appears a bit too narrow: for across the specific age groups for males it is 3.8 percent; for females it is 2.3 percent; and for both sexes combined under the 95% level of confidence for the medium scenario, it is 3.0 percent.

Table 8a High scenario projection of the 2000 Population of Nye County, Nevada, by age and sex: 66% MSC Confidence Interval and 2000 census count.

	FEMALE			MALE			TOTAL		
Age	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound
0-4	926	938*	943	979	999	994	1,906	**1,937**	1,937
5-9	1,018	1,071	1,043	1,071	1,123	1,093	2,089	2,194	2,135
10-14	1,059	1,094	1,065	1,200	1,210	1,207	2,260	2,304	2,272
15-19	1,018	905	1,041	1,125	975	1,159	2,143	1,880	2,200
20-24	868	574	874	872	569	882	1,740	1,143	1,756
25-29	834	651	869	860	684	953	1,694	1,335	1,823
30-34	871	887*	888	871	863	940	1,742	**1,750**	1,828
35-39	933	1,153	940	789	1,153	823	1,722	2,306	1,763
40-44	1,011	1,154	1,021	1,065	1,252	1,084	2,077	2,406	2,105
45-49	1,281	1,130	1,295	1,243	1,138	1,281	2,524	2,268	2,576
50-54	1,336	1,162	1,350	1,368	1,136	1,406	2,703	2,298	2,756
55-59	1,317	1,109	1,330	1,273	1,248	1,316	2,590	2,357	2,647
60-64	1,272	1,117	1,290	1,373	1,206	1,411	2,645	2,323	2,701
65-69	1,224	1,055	1,249	1,418	1,179	1,451	2,642	2,234	2,701
70-74	957	766	983	1,320	964	1,355	2,277	1,730	2,338
75-79	769	604	795	958	551	989	1,727	1,155	1,784
80+	450*	465	473	664	400	692	1,114	865	1,165
Total	17,144	15,835	17,450	18,451	16,650	19,035	35,595	32,485	36,485

*See note below Table 8c.

Table 8b High scenario projection of the 2000 Population of Nye County, Nevada, by age and sex: 95% MSC Confidence Interval and 2000 census count.

	FEMALE			MALE			TOTAL		
Age	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound
0-4	918	938*	952	972	999*	1,001	1,890	**1,937**	1,953
5-9	1,006	1,071	1,055	1,060	1,123	1,103	2,066	2,194	2,158
10-14	1,057	1,094	1,068	1,198	1,210	1,210	2,254	2,304	2,277
15-19	1,007	905	1,052	1,109	975	1,175	2,116	1,880	2,227
20-24	865	574	876	868	569	887	1,733	1,143	1,763
25-29	817	651	887	815	684	998	1,631	1,335	1,885
30-34	863	887	896	837	863*	974	1,701	**1,750**	1,869
35-39	929	1,153	944	774	1,153	838	1,703	2,306	1,782
40-44	1,007	1,154	1,025	1,056	1,252	1,094	2,063	2,406	2,119
45-49	1,274	1,130	1,302	1,225	1,138	1,299	2,499	2,268	2,601
50-54	1,329	1,162	1,357	1,349	1,136	1,424	2,678	2,298	2,781
55-59	1,310	1,109	1,337	1,253	1,248	1,337	2,563	2,357	2,674
60-64	1,264	1,117	1,299	1,355	1,206	1,429	2,618	2,323	2,727
65-69	1,211	1,055	1,262	1,403	1,179	1,467	2,614	2,234	2,729
70-74	945	766	995	1,303	964	1,372	2,248	1,730	2,367
75-79	757	604	807	943	551	1,004	1,700	1,155	1,811
80+	438	465*	485	651	400	705	1,089	865	1,190
Total	16,998	15,835	17,597	18,170	16,650	19,316	35,168	32,485	36,913

*See note below Table 8c.

Discussion

As stated earlier, strategic, logistical, and tactical assumptions associated with a given forecast are viewed as boundary conditions not subject to the measurement of uncertainty provided by the *MSECI*. That is, there is no between-scenario uncertainty because the *MSECI* is designed to examine within-scenario uncertainty. As

Table 8c High scenario projection of the 2000 Population of Nye County, Nevada, by age and sex: 99.99% MSC Confidence Interval and 2000 census count.

	FEMALE			MALE			TOTAL		
Age	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound	projected lower bound	2000 Census	projected upper bound
0-4	901	938*	969	957	999*	1,016	1,858	**1,937**	1,985
5-9	981	1,071*	1,080	1,038	1,123*	1,125	2,019	**2,194**	2,205
10-14	1,051	1,094	1,073	1,191	1,210*	1,216	2,243	2,304	2,289
15-19	983	905	1,076	1,076	975	1,209	2,059	1,880	2,285
20-24	859	574	883	858	569	897	1,716	1,143	1,779
25-29	780	651	923	719	684	1,094	1,499	1,335	2,017
30-34	847	887*	912	766	863*	1,045	1,613	**1,750**	1,957
35-39	922	1,153	952	740	1,153	872	1,661	2,306	1,824
40-44	997	1,154	1,035	1,036	1,252	1,113	2,033	2,406	2,148
45-49	1,259	1,130	1,317	1,187	1,138	1,338	2,446	2,268	2,654
50-54	1,314	1,162	1,372	1,311	1,136	1,463	2,625	2,298	2,834
55-59	1,297	1,109	1,351	1,209	1,248*	1,381	2,506	2,357	2,731
60-64	1,245	1,117	1,317	1,316	1,206	1,467	2,562	2,323	2,784
65-69	1,185	1,055	1,288	1,369	1,179	1,500	2,555	2,234	2,788
70-74	919	766	1,021	1,266	964	1,409	2,185	1,730	2,429
75-79	731	604	833	911	551	1,035	1,642	1,155	1,868
80+	414	465*	509	623	400	733	1,037	865	1,242
Total	16,686	15,835	17,909	17,574	16,650	19,912	34,260	32,485	37,821

*The census number is within the confidence interval for a specific age-sex group. Technically, confidence intervals are not generated for summations of age-sex groups. However, the summed values are provided to get an idea of the utility of the procedure and where the census value falls within the summed values, the census number is boldfaced.

can be seen from the empirical examples, there is clearly uncertainty beyond that of within-scenario. The projections under both the low and high scenarios can be viewed as empirical examples of this limitation.

In terms of the level of confidence, the average width of the intervals appears to me to be too narrow at the 66% and even the 95% level. In the case of the 66% *MSECI*, the average absolute relative widths for the male age groups in the low, medium and high scenarios, respectively are 2.4 percent, 1.9 percent, and 1.7 percent, respectively; for females, the age-specific averages in these same scenarios are, respectively, 1.4 percent, 1.1 percent, and 1.0 percent. For the 95% level, the age-specific absolute relative averages for males in the low, medium, and high scenarios are, respectively, 5.0 percent, 3.9 percent, and 3.4 percent; for females, the age-specific averages for in these same scenarios are, respectively, 2.8 percent, 2.2 percent, and 2.0 percent. Compare these averages with those taken respectively from the low, medium, and high scenarios using the 99.99% level: for males, they are 11.0 percent, 8.4 percent, and 7.3 percent, respectively; while for females they are respectively, 6.0 percent, 4.8 percent, and 4.1 percent. Although traditional statistical practice as well as prior work by Swanson and Beck (1994) on confidence intervals derived from regression-based forecasts, suggests that 66% confidence intervals are feasible, the results shown here suggest that in using the *MSECI* for the cohort-component method, a 99.99% level of certainty should be specified for this application. In large part, this is due to the crudity of the age-specific net migration rates used to force the projection to match the 1995 total population estimate of Nye County, which as described earlier, were purposefully used to avoid fudging results. With more refined net migration rates, one could expect a relaxation of this level of certainty and better coverage of the age-specific results. As is also noted in the footnotes to Tables 6a through 8c, confidence intervals are technically generated only for age-sex specific groups in this paper. The "confidence intervals" shown for summations of the low and high boundaries for age-sex specific groups are only implied. However, these implied confidence intervals are useful in judging the adequacy of the width of the intervals so formed and are therefore presented for this purpose.

As indicated by the empirical examination in this paper, the *MSECI* system clearly is subject to limitations.[3] However, the 99.99% level appears to be potentially viable, particularly in regard to the implied intervals around the projection of total populations, both by sex and for both sexes combined. Further work will result in a better understanding of these limitations, which should result in fewer limitations and greater generality. One direction to pursue would be to examine cohort-component projections by age and sex for different race and ethnic groups. This, of course, could utilize the net undercount data by age and sex for specific race and ethnic groups. It would be useful not only because race and ethnic groups are associated with different rates in terms of their components of growth (McKibben 2004: 175), but also because of the differences in net census undercount error by race and ethnic groups (Hogan 1993, Passel et al. 1982, Robinson et al. 1991, 1993, 2002, U.S. Bureau of the Census 1974).

Another direction for future research would be to examine larger populations, especially those not subject to the rates of change found in Nye County, Nevada. Smith et al. (2001: 315–328) observe that size and rates of growth have significant effects on forecast errors. As such, the test done in this paper represents a very high standard for *MSECI* to meet and is likely to perform better with large and less volatile populations.

Yet one more direction is to develop a scaling factor that increases the width of both generated and implied intervals as one moves from a higher level of geography for which net undercount estimates are available (e.g., the U.S. as a whole) to lower levels in the same geographic hierarchy which are subject to more uncertainty (e.g., a specific county). Such a factor would need to reflect the increased uncertainty associated with moving from higher to lower levels within the same geographic hierarchy. Something along these lines would severely damage the idea of confidence intervals from a frequentist perspective, but perhaps it is feasible using a Bayesian or some other non-frequentist perspective.

Even with its limitations, the system provides a starting point for formal statements about uncertainty in estimates and short-term forecasts made using the cohort-component system. The importance of such a step is perhaps best summar-

[3] One obvious limitation is that the *MSECI* requires net census undercount error data. For areas in which these data are not available (whether directly or indirectly), the system cannot be used.

ized by Rives (1982: 85), who in arguing for his "survey-based" method of population estimation, observed:

> Most population estimation techniques, particularly demographic techniques, permit only statements about error that tend to be judgmental in nature. Such statements can be useful, but they do not have a strong empirical basis.

I believe that the *MSECI* system provides a way to generate data using the cohort-component method for estimates and for short-term forecasts (i.e., no more than a 10-year horizon) that is consistent with Rives' suggestion. It provides a conceptual framework for measuring total forecast uncertainty that is analogous to ANOVA and at the very least provides a way to identify sources of forecast uncertainty, given its limiting assumptions.

One of the limitations I have placed on the use of this system is in regard to the length of the forecast horizon. Why do I recommend that this system be used only for current estimates and short term forecasts of no more than 10 years? The answer is that the net undercount errors used to develop bias are fixed, which means that bias by age and sex groups is fixed. This means that uncertainty cannot change over time. Clearly, for a 20-year horizon, the uncertainty should be higher at the end of it rather than the beginning of it. However, in this context I note that more than twenty years ago, Alho and Spencer (1985: 314), stated that the problem of assessing the uncertainty of a long-term forecast appeared to be quite difficult; I do not believe that it has appeared to become any easier in subsequent years in spite of many advances (Alho and Spencer 1990, 2005, National Research Council 2000). As such, I believe that it is more fruitful to focus attention on the development of formal measures of uncertainty for the cohort-component method only in regard to current (and past) estimates and short-term forecasts (Swanson 1989, Swanson and Beck 1994, Swanson et al. 1995, Tayman et al. 1998). The development of formal measures for long-term forecasts is perhaps a goal too ambitious for what we currently know about forecast errors and their propagation, especially in regard to the cohort- component method (Alho and Spencer 1985, George et al. 2004: 592–595, Lee and Tuljapurkar 1994, Smith et al. 2001: 334–339).

Given the preceding statement, it is worthwhile to conclude this paper by reflecting not only on the feasibility, but also on the desirability of developing measures of uncertainty for population projections. I believe that efforts to develop formal or even quasi-formal measures of uncertainty around long-term forecasts of any type are misguided because of arguments made implicitly by de Gans (1999: 233–238), and more explicitly by Moen (1984) Pittenger (1978), and Romaniuc (2003). Why do I believe this? Because in large part it appears to me that these authors take the positions they do because of the ability of humans to both re-interpret the past and present and, therefore consciously affect the future, and I find this to be a convincing position. However, I note that while the re-interpretation of a demographic past is possible, consciously affecting such a past is not possible. Similarly, it is possible to re-interpret a demographic "present," but while not impossible, it is very difficult to consciously affect it, given the momentum of demographic change, even in small areas. Thus, I believe that the formal statements of uncertainty developed for current (and past) population estimates by, among others, Espenshade and Tayman (1982) and Swanson (1989) are as valid and reliable as those developed for samples taken from a population in the "demographic present" (see, e.g., Fay and Herriot 1979, Kish 1965, Longford 2005, Roe et al. 1992). Because consciously affecting a short-term demographic future is nearly as difficult as it is for a demographic "present," I also believe that formal statements about the uncertainty of short-term forecasts made using the cohort-component method have the potential to be as valid, reliable, and useful as the ones developed for regression-based short-term population forecasts by Swanson and Beck (1994) and Tayman et al. (1998).

Appendix

Biased estimation has been found useful in estimating the accuracy of net migration derived from a survival method because the *MSECI* provide a more realistic picture of accuracy than do "adjusted" unbiased estimators with se-based confidence intervals around them (Kintner and Swanson 1993a, 1993b). This position is based on the arguments of Kintner and Swanson (1993a, 1993b), as well as those of others who have explored the use of biased estimators (Cochran 1977, Hoerl and Kennard 1970, Harville and Jeske 1992, Kish 1965, Marquardt and Snee 1975, Reinsel 1985). Further, this position has a strong theoretical foundation and does, in fact, lead to valid and formal interpretations of the measures of accuracy we present. Thus, I believe that the *MSECI* system can generate intervals that are empirically meaningful, which is important (Roe et al. 1992).

Many analysts prefer to work with an "unbiased" estimator, and its corollary measure of uncertainty, *se,* instead of a biased estimator, and its corollary measure of uncertainty, mean square error (MSE). In terms of this system, these analysts would suggest that we adjust our biased estimator directly using, for example, "DA" net undercount error (Robinson et al. 1991) so an "unbiased estimator" of net migration could be obtained. In this approach, one would then calculate a confidence interval using the standard error (*se*) associated with the unbiased estimate.

Swanson et al. (1994) agree that the preceding approach is one that could be taken, but rejected it in favor of a biased estimator because of dissatisfaction with the width of the confidence interval generated from the standard error (*se*) associated with the source of random variation in the original models developed for measuring uncertainty around net migration estimates (Kintner and Swanson 1991, 1993b). This dissatisfaction was based on empirical grounds. It is not unique to Swanson et al. (1994) in regard to using unbiased estimators and se. Dissatisfaction with the width of confidence intervals generated by the traditional approach to multiple regression (unbiased estimators) is directly responsible for the development of "Ridge Regression" (Hoerl and Kennard 1970), which has found considerable use in many fields. Ridge Regression offers a non-simplistic solution to the problem of an ill-conditioned matrix (Hoerl and Kennard 1970, Marquardt and Snee 1975), which in extreme cases produces artificially inflated se values and leads to Type

II inferential errors about regression coefficients. The solution in Ridge Regression is non-simplistic because it does not simply eliminate independent variables from a model. Rather, it seeks to retain all relevant independent variables by generalizing the definition of "error" from *se* to MSE. To accomplish this, biased estimators are used in place of unbiased ones. In return, a user of Ridge Regression seeks to achieve a greatly reduced MSE, which, in turn, greatly reduces the possibility of Type II errors.

Although the dissatisfaction with the width of confidence intervals in the system developed by Swanson et al. (1994) was because they were "too small" (while the dissatisfaction that led to Ridge Regression was because, in essence, that confidence intervals were "too large" in the presence of high collinearity), their solution is exactly the same as that in Ridge Regression: A biased estimator and incorporate MSE to measure "total error" (accuracy) rather than using an unbiased estimator and incorporating se, which can only measure "sampling error" (precision).

"Ridge Regression" is not the only area in which the use of a biased estimator and MSE is found instead of an unbiased estimator and se. A closely related line of study is within the context of examining fixed and random effects in multiple regression/general linear models (Harville and Jeske 1992, Reinsel 1985). Another line of the "biased estimator/MSE" literature is found within survey research (Cochran 1977, Kish 1965). This has been a particularly rich field for those attempting to understand biased vs. unbiased estimators because of the "obviousness" of non-sampling error – bias – to those involved in collecting and analyzing primary data.

Finally, Swanson et al. (1994) note that an important theoretical development in the biased estimator/MSE approach is that it has been linked to Empirical Bayesian (EB) interpretations (Fay and Herriot 1979, Morris 1983a, 1983b, Prasad and Rao 1990, Reinsel 1985). This linkage indicates that *MSECI*s have a sound theoretical foundation and are not interpretable in only an ad hoc or informal manner.

The point in reviewing these developments is that biased estimation constitutes a well-established area within inferential statistics and has been fruitfully applied in a number of areas, including small area demographic estimation (D'Allesandro and Tayman 1981, Fay and Herriot 1979, Prasad and Rao 1990, Swanson 1978, 1980). Swanson et al. (1994) argue that their application of biased estimation falls squarely within this area and that it can be drawn upon for not only a theoretical foundation but also for empirical justifications. It is important to note again here that *MSECI* yields a *valid* statistical interpretation. However, because of the inclusion of bias in the definition of error some adjustments are required in this interpretation (Kish 1965: 566–571, Swanson et al. 1993).

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Section III

APPLIED DEMOGRAPHY AND HEALTH

Chapter 11
Tuberculosis and Perception of Risk: A Comparison of Native Born and Foreign Born Persons in the United States

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Introduction

While migration is not a new phenomenon, the nature of migration has changed over time in volume and composition, and these changes have global implications. In addition to the economic impacts created by mass movements of people, there are tremendous health impacts. Gushulak and MacPherson (2006a: 250) note, "migration and travel, by creating a functional global village in terms of health, increase the opportunities for disease and illness to present beyond the boundaries and historical epidemiological patterns." This paper will explore the health implications of changes in mobility patterns with the goal of understanding both the real and perceived risk of contracting tuberculosis.

Global Patterns of Migration

Technological advances in communication and transportation ensure that those who want to move can do so with relative ease and rapidity. Global communication networks narrow the gaps between cultures by increasing knowledge of both conditions and opportunities in other areas of the world, while improvements in transportation have lowered the cost of migration, making it affordable for a greater number of migrants (Martin and Widgren 2002, Population Reference Bureau 1996). Indeed, "the international network of flights can take a migrant anywhere within a day or two for less than the average monthly earnings of even an unskilled worker in an industrial country" (Population Reference Bureau 1996: 14).

With transportation issues eased and information on areas of destination more readily accessible, migrants are moving in greater numbers than ever before. Between 1960 and 2005, the number of international migrants increased by a factor of 25 from 75.4 million to 190.6 million (United Nations 2006a).

S.H. Murdock and D.A. Swanson (eds.), Applied Demography in the 21st Century, 193–212.

Compositional Changes in Migration

It is not only that the flow of migration is increasing, but also that the composition of the flows is becoming more diverse. Historically, Europe dominated international migration flows (Castles and Miller 2003, United Nations 2004). Today, the majority (63%) of these movements are from developing countries to developed countries (International Organization for Migration 2005) as aging populations and labor shortages in developed countries coupled with rapid population growth and surplus labor in developing countries create the impetus for large scale movement (MacPherson 2001a). The Asian region, once a destination area, has become the source of the largest out migration flows. Europe has gone from a region of out migration to a destination region for migrants while the Americas continue to be the dominant region of destination. Gushulak and MacPherson (2006a) note that prevalence gaps or disparities in certain diseases or conditions exist between different regions of the world. Migrants link these differential risks as they travel between regions and may, in fact, elevate the risk of certain infectious diseases further depending on whether the migration is legal or illegal and the mode of transportation.

According to the International Organization for Migration (2005) approximately 20 percent of current migrant flows are illegal movements involving 30–40 million immigrants worldwide. It is often the case that the very factors that spur unauthorized immigration are the same factors that facilitate the spread of infectious disease – poverty, discrimination, and exploitation (International Organization for Migration 2005). Throughout their journey and even once these migrants arrive in their areas of destination, they find a lack of clean water and basic sanitation, which exacerbate the risk of contracting an infectious disease. Further, the densely populated areas in which they live create environments ripe for epidemics of disease and are places where rare or geographically isolated illness may be more commonly encountered (MacPherson 2001b).

Another compositional difference in migration relates to the gendered nature of migration. Nearly half of all migrants are women (International Organization for Migration 2006). The health risks of women migrants may differ from the risks male migrants face depending on whether their migration process is legal or illegal, their work status, and their mode of travel. The World Health Organization (2004), for instance, indicates that the number one killer of women in many countries is infectious disease due primarily to their unequal access to resources, discrimination, and victimization. The migration process itself as well as illegal migration expose women to increased risks of victimization while the jobs that migrant women hold in sweat shops or service occupations and even as sex workers may also increase their risks of exposure to infectious disease (Gushulak and MacPherson 2006a).

Length of Stay

Migrant flows also differ from past patterns in duration of stay. Historically, when people elected to move, the move was permanent. Today, there are greater opportunities to enter in student categories or as skilled migrants. As a result, many of these transnational moves are now temporary and may involve multiple return visits to countries of origin before returning home permanently (International Organization for Migration 2005). While initial authorization to enter a country probably involved some sort of health screening process, subsequent travel with approved documentation does not require the same health screening measures.

Tourism

The health implications of international movements are not limited to immigrants. Short-term international tourist travel has increased considerably. Between 1990 and 2005 the number of international tourists grew from 439 million to 806 million. The primary tourist destination is Europe but Asia is now the second most frequent destination, while travel to Africa and the Middle East has more than doubled (World Tourism Organization 2006). In addition to the risks imposed by not screening short-term visitors and returnees, the speed of travel means that some diseases may not evidence themselves until after travel is complete because the incubation period of the disease is longer than the duration of the travel (MacPherson and Gushulak 2001).

Migration and Disease Risk

All of these changes in migration patterns become important because health disparities are increasing globally (Ravdin et al. 2006) and, as mentioned previously, migrants are bridging regional prevalence gaps[1] in their travels. These disparities in health are particularly apparent in comparing developing and developed areas of the globe. The problem, as previously shown, is that where the disease burden is highest is also where the majority of migrants originate. Infectious diseases that would have been confined to a specific geographic area now spread rapidly as migrants and travelers expose populations to disease risks that they otherwise would not have encountered. Of concern to the World Health Organization (WHO) is the

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[1] The phrase "bridging regional prevalence gaps" refers to the movement of migrants from an area of one level of risk of disease to another area with a different level of risk for that disease.

increased threat of tuberculosis that migrants bring to resident populations particularly the threat of treatment-resistant forms of the disease.[2]

World Health and Tuberculosis

Globally, HIV/AIDS and tuberculosis were among the top three leading causes of death for persons aged 15–59 (WHO 2004) and the incidence of both diseases continues to increase. WHO (2006a) projects that these two causes of death will continue to account for a higher than average proportion of years of life lost through 2030. In many regions of the world, persons infected with HIV bear the double burden of also being infected with TB. It is estimated that nearly half of the HIV population is infected with TB, and this proportion increases to above 70 percent in high prevalence areas of the world like Africa and Southeast Asia (The Global Fund 2005a). For those with HIV, TB is the leading cause of death. The difference between HIV and TB is that while both conditions are preventable, TB is mostly curable.

Worldwide, there were more than 8.9 million incident cases of TB in 2004. The World Health Organization estimates that the incidence of TB is growing 0.6 percent annually and that nearly a third of the world population is infected (WHO 2006a). The prevalence of TB is higher in some parts of the world than in others. For instance, TB mortality, prevalence, and incidence are highest in Africa, Southeast Asia, and the Eastern Mediterranean. Compared to the Americas, TB prevalence is ten times higher in Africa, six times higher in Southeast Asia, and four times higher in the Eastern Mediterranean and Western Pacific.

Aggregating this data to the regional level, however, conceals major differences between countries within regions. For instance, WHO has identified 22 countries that account for 80 percent of TB cases every year (WHO 2006b). Half of all new TB cases originate in Bangladesh, China, India, Indonesia, Pakistan, and the Philippines (WHO 2006c). Swaziland in Africa has the highest incidence at 1,225.87 followed by Djibouti at 733.67, although in terms of prevalence, Djibouti has a higher rate. The lowest incidence is found in Monaco at 2.22 followed by Iceland at 2.69. Prevalence is lowest in both of these countries also. These findings are not surprising since TB is a disease of poverty and per capita GDP is merely $1,323 in Djibouti and $5,893 in Swaziland compared to $32,590 in Iceland and $48,371 in Monaco (WHO 2006a).

Within the Americas there is also great diversity. The lowest prevalence and incidence rates are in Canada, Grenada, and the United States. The highest rates are found in Bolivia, Haiti, and Peru. The difference between the low and high prevalence countries is considerable. Prevalence in the U.S. in 2004 was 3.56 per 100,000

[2] The incidence of Multi-Drug Resistant (MDR) TB is increasing. Inconsistency or noncompliance with treatment in addition to the use of inappropriate drugs to treat the disease are the primary reasons for the development of MDR TB. Once a person has developed MDR TB, that strain of the disease is passed on to others (The Global Fund 2005a).

while the rate in Haiti was 386.53 – 108 times higher than the U.S. rate. Even what would seem a comparatively modest rate, like Mexico”s 43.25, is still twelve times higher than the U.S. rate and represents a considerable prevalence gap between the two countries.

Tuberculosis in the U.S.

TB mortality, incidence, and prevalence are lowest in the Americas. While there is much variation within the region, the United States has the lowest incidence and prevalence rate. As discussed previously, it is also true that North America also has the highest net migration. Because the U.S. represents a low prevalence region with high migration, subsequent discussion and analyses will focus on the U.S.

While incidence and prevalence rates in the U.S. are already among the lowest globally, they continue to decline. Between 1953 and 2005 the TB case rate[3] decreased from 52.6 to 4.8. This steady decline in rates over time has been coupled with a change in the proportion of TB cases that are attributable to foreign born persons. This shift first occurred in 2001 and has been increasingly steadily since that time. In 2005, 55 percent of TB cases occurred among foreign born persons residing in the U.S. Concomitant with the change in proportion of cases attributable to the foreign born there is a prevalence gap between the native born and the foreign born population. In 2005, the case rate for native born persons was 2.5 and for foreign born was 21.9.

Over 70 percent of cases in the foreign born population in 2005 are attributable to just three regions of origin – Southeast Asia (10%), Western Pacific (21%), and the Americas (41%). Within these regions, over 50 percent of cases originated with persons from Mexico, the Philippines, Vietnam, India, and China (CDC 2006d). An issue of increasing concern is the proportion of persons who have been diagnosed with multidrug-resistant tuberculosis (MDR TB).[4] While the proportion of TB patients with this form of disease has declined since 1993, the proportion attributable to the foreign born population has increased. Eighty percent of MDR TB in 2005 was attributable to foreign born patients (CDC 2006a). Mexico, the Philippines and Vietnam were the countries of origin for the majority of these cases (CDC 2006b). The Philippines and Vietnam represent countries with a high prevalence of TB disease. While the prevalence of TB in Mexico is negligible in comparison to the rates for these other two countries, it is still ten times the rate for the U.S.

Also noteworthy is that the majority of foreign born patients diagnosed with TB have been in the U.S. five or more years. There are exceptions particularly for migrants from the Americas region. For these areas, the majority of TB cases are diagnosed within four years. Latent TB occurs when a person has been exposed to TB

[3] According to the CDC (2006a: 134), a TB case is “an episode of TB disease in a person meeting the laboratory or clinical criteria for TB.” TB is a nationally notifiable infectious disease.

[4] MDR TB is defined as resistance to at least isoniazid and rifampin, the front-line drug therapies for TB.

and tests positive on tuberculin skin tests but has not developed active TB and is not contagious. It is possible that these persons entered the U.S. with latent TB, however, the risk of developing active TB is highest in the first two years following exposure and only 10 percent of those exposed will ever develop active disease although the Centers for Disease Control and Prevention (CDC) recommends treating latent TB to prevent the active disease from developing.

The widening gap in TB prevalence between native born and foreign born populations may be evidence of changing migration patterns in the U.S. It is possible that this is a result of migrants bridging prevalence gaps as discussed earlier. If so, it would be reflected in changing immigration patterns in the U.S. Whether global migration changes are mirrored in the U.S. experience will be explored in the next section.

Migration in the U.S.

Following a substantial peak in the 1990s, immigration levels in the U.S. have been quite variable. There was a substantial drop in 2003 probably in response to events of September 2001, but immigration has increased steadily since then to levels not seen since the late 1980s and early 1990s. In 2005, over one million persons became legal permanent residents of the U.S. (United States Department of Homeland Security 2006).

Movement within the Americas[5] region has always contributed significantly to U.S. immigration flows. Since the 1960s it has contributed the largest proportion of legal immigrants to the U.S.

Europe, historically, contributed substantially to the immigration flow to the U.S. and was the primary source of immigrants to the U.S. However, immigration from Europe began to decline in the 1970s, and today Europe is the third largest source of migrants. Immigration from Asia, however, has increased substantially since the 1960s, and Asia is the second largest source of migrants to the U.S. today. While migrants from Africa do not constitute a large proportion of U.S. immigrants, the flow from there is increasing over time. As discussed previously, Africa and Asia account for a substantial portion of the TB burden globally and, perhaps not coincidentally, the majority of asylees and refugees. The processes of migration to find asylum as well as the living conditions in refugee camps create ideal conditions for the spread of infectious and communicable diseases.

Migrants from the Asian region are primarily coming from China, India, and the Philippines – all high burden TB countries and all on the WHO list of 22 countries targeted for intervention. Egypt has remained the primary country of origin for migrants from the African region since the 1960s. However, African migration from Ethiopia, Liberia, and Morocco has increased substantially since 1960 because of

[5] The Americas region includes the following countries: Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, Guatemala, Mexico, Nicaragua, Paraguay, Peru, Puerto Rico, Suriname, Trinidad, United States of America, Uruguay, and Venezuela.

extreme poverty, civil war, and massive refugee movements. Among these countries, only Ethiopia is considered by WHO to be a high burden TB area.

Finally, within the Americas, immigration has not increased, but the proportion of immigration from certain regions of the Americas has shifted. In the 1960s, immigration from Canada and Newfoundland was 25 percent of immigration to the U.S. In 2005, it was less than seven percent. In contrast, immigration from Mexico has risen from 26 percent of all immigration to the U.S. in the 1960s to 36 percent in 2005. The proportion of immigration from Central America has doubled from six percent to 12 percent, while the proportion of immigrants from South America has risen from 15 to 23 percent. The countries representing the major legal flows within these regions all have substantial TB prevalence gaps with the U.S.

Undocumented Migration

Passel (2005) estimates the undocumented population size at 11 million as of March 2005. Mexicans comprise the largest proportion (57%) of the undocumented population. An additional 24 percent of the illegal flow originates in other Latin American countries while nine percent are from Asia and six percent from Europe and Canada. As observed previously, there is a substantial prevalence gap between most of Latin America and Asia compared to the U.S.

Health Screening

With legal immigration, migrants are required to go through a screening process prior to entry. This medical screening includes past medical history, a physical examination, chest radiography (x-ray), lab tests, and vaccination screening to ensure potential entrants are up to date on U.S. recommended vaccinations (CDC 2006a). These examinations are conducted in the country of origin by physicians approved by the U.S. Citizenship and Immigration Service. A chest X-ray is required of all persons 15 and older and the physician is to indicate to the USCIS whether the TB disease state is assessed as active or inactive. Tuberculosis is considered a communicable disease of public health significance that would constitute medical grounds for inadmissibility although a waiver can be requested. Maloney et al. (2006) noted that overseas screening is not very effective in detecting tuberculosis.[6] MacPherson and Gushulak (2006) note that chest x-rays are not effective in detecting latent TB, which is a common condition in many migrant groups. Further, they suggest that it is a reactivation of prior TB infection that occurs in most cases of TB in the foreign born. While screening may identify some cases of TB in legal immigrants, undocu-

[6] Nearly two-thirds of those cases examined were not diagnosed nor given treatment prior to entry to the U.S. They were instead recommended for follow-up in the U.S.

mented immigrants are not screened at all, and the conditions under which they live and migrate often facilitate the transmission of TB.

To summarize, immigration is increasing world-wide though the nature of this immigration has changed over time. Europe once dominated global migration flows, but Asia is now the primary source region for migrants. Twenty percent of migrant flows are estimated to be illegal and these flows probably contribute substantially to the TB burden worldwide, but we have no way of measuring the impact of this with the data currently available. Migration today is also more temporary, related to the economic motive for the migration and the ease and relatively low cost of transportation. TB is increasing worldwide, and certain regions of the world share a disproportionate TB burden (particularly Africa, Southeast Asia, and the Eastern Mediterranean regions). The implication for the U.S. is that increased immigration and the shifting origins of immigrants has resulted in an increasing prevalence gap between the foreign born and native born, particularly with regard to multidrug-resistant TB.

Theoretical Framework

With the prevalence gap between the foreign born and native born increasing, it is clear that mitigating the TB threat in the foreign born population is critical. One element of disease control programs is screening for disease among those most at risk. Screening presumes populations at risk are able to access such programs and that they will access such programs if they believe they are at risk for the disease.

The Health Belief Model is a theory that was developed to explain lack of participation in a tuberculosis screening program. It has since been modified for use in other screening programs. The Health Belief Model examines the factors predisposing persons to take a particular health action. Glanz et al. (1997: 13) note that action results from perceived susceptibility, severity, benefits, and barriers as well as cues to action and self-efficacy. Persons will take action to protect their health, if they believe that the risk for contracting TB is high and that TB has serious health consequences. Additionally, an individual must believe that the benefits of the actions outweigh the costs. Finally, individuals must perceive no barriers to a course of action.

This analysis will focus on risk perception – the idea that those who believe they are at risk will act to protect themselves. Research has found that mortality risks vary considerably by ethnic origin (Stirbu et al. 2006, Singh and Siahpush 2001). Singh and Siahpush (2001, 2002) found that immigrants were healthier than their native counterparts and had lower mortality rates for most chronic conditions. The term “healthy immigrant” effect is used to describe this phenomenon. However, others (Stirbu et al. 2006, DesMeules et al. 2004, 2005) found the risk for mortality from infectious disease was higher for immigrant groups compared to native populations.

This healthy immigrant effect diminishes over time so that the mortality and morbidity experience of foreign and native born begin to converge (Singh and Hiatt 2006, Antecol and Bedard 2006, Grantmakers in Health 2005). This process has been attributed to acculturation and the uptake by immigrants of the unhealthy behaviors of native-born populations such as smoking and drinking. While most research has focused on the negative consequences of acculturation, there is evidence, however, that acculturation is associated with some healthy behaviors (Abraido-Lanza et al. 2006) indicating that immigrants may be choosing to adopt some attitudes and beliefs and not others.

It is often the case that immigrants face tremendous barriers to acting to protect their health. Portero-Navio et al. (2002) found that low income was a barrier to care-seeking behavior in Filipino patients so they often relied on native healers and herbal medicines. This is true for immigrants in general and particularly true of undocumented immigrants as these groups are more likely to lack regular medical care and preventive care (Rodriguez et al. 2005, Berk et al. 2000, Leclere et al. 1994, Dey and Lucas 2006, Ku and Waidmann 2003). Although there is evidence to suggest that differences with native-born populations in physician contacts diminished over time. For instance, Leclere et al. (1994) found differences in physician contacts between native and foreign born disappeared after ten years or more in the destination country.

The lack of physician contact is probably due to both the lower incomes and lower rates of health insurance coverage among the foreign born population compared to the native born population (Lucas 2005, Dey and Lucas 2006, Ku and Waidmann 2003, Grantmakers in Health 2005). Despite the fact the employment rates are very high for the foreign-born, they are more likely to work in businesses that do not offer health insurance or do so at a price that makes the benefit unaffordable. Further, the foreign born in most cases are not eligible for government insurance programs for a period of time following arrival in this country. Lucas (2005) found that immigrant pay is generally lower than the pay for native born populations even when controlling for occupation. This disadvantage usually dissipates within ten years. Lower income is generally thought to be associated with a higher perception of risk (Public Health Agency of Canada 2003).

Differences in the social roles of men and women may also impact perceptions of risk. It is often the case that the burden of caring for those who are ill with TB falls to women. The caretaker role increases the risk that a woman will develop the disease (Bates et al. 2004), which is why TB is the leading cause of death of women of reproductive age (The Global Fund 2005a). Women are then faced with the problem of being ill and being poor, which exacerbates an already tenuous living situation. Savage (1993) found that women rate their risk higher than men, but Hakes and Viscusi (2004) found that education intervenes in the relationship between sex and perception of risk with increasing education mitigating differences. Education provides access to information that allows individuals to better evaluate health risks. Given their higher risk of contracting and dying from TB coupled with the tendency of women to rate their risks higher than men, it is expected that women will perceive themselves at some risk for TB. However, observed differences between men and women should disappear when controlling for education.

As Gushulak and MacPherson (2006b) note, "migrants reflect the health characteristics of their place and environment of origin." The CDC (2000) indicates that immigrants who come from areas of the world with high TB rates have rates of TB infection similar to their countries of origin for several years following their arrival in the U.S. These rates decline over time and approach the rates of those born in the U.S. Thus, it is expected that immigrants who originate from areas with large TB prevalence gaps compared to the U.S., should rate their risks higher than native-born persons. However, acculturation should mediate this relationship with those who have been in the U.S. longer, leading to a lower perception of risk.

The Health Belief Model presupposes some existing knowledge of tuberculosis. Whether that knowledge is accurate impacts the decision process. A general lack of knowledge of the disease and its determinants has been found to be associated with higher perceptions of risk (Public Health Agency of Canada 2003, Khan et al. 2006). Thus, knowledge is expected to be inversely related to risk perception.

Access to care and treatment is impacted by income and insurance status. Since lower income is associated with higher perception of risk, it is expected that income will be negatively related to risk perception. Given the association between insurance and income, it is expected that insurance status will also be negatively associated with risk perception.

Savage (1993) found that race and age also influence risk perception. Black respondents rate their risk higher than non-blacks while younger people rated their risks higher than older people. In contrast, Murphy and others (2000) found that older people perceived themselves as more vulnerable despite higher levels of TB knowledge. Weinstein and Lyon (1999) indicate that, in general, people are more likely to underestimate their risk. Given the higher TB rates among minorities and the tendency of minorities to perceive higher risks, it is expected that minorities will be more likely than non-minorities to perceive some risk. With regard to age, TB cases are concentrated in the 25 to 64 year age interval although there is some increased risk in those over 65 due to institutionalization in long-term care facilities (CDC 1990). Given the conflicting research findings on risk perception, it is expected that perceptions will follow actual disease risk and increase with age.

Methods

The data used in this analysis come from the 2005 National Health Interview Survey. This survey is a multistage national probability sample of the non-institutionalized U.S. civilian population. The basic module of the survey is comprised of three components – family, adult, and child. The family component collects information on everyone in the household while the adult component selects one adult from each family to participate. In 2005, 38,509 households were surveyed yielding 98,649 persons in 39,284 families. The Sample Adult component of the survey sampled 31,428 persons 18 years of age and older. The Person dataset (all persons interviewed), the Sample Adult dataset and the Imputed Family Income/Personal Earnings dataset were merged for this analysis. The imputed family income/personal earnings dataset is a file imputing missing income data using multiple-imputation methodology. A weighting variable for the Adult Sample (WTFA_SA) was applied to the data to make the sample representative of the U.S. population. Logistic regression with SAS statistical software was used to analyze perception of risk for contracting tuberculosis.

Dependent Variable

The dependent variable in the analysis is "Perception of Risk" in which respondents are asked, "What are your chances of getting TB?" Responses were dichotomized into categories of "no risk" and "some risk." The "no risk" category results from a response indicating the chance of getting TB was "none." The "some risk" category is a combination of either a "high," "medium," or "low" response to the question. The variable was dichotomized because the analysis is looking only at perception of some level of risk not the degree of risk. Dichotomizing responses results in a near even distribution in response categories (see Table 1).

Independent Variables

Combined family income. This variable measures total combined family income for all sources. "Don't Know" and "Refused" responses for the income variables were imputed by the National Center for Health Statistics (NCHS) using multiple-imputation methodology to address the high rate of non-response on these series of questions. Combined family income is a grouped variable with 11 categories that were recoded by selecting the midpoint of each interval as the value. The value for the last category was top coded using the value defined by NCHS ($75,000).

TB Knowledge. Respondents' knowledge of TB is measured on two criteria – knowledge of whether TB can be cured and knowledge that TB is transmitted by "breathing the air around person who is sick with TB." If a positive response was given to the question, "Can TB be cured?," the variable was coded 1. If the respondent did indicate "no" or "don't know," then the variable was coded 0. For the transmission variable, if respondents mentioned this transmission mode then the variable was coded 1. If not mentioned or if respondents indicated "don't know," then the variable was coded 0.

Sex. The variable is coded 1 if the respondent is a female.

Race/Ethnicity. The race and ethnicity variables derive from a NCHS recode of these variables. Respondents are classified into four categories – non-Hispanic white, Hispanic, non-Hispanic black, and non-Hispanic all other. Dummy variables were created for these categories. Non-Hispanic white respondents are the excluded category.

Health Insurance Status. Health insurance status was measured using the NOTCOV variable which measures whether a respondent has health insurance or does not. For this analysis this variable was recoded into INSURED with categories of 0 for those not covered by health insurance and 1 if covered by health insurance.

Region of Birth. NCHS recoded responses to country of birth questions into the REGIONBR variable which lists 11 regions. Those responses for unknown and elsewhere were set to missing for this analysis. Dummy variables were then created for the various regions. To facilitate comparisons with WHO data, some NCHS regions were combined. If region of birth was the United States, respondents were coded 1 on the NATIVE dummy variable. Respondents from Mexico, Central America, Caribbean Islands, and South America were combined into one dummy variable, LATAM. Responses for Europe and Russia were also combined into the EUROPE variable. The African Region remained a single category – AFRICA – as did the Middle Eastern region which became MIDEAST. India and Southeast Asia were combined into one category – SEASIA. Finally, Asian responses were coded ASIA. NATIVE is the excluded category in this analysis.

Education. Education responses derived from the NHIS variable EDUC1. Dummy variables were created for those not completing high school or an equivalency exam, high school graduate or equivalent, some college, and bachelor's degree or higher. The completion of high school is the excluded category in the analysis. The division of education into these categories is consistent with the risk perception literature.

Years in the U.S. This categorical variable measures the number of years that a respondent has been in the United States. It was only asked of those who were not born in the United States. For this analysis a new variable was created by combining category one (less than one year) and category two (1–5 years) then selecting the midpoint of the ranges in each of the categories. Bivariate analysis confirmed the missing cases (82,171) were attributable to those born in the U.S. Excluding these individuals from the analysis substantially decreased the observations available for analysis. To prevent the loss of observations, it was decided that for native-born individuals, a value equal to the individuals' age would be assigned for years in the U.S.

Age. This is an NCHS recoded variable (AGE_P) with values assigned from respondents' date of birth. Since the adult sample only included those aged 18 and over, observations for those less than 18 were excluded. The top category, 85, includes all of those aged 85 and over.

Results

Univariate analyses (Table 1) of the data reveal that the weighted demographic characteristics of the study population approximate the characteristics of the U.S. population in the 2005 American Community Survey (ACS). The foreign born population is more likely to be Hispanic and less likely to be non-Hispanic White compared to

Table 1 Descriptive statistics.

	Total 2005 NHIS	Total 2005 ACS	Foreign-born 2005 NHIS	Foreign-born 2005 ACS
Sex				
Male	48.2%	49.0%	51.3%	50.1%
Female	51.8%	51.0%	48.7%	49.9%
Race/Ethnicity				
Hispanic	12.8%	14.5%	53.8%	47.0%
Non-Hispanic White	71.3%	66.8%	20.1%	20.9%
Non-Hispanic Black	11.3%	11.9%	6.7%	---
Non-Hispanic Other	4.6%	6.8%	19.4%	---
Region of Birth				
United States	84.8%	87.6%	---	---
Asia	3.1%	3.3%	---	---
Africa	0.5%	0.4%	---	---
Europe	1.9%	1.7%	---	---
Middle East	0.4%	Included in Asia	---	---
Latin America and Caribbean	8.9%	6.9%	---	---
Education				
Less than High School	16.3%	15.8%	35.7%	32.4%
High School or GED	29.7%	29.6%	22.9%	22.8%
Some College	28.3%	27.5%	18.0%	18.1%
Bachelors Degree or Higher	25.8%	27.2%	23.4%	26.7%
Median Family Income	$50,000	$55,832	$40,000	---
Median Age	44.0	36.4	40.0	39.3
Median Years in US	40.8	---	15.0	---
Health Insurance Status				
Without Insurance	16.6%	---	33.6%	---
With Insurance	83.4%	---	66.4%	---
Perception of TB Risk				
No Risk	51.2%	---	59.2%	---
Some Risk	48.8%	---	40.8%	---
Knowledge of TB Transmission				
TB not spread through air	31.1%	---	28.6%	---
TB spread through air	68.9%	---	71.4%	---
TB can be cured				
No	51.9%	---	37.9%	---
Yes	48.1%	---	62.1%	---

Table 2 Parameter and odds ratio estimates.

Parameter	Odds Ratio	95% Wald CI Odds Ratio	Probability
INTERCEPT			
Knowledge of TB transmission	1.734	1.733, 1.736	0.63
TB can be cured	0.909	0.908, 0.909	0.48
FEMALE	0.854	0.853, 0.854	0.46
HISPANIC	0.630	0.629, 0.631	0.39
BLACK	0.971	0.970, 0.972	0.49
OTHER	0.807	0.805, 0.810	0.45
Latin American origin	0.961	0.958, 0.964	0.49
European origin	0.792	0.789, 0.795	0.44
African origin	0.810	0.806, 0.815	0.45
Middle Eastern origin	0.364	0.362, 0.367	0.27
Southeast Asian origin	0.617	0.615, 0.620	0.38
Asian origin	1.334	1.326, 1.342	0.57
Years in US	1.001	1.001, 1.001	0.50
Less than high school education	0.882	0.881, 0.883	0.47
Some college	1.079	1.078, 1.080	0.52
Bachelors degree or higher	1.495	1.494, 1.497	0.60
Combined family income	1.000	1.000, 1.000	0.50
Health Insurance	1.021	1.020, 1.022	0.51
Age in years	0.982	0.982, 0.982	0.50

* $p < 0.0001$

the 2005 NHIS or 2005 ACS population. Further, the foreign born population according to the ACS is more likely to be male and have less than high school education compared to total 2005 NHIS population. The median family income is lower and the median age is slightly lower for the foreign born respondents in the NHIS sample. Finally, the foreign born are less likely to have health insurance and more likely to perceive no TB risk.

Results of the logistic regression procedure are contained in Table 2. The value for Tau-a can be used to estimate the generalized R-square (Allison 1999). Its value of 0.143 indicates approximately 14.3 percent of the variation in perceived risk can be attributed to the variables in this model. The Chi-Square values testing the global null hypothesis are all statistically significant, indicating that at least one of the coefficients is not equal to zero. Tests of multicollinearity show the variance inflation factors all are within the acceptable range.

All of the model parameters are statistically significant. Knowing how TB is transmitted strongly predicted perception of some TB risk. Being of Asian origin, having at least some college education, being covered by health insurance, increasing years in the U.S., and increasing family income, all increase the odds of perceiving some TB risk. The relationships for family income, insurance status, and years in the U.S. are rather weak based on the odds ratios.

Increasing age decreases perception of risk although this relationship, too, is weak. All areas of origin other than Asia increase the odds of perceiving no risk relative to the native-born. This relationship is strongest for respondents of Middle Eastern and Southeast Asian origin. All racial/ethnic groups have decreased odds relative to non-Hispanic white respondents of perceiving TB risk. This is particularly true for Hispanics. Being female decreased the odds of perceiving risk relative to men though the relationship is rather weak. Knowing TB could be cured negligibly decreased the odds of perceiving risk. With regard to age, increasing age decreases the odds of perceiving risk.

In summary, while all variables in the analysis were statistically significant some of the relationships were weak, indicating that they may not be substantively important. The strongest predictors of perception of risk were TB knowledge, Hispanic, Middle Eastern, or Southeast Asian origin, and education.

Discussion

The results of the analysis are, for the most part, very different from what was predicted. With regard to areas of origin, it was thought that people from areas with higher rates of TB would perceive some risk of TB compared to those who were U.S. natives. Instead, people from areas outside of the U.S. tend to rate their risks lower relative to U.S. natives. The difference between U.S. natives and others is particularly strong if the area of origin is Southeast Asia or the Middle East. The Southeast Asia region does have the second highest prevalence rate. The Middle East has a prevalence rate four times higher than the Americas region but is still among the areas with the lowest rates. And those originating from Asia are the only group more likely than U.S.-natives to perceive some level of risk. Years in the U.S. may mediate this relationship but the effect of time in the U.S. appears to be negligible. This finding may be due in part to the fact that few survey participants (12%) have been in the U.S. five years or less. The majority of the sample has lived in the country 15 years or more. Additionally, immigrant type is probably very important in explaining some of these differences, but the data are not available to test whether type of immigrant is an important predictor.

It was hypothesized that increasing income and education would decrease the odds of perception of risk. Instead increasing income and education raise the odds slightly of perceiving some risk. The same is true of insurance status. Having insurance increases the odds of perceiving risk, contrary to what was projected. The results for insurance though are probably influenced by the number of missing observations (approximately 10 percent or 931 unweighted observations are missing). Among these variables, education seems to have the most impact, though the direction of the relationship with perception of risk is contrary to what was expected.

Women were thought to perceive their risk of TB to be higher relative to men. What was actually found was that women have a lower probability of perceiving risk relative to men. With regard to race and ethnicity differences, it was thought that the odds for minorities would be higher relative to non-Hispanic whites. However, the probability of perceiving some risk is lower for minorities relative to non-Hispanic whites, particularly for Hispanics. It was also hypothesized that increasing age would increase the probability of perceiving risk, but it was found that increasing age actually decreased the probability of perceived risk. Savage (1993) notes that as individuals age they become better informed, so it may be that older participants believe they are less exposed to risk because they have more information available to assess risk.

Finally, knowledge was thought to be negatively related to risk. The logistic regression results indicate that knowledge of transmission mode increased the probability of perceiving some risk relative to those without knowledge. Knowledge that TB could be cured had a negligible but opposite effect. Knowledge of transmission does appear to be a key variable in the analysis, however.

For many of these relationships, education may be intervening. As Hakes and Viscusi (2004) note, education alleviates all differences in perception by sex as well as by race and ethnicity. Bivariate analysis of the relationships between education and race/ethnicity and region of origin indicate education is lowest for Hispanics and those from Latin America. Both education and Latin American origin have a lower probability of perceiving risk relative to non-Hispanic white respondents and native born respondents. Education is highest for those from Southeast Asia. In general, however, mean educational levels indicate most respondents have at least a high school education.

This dataset may not be as representative of the immigrant population as was needed for this analysis and thus may not have been the best choice for this analysis. Additional variables on housing arrangements and neighborhood characteristics would have been helpful as immigrants are more likely to reside in low income neighborhoods in urban and inner city areas in overcrowded housing (Singh and Hiatt 2006, Grantmakers in Health 2005, Dey and Lucas 2006). All of these characteristics increase the risk of tuberculosis transmission and might have had more of an impact on perceptions of risk (Bates et al. 2004). Additionally, it may be that immigrant type is an important consideration. For instance those who arrive as students may differ from those who are given family visas. Finally, the inclusion of interaction terms might have helped explain some of the observed relationships more fully.

The issue is that the prevalence gap between the foreign born and the native born is increasing in the U.S. It is also true that immigration is increasing from areas where TB prevalence is high and where there is greater risk of both exposure and infection. Screening is an important component of any disease control program. As the Health Belief Model asserts, however, before people will take action (i.e., participate in a screening program), they must first believe they are at some risk for contracting the disease. It is apparent from this analysis that those who appear most at risk for TB are not the ones who perceive they are at risk. In contrast, those who are least at risk perceive a higher risk of contracting TB. Weinstein and Lyon (1999) note that underestimating the risk of a low probability event will seldom have consequences. In most cases this may be true, but with the prevalence gap increasing, it behooves us to take action that mitigates the small risk from becoming a much larger one.

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Chapter 12
Causes of Fire Deaths and Injuries in Anchorage, Alaska: Policy Implications

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Introduction

Fatal and nonfatal injuries are major public health problems for Americans (Vyrostek et al. 2004). Fatal injuries have received more attention than nonfatal injuries, most likely due to the greater accessibility of mortality data (Runyan et al. 2005). However, deaths constitute only a small proportion of injury incidence overall (Runyan et al. 2005). For example, in 2001 there were about 157,078 fatal injuries in the United States and nearly 30 million estimated nonfatal injuries (Vyrostek et al. 2004). That year, unintentional injuries or accidents ranked as the fifth leading cause of death nationally, with the highest rates in New Mexico, Wyoming, Mississippi, and Alaska (Anderson et al. 2004).

In 2005 there were 21,600 civilian fire injuries (fatal and nonfatal) in the U.S. (Karter 2006), and they were not distributed evenly across states. Alaska, as well as Mississippi, South Carolina, Alabama, Arkansas, Tennessee, and Louisiana, have had relatively high death and injury rates from fires over time, disproportionately occurring among vulnerable sectors of the population (Hall 2006). Alaska had the sixth highest average fire death rate by state from 1998 to 2002 (Hall 2006). Although progress has been made in recent years on child fire fatalities (Powell 2004), Alaska's fire death rates have been consistently high (Hall 2006). Little has been written specifically on fire injuries in Alaska outside of publications of fire departments and fire protection agencies and epidemiological literature from Alaska (see, e.g., Moore and Murphy 2001).

This paper reports on a study of civilian deaths and nonfatal injuries in structural fires in Anchorage 1999 to 2005. "Structural" refers mainly to residential structures but can include educational, health care, and industrial structures as well (Powell 2004). The majority of civilian fire deaths and injuries in Alaska occur in residential structures (Powell 2004), as is the trend nationally (Karter 2006). The fire injuries include both unintentional injuries, as when a person suffers severe exposure to flames or smoke inhalation due to a fire that starts by accident, as well as intentional

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injuries, which are deliberately inflicted, for example, by arson. After a discussion of the background, methods and findings of the study, the prevention and policy implications are addressed.

Background

Alaska has a small population relative to its geographic size, and almost one-half or 260,283 persons live in Anchorage (U.S. Census Bureau 2000). The Anchorage Municipality encompasses nearly 2,000 square miles, much of which is wilderness (Freedman 2000). Due in part to the long winters, and sometimes bitterly cold temperatures, in-migration selects for young adults and risk-takers (Moore and Murphy 2001, Gallagher 1994), a form of the "healthy migrant" effect in which persons who are in good health selectively migrate (Markides and Eschbach 2005). There have also been increases in internal migration from rural Alaska to Anchorage recently, especially by Native Alaskans, leading to a population that is mainly in the adult years with small percentages of children and the elderly (U.S. Census Bureau 2006). The result is that the Anchorage population is heavily concentrated in one of the age groups most at risk of fire injuries – young and middle-aged adults (Hall 2001).

An interesting question is whether the cultural background of Anchorage residents may play a role in fire injuries. Although Anchorage is Alaska's largest city, its remote northern setting and unique geography lead its residents to identify with the "frontier" image of the wilderness just beyond its settled area (Partnow 1999). Residents of Anchorage feel that "… Alaska represents something truly different" from the rest of the United States, which is referred to as "Outside" or "the lower 48" (Kollin 2001: 47). The self-reliance and "pioneer spirit" in Alaskan culture can affect fire injuries in at least two ways. First, in an environment in which climate and forces of nature can be issues of life or death, helping and rescuing others is essential and highly valued. During a residential fire, if the fire department has not yet arrived, neighbors and even passers-by may help rescue victims or save a house from damage, sometimes getting injured in the process (Aurand 2005).

On the other hand, the Alaskan code of "rugged individualism" (Kollin 2001: 117) may result in persons ignoring rules and regulations concerning fire prevention. According to Irvin Rothrock, a Fairbanks psychiatrist quoted by Gallagher (1994: 165), "There is no doubt that Alaska draws a risk-taking personality who likes the idea of being able to do pretty much what he wants, with minimal interference from others, including the government." This risk-taking can be manifested in the violation of building codes, which may increase the risk of fire and fire injuries (Brant 2004).

As in other northern frontiers, migrants to Alaska usually leave their extended families behind, so that friends often replace family (Leipert and Reutter 2005). Alaskans depend on social networks of friends, especially in emergencies. Like many American cities, Anchorage is experiencing increased migration from other countries (Singer 2004). Persons who do not speak English fluently may be at increased risk of fire injury both through difficulty in reading safety instructions on equipment and not comprehending public health warnings in English over the mass media (Shai 2006). Minority populations in the high North who do not speak English adequately may find themselves socially isolated from support networks among the general population, especially if they are unemployed and have difficulty in getting around during the winter (Choudhry 2001). They may lack sufficient social support for recovery in the event of a fire, relying on public agencies such as the Red Cross and donations from strangers.

Methods

The data acquired from the Anchorage Fire Department were comprised of 161 fatal and nonfatal structural fire injuries to civilians, including date of injury, severity of injury, census tract, cause of ignition, and heat source for the years 1999–2005. The injuries had been coded according to the Alaska version of the National Fire Incident Reporting System 5.0 (ANFIRS) (U.S. Fire Administration 2006). All Anchorage Municipality census tracts were included with the exception of two relatively remote areas that have volunteer fire departments and do not report to the Anchorage Fire Department: Chugiak (tract 1.02) and Girdwood (tract 29). Descriptions of three cases of fire injuries occurring in methamphetamine labs were obtained from the Anchorage Police Department.

In addition, the on-line news archives of the *Anchorage Daily News*, the largest daily newspaper in Anchorage, and the on-line Lexis Nexus (Academic) news search were used to retrieve matching articles in order to provide more information concerning the circumstances of the fire injury and which factors needed to be addressed in prevention policies. The keywords *fire* and *blaze* were used, and articles were matched by date, injury, cause, heat source, and census tract.

Results

Of the 161 structural fire injuries to the civilian population between 1999 and 2005 listed by the Anchorage Fire Department, 17 were fatal and 144 were nonfatal. It is likely that there is an undercount as is usual in fire injury statistics (Karter 2006). In Alaska, due to the lack of a major burn center, a seriously burned person is flown out of state, for example, to Harborview Medical Center in Seattle. In the event that the patient dies there, the death certificate should be returned to Alaska. If it is not, that death may not appear in Alaska vital statistics or the Anchorage Fire Department database. In the case of nonfatal fire injuries, some may never be reported to the Fire Department, particularly if the fire is small and the injuries are minor. A fire department may not be called to such a fire, and if it is, the department may be

Table 1 Fire injury rates per 1000 and socioeconomic characteristics. Anchorage Municipality and tracts at high risk of fire injuries (5 and 6).

Socioeconomic Characteristic	Anchorage	Tract 5	Tract 6
Fire injury rate per 1000 (1999–2005)	00.6	02.6	03.4
Percent of persons with less than 9 years of education	03.1%	06.7%	09.4%
Percent of foreign-born persons	08.2%	19.7%	14.7%
Percent of foreign-born who were born in Asia	49.5%	66.1%	48.2%
Median household income	$55,546	$30,825	$30,725
Occupants per room (1.51 or more)	02.4%	06.1%	09.4%

Source: U.S. Census Bureau, 2000 Census (SF3).

unaware of injured persons who were not transported to medical facilities (Karter 2006). In other cases, the injured may refuse treatment. In the case of fires involving illegal activities, injured persons may flee when law enforcement arrives. Examples are the homeless who start fires for warmth on construction sites and persons involved in meth lab fires. Sometimes persons involved in illegal activities will go to a hospital emergency room stating that they were burned on a camp stove or other heat sources. In that case they may show up on emergency room records but not in the Fire Department database.

Sixty of the database injuries could be linked to a newspaper account. In addition, five injuries were described in the news archives that were not listed in the database. There are several reasons why not all cases could be linked with a news item. Not every fire injury event is published. The factors might be the number of newsworthy items and space available on a particular day, how extensive the fire was, how serious the injuries, and the age of the victim(s). Even a published item may not appear in the archives or Lexis Nexus.

Two adjacent census tracts which border the downtown area to the northeast and northwest, tract 5 (Government Hill) and tract 6 (Mountain View), had the highest fire injury rates per 1000 (2.6 and 3.4, respectively). Their median household incomes were among the lowest in Anchorage (U.S. Census Bureau 2000). The two targeted areas also had the highest percentages of persons with a low proficiency in English. The most common foreign languages spoken at home were Korean in Tract 5 and Laotian in Tract 6. Both tracts had large percentages of persons with low education and relatively high percentages of crowdedness (occupants per room) compared to Anchorage as a whole (see Table 1).

Causes

An analysis of the 134 fire injury cases where the heat source was determined shows that powered equipment is the leading cause of fire injury (see Table 2). Powered

Table 2 Identified heat source in fire injuries (fatal and nonfatal), Anchorage, Alaska, 1999–2005 ($N = 161$).*

	N	Percentage
Powered equipment	30	22.4
Cigarettes/smoking mat.	16	11.9
Radiated heat	12	9.0
Open fire and flame	11	8.2
Lighters and matches	10	7.5
Improperly used equipment	9	6.7
Candles	9	6.7
Multiple ignition	7	5.2
Arcing	6	4.5
Hot ember/ash	5	3.7
All others	19	14.2
Undetermined	(27)	

*Includes 27 injuries from undetermined heat sources.

equipment includes, among other sources, appliances, electronics, wood burning stoves, furnaces, space heaters, and water heaters. Cigarettes/smoking materials are the second leading cause. Heat radiated to a combustible material or surface, as in a space heater placed too close to bedding, was the third (see Table 2).

Alaska has experienced an increased methamphetamine trade in recent years (Demer 2005). While meth labs are found mainly in rural areas of Alaska, a number have been discovered in Anchorage, often in trailers and recreation vehicles when explosions and fires occur (*Anchorage Daily News* 2004). According to the Anchorage Police Department, three operations came to light during the study period that resulted in burn victims being flown to Seattle's Harborview Medical Center. Three additional methamphetamine-related fires were reported in the *Anchorage Daily News* during the study period with no apparent injuries. However, since suspects fled the scene when police or firemen arrived, there are possibilities of unreported fire injuries in these fire events.

Policy Implications

Preventing Injuries

Providing smoke alarms in buildings, particularly residences, is the first and most important step in reducing fire injuries. In many of the cases, a working smoke alarm would have given the occupants time to leave the structure before being overcome by smoke inhalation or suffering cuts and fractures in jumping to escape flames. While the Anchorage Fire Department already offers a free safety inspection of a home by a fire inspector and distributes photoelectric smoke detectors, additional efforts could concentrate on tracts 5 and 6 (Government Hill and Mountain View), which have the highest fire injury rates. Research has shown that the direct installation of smoke alarms is more effective than vouchers (Harvey et al. 2004), and that as smoke alarms are installed, the cost per alarm decreases (Parmer et al. 2006).

Since many fires involving injuries occurred in high-density housing such as hotels, apartments, and multiplexes, sprinkler system installation by landlords needs to be mandatory and enforced. Kay and Baker (2000) argue that automatic fire sprinkler systems are extremely valuable in preventing fire injuries and deaths, even more than smoke detectors alone. Smoke detectors work well for people who can quickly evacuate a building, but may not be enough for "children, the elderly, the disabled, [and] the intoxicated" who cannot escape quickly on their own (Kay and Baker 2000: 72). Fire sprinklers have been shown to greatly reduce fire deaths and injuries by extinguishing the fire quickly after onset, preventing the build-up of toxic smoke, increasing visibility, and doing less damage than water from fire hoses (Kay and Baker 2000). Some jurisdictions in the United States have mandated sprinkler installation in all new single family and multifamily housing (Kay and Baker 2000: 73). Sprinkler systems could be especially helpful in Anchorage multiplexes and housing in some remote locations. A number of multiple apartment dwellings have experienced more than one fire. Those in high-risk locations could be retrofitted with automatic sprinkler systems prior to reopening. Insurance companies in Anchorage should be urged to offer free home inspections in high-risk neighborhoods, offering residents the benefit of reduced rates for homes which include fire extinguishers, smoke alarms, sprinkler systems, and security systems linked to the fire department and police.

As the most important cause of fire deaths and injuries was powered equipment (see Table 2), directions and warnings on equipment need to be clear and, if at all possible, remain with the item as it changes hands, since some equipment may stay in a residence when it is sold. Persons who have difficulty reading and understanding English need safety information in their native languages, such as Korean and Laotian. Local immigrant organizations, literacy projects, and school district programs can be helpful (O'Malley 2006, Pesznecker 2005). Other possibilities include having fire safety articles in community newsletters and/or distributing a calendar in native languages with fire safety messages.

The second most important cause of fire injuries was the careless handling of cigarettes and smoking materials, sometimes aggravated by alcohol consumption. Anchorage is already carrying out an aggressive anti-smoking campaign which could do a great deal to reduce fires and fire injuries, not only through the danger of carelessly discarded cigarettes but also the accompanying lighters and matches in the home. For those who smoke, safe practices should be promoted.

Flammable material placed too close to a heat source, such as a space heater or water heater, was an important cause of fire injury. A campaign in the high-risk areas could work through local leaders and organizations with the goals of warning residents about keeping a free area around heat sources and offering safe solutions for organizing belongings or storing working materials. A home improvement store could provide workshops on organizing materials safely inside and outside the home. While clutter alone will not cause a fire unless it comes close to a heat source, it can add fuel to a house fire and impede firefighters trying to extinguish a blaze. Projects could include eliminating clutter through inexpensive remedies such as shelving, storage cubicles, and milk crates. Low-cost organizers for belongings should be for sale at the demonstration. A fire department representative could be present to comment on safety aspects. Promotional discounts on products could be an incentive for people to come to the workshops. A special demonstration for persons living in trailers could emphasize the dangers of using heat sources other than those that are built into the trailer, as well as the importance of a smoke detector. Similar demonstrations could be featured in local news programs.

Preventing Fires

Children are an important target for outreach, both to save lives and teach fire safety. Families should have an escape plan, which includes responsibility for pets. If roll-up ladders for windows are purchased, household members should all try them out before an emergency. These ideas could be communicated to the Anchorage population through the use of the Alaskan mascot, the Safety Bear.

Messages about safe fire behavior by newspaper, radio, and television news programs should be maximized. Having the fire marshal, fire chief, or fire inspector speaking in these segments would greatly strengthen the message. In presenting cases of fires as news, warnings to the public can be illustrated with films on how fast a fire can flare up, available from the National Fire Academy. Seasonal announcements, now made in the newspaper, could also be made over the radio and television. During fishing season, warnings can be given about the safe use of fish smokers. In summer, the use of citronella candles and the safe barbecue can be emphasized. In autumn, announcements can be made about the importance of having chimneys, furnaces, and space heaters cleaned and inspected before heat is turned on. Finally, in winter, firemen can discuss how to thaw frozen pipes safely, the care of Christmas trees, and precautions with candles and holiday lights. All of the above caused fires during the study period.

Public safety messages should be integrated into the health system with articles on fire safety available in physician's offices, clinics, and emergency rooms. Given the number of pets that perish or are injured in Anchorage fires, as well as the importance of animals in Alaskan life, additional materials should be made available for distribution at veterinary offices and the Humane Society adoption centers.

As mentioned earlier, methamphetamine labs are less likely to be found in Anchorage than in rural Alaska. The greater number of law enforcement officers in the city and the greater density of population make it harder to hide illegal activities. Within Anchorage, trailers and recreational vehicles appear to be the most usual site of meth labs. Prevention of meth-lab fires needs to include trailer camps.

Conclusion

Few demographers have concentrated on mortality and morbidity by fire, but such studies can be helpful by placing the injuries within the larger contexts of population, age structure, gender, immigration, and culture. In the case of fire injuries in Anchorage, the worldview that proves useful in a frontier: self-reliance, tolerance for risk, mutuality, and a desire for privacy and independence, may contribute to behavior that is also potentially dangerous, including trying to fight the fire using fire extinguishers and garden hoses before calling the fire department and building in ways that violate fire codes. This worldview can also be isolating for newcomers from foreign countries, who may have few resources and not be well-integrated into the available social networks. In such cases, the newcomers may have difficulty communicating with others in a fire disaster and experience longer recovery periods following the event. Interesting areas to explore further would be cultural differences in fire safety behavior and the possibilities for tension between frontier self-reliance and dependence on others in fire events.

While Anchorage has many aspects that are unique in the United States, including climate and culture, there may be similarities with other cities with high rates of fire mortality and morbidity, such as areas of relative poverty, smoking and alcohol consumption, the use of space heaters, and non-English speaking immigrants. The suggestions in prevention policy made here, therefore, may be applicable to cities in other parts of the United States with high rates of fire deaths and injuries.

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Chapter 13
Dispersion of Registered Death Causes as a Function of Age in the 1999 U.S. Population

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Introduction

It is a common proposition in gerontology that variation increases with increasing age. Examples are from many areas of investigations, such as physical performance. At 7 years of age almost all children can get out of their beds but none compete in marathon races while at 80 years of age there are some who are tied to their beds and some who compete in marathon races. Contrary to a possible phenomenon of increasing variation with higher age is the attitude towards the elderly. Attitudes consist of stereotyped concepts, emotions and behavioral dispositions. If the phenomenon captured by a stereotyped concept shows increasing variation with increasing age, then the stereotype will fit less well with increasing age. When this stereotyped concept constitutes one of the three components of an attitude towards the aged, there is a risk of discrimination against the aged in a society. This tendency has been labeled ageism (Butler 1969). In this context it is important to investigate variation as a function of age in a society. My main interest here is to investigate how the variation of registered death causes varies with increasing age. Death causes are registered in categories. Variation among frequencies of categories is often called dispersion. I examine how the dispersion of death causes varies with increasing age in the United States population of 1999.

My initial hypothesis is that as a population grows older, its members' reserve capacities decrease and they become more vulnerable to many more, possibly fatal, risks. Thus I expect an increase in the dispersion of registered death causes with increasing age, with a possible exception of the highest ages where there are few deaths. Contrary to my hypothesis, it is also a possibility that the persons who reach the greatest ages have a constitution which makes them less vulnerable to minor risks and thus they die from more severe, and consequently more uniform, death causes (Smith 1997, Bordin et al. 1999, John and Koelmeyer 2001, Gessert et al. 2002). This possibility might give a decrease in the dispersion of death causes in the highest ages. Registered death cause is, however, the result of a judgment made

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by professionals and is thus influenced by their knowledge, expertise, interest, and carefulness, as well as of the administrative routines producing relevant documents. There is evidence that cause of death is not investigated as well for older persons as for younger persons (Lloyd-Jones et al. 1998, Leibovitz et al. 2001, Al-Shahi et al. 2003, Gosney, 2005) thus leading to a stereotyped reporting of death cause which might decrease dispersion. The general quality of information on death certificates is also problematic, and common to many countries (James and Bull 1996, Maudsley and Williams 1996, Jansson et al. 1997, Jougla et al. 1998, Myers and Farquhar 1998, Smith et al. 1998, Ermenc 2000, Lu et al. 2000, Lahti and Penttila 2001, Johansson and Westerling 2002, Swift and West 2002, Lahti and Penttila 2003, Rinaldi et al. 2003, Lakkireddy et al. 2004, Ducimetiere et al. 2006), and it has been reported that items such as age, education, and race have been difficult to assign correctly (Elo et al. 1996, Hahn et al. 2002, Harwell et al. 2002).

Methodological Considerations

Categorical dispersion has been widely discussed (Agresti and Agresti 1977), and a variety of measurements have been suggested. Among the more commonly used are the Shannon's H (Shannon and Weaver 1949) and the Simpson (1949) index of variation D. Both equal 0 when all observations are in one category and have their maxima when there is an equal distribution among the observed categories. With a large number of categories, the maximum value approaches 1. There are many functions like these two and an investigator ought to provide arguments for the application of a special function for a specific problem. My choice is governed by a common way of defining variance for variables with two categories. As an example:

Let the proportion of males be p and the proportion of females be q so the $p+q=1$. The variance, S^2, in this case is (Mueller et al. 1977):

$$S^2 = p * q, \tag{1}$$

where p is the proportion in one category and q that in the other category. I suggest that this standard formula should be used in a uniform treatment of categorical dispersion with multiple categories through its generalization to Simpson's D.

Simpson's (1949) D is a standard way of describing variation in properties measured on a nominal or categorical level. An example is the variation of classified death causes in a population at a particular time. Let there be k classified death causes in a population and let i denote one category at a time starting with 1 and ending at k. The proportion p_i in each category i is the observed frequency of i divided by the total of observed individuals. Simpson's D is defined as:

$$D = 1 - \sum_{i=1}^{k} p_i^2. \tag{2}$$

A standard interpretation of this index is the probability that two individuals selected at random from the population would be in different categories. There is a standardized version which varies from 0 to 1 by multiplication of D by $k/(k-1)$. This formula might be preferable for comparing dispersions measured by classifications with varying values of k. With large values of k, the standardization is less important as the factor is close to 1.

Simpson's D is a generalization $S^2 = p * q$ by taking the sum of $p_i * q_i$ where p_i is the proportion in the ith category and q_i is the proportion of the rest of the population. The proof of this is a simple use of the equation $p_i = 1 - q_i$ and the sum of all the proportions ($\sum p_i$) is 1. The derivation written without the superscripts and subscripts denoting i and k:

$$\begin{aligned} D &= 1 - \sum p^2 = 1 - \sum p(1-q) = 1 - \sum (p - pq) \\ &= 1 - \left(\sum p - \sum pq\right) = 1 - 1 + \sum pq = \sum pq. \end{aligned} \tag{3}$$

Thus, in the case of just two categories, it is shown that Simpson's D equals $2pq$, which is twice the variance in this case.

Another aspect of categorical dispersion is the number of categories. If there is no predetermined number of categories, then another important aspect of categorical dispersion is the number of observed categories. Since these numbers can depend on the total number of observations, I present these numbers for each one-year age class.

Data

I used data from the National Center for Health Statistics (NCHS) deposited at the ICPSR under study number 3473 (National Center for Health Statistics 2001b) for multiple causes of death in 1999. There are death causes for 2,394,871 persons divided into one-year age classes during 1999 (Figure 1). The source for establishing the underlying cause of death is the death certificate. The certifier is asked to provide the causal chain of morbid conditions that led to the death, beginning with the condition most proximate to death and working backwards to the initial condition. The underlying cause of death is defined as the disease or injury which initiated the train of morbid events leading directly to death (National Center for Health Statistics 2001a). The death causes were coded following the WHO ICD-10 code (World Health Organization 1992). These codes were recoded into fewer categories for 39, 113, 130, and 358 groups of causes reflecting the WHO mortality tabulation lists (National Center for Health Statistics 2004) of underlying cause of death. There is no written rationale as to why particular causes are included in the lists. The criteria used are that the diseases are preventable, e.g. vaccine-preventable, frequent, and costly in terms of health care expenditure or of public health importance (L'Hours 2003). The 130-cause categories were developed especially for the study of infant

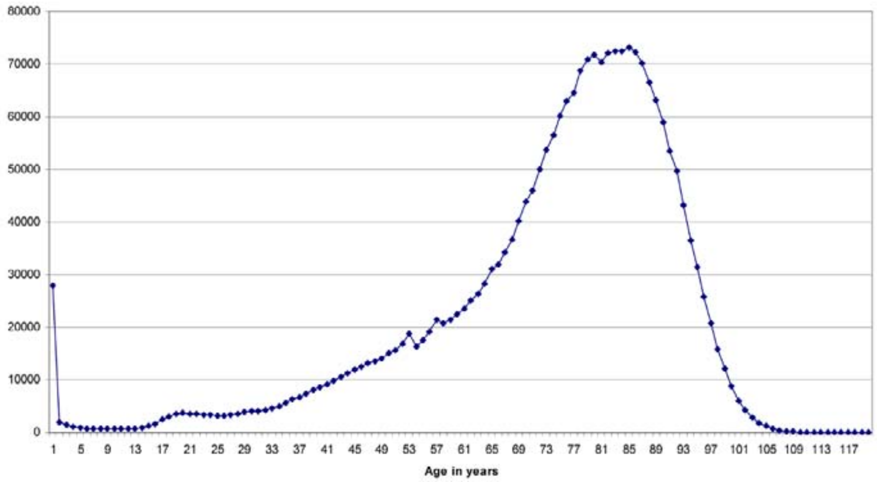

Fig. 1 Frequency of U.S. deaths by age in 1999.

mortality and left out of this study, which is focused on older ages. I chose the categorization using the most categories, which is 358, for use in this study. Appendix 1 presents 20 titles describing these categories. The general tendencies, not presented here, are similar for the death causes recoded in 39, 113, and 358 categories. I restrict the study of D from 20 to 100 years of age. Before and after that interval there are so few deaths that the dispersion of causes is of less interest. I present the results in graphs where I restrict the scale to show the change in dispersion by age. I have made the same calculations for 1998 U.S. mortality data coded by ICD-9. The results are not published here but are similar.

Results

All the tabulated 2,394,871 deaths were recoded into the 39, 113, and 358 categories. There were 360 missing values for age, so there were 2,394,511 deaths included in the study. Since the possible variation in causes of death also depends on how many registered deaths there were at each age, the distribution of deaths by one-year age classes is shown in Figure 1. Except for the first year, there was generally an increased number of deaths each year until 85 years of age, followed by a decrease. There were about the same frequencies of deaths among 40-year olds, 8,549, as among 100-year olds, 8,833. In this interval, there were enough deaths to make dispersion comparisons by year of age.

For all observed years of age, there is no single year when all the categories were used to describe the deaths in the US, as would be expected because of rarely occurring causes like cholera, plague, and diphtheria and because some causes are

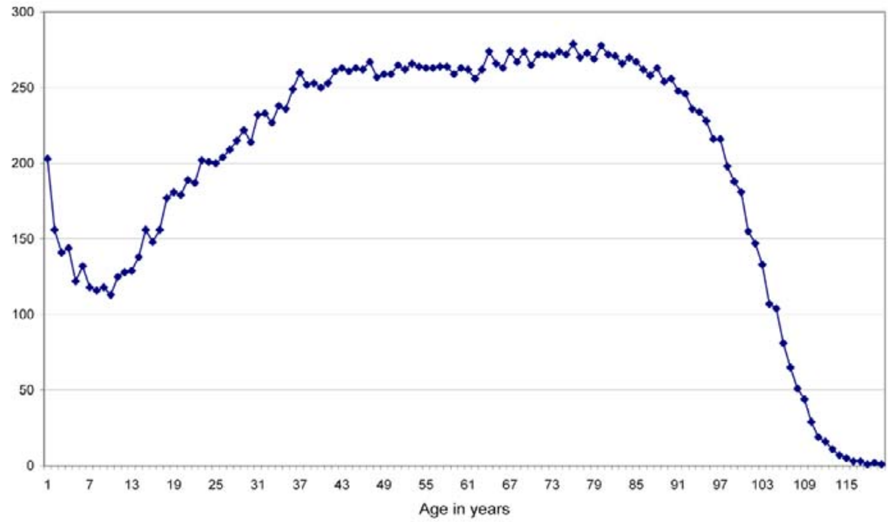

Fig. 2 Frequency of death causes used in each year of age for U.S. death by 358 causes.

rare in some age groups, such as whooping cough and Alzheimer's disease. Some causes are not found outside the interval of female fertility, such as obstetric deaths. The number of categories used in each one-year class and for the 358 categories is shown in Figure 2.

In Figure 2 the maximum number of categories was at age 76, when there were 279 used categories out of a possible 358 categories There was a decline in number of death causes at each age from the age of 80 (Figure 2) that is not related to a decline in the frequency of deaths, since the onset of the decline in frequency of deaths starts after 85 years of age. The number of causes used at age 100 was only 181, compared with 250 used at 40 years of age, though the total number of deaths was similar at both ages. Thus the late decline in number of death causes is not because of the frequency of deaths in the age classes. (The same type of decline in number of death causes was observed, but not shown here, in the two classifications of 39 and 113 causes.)

The dispersion, D, for the classification of 358 death causes is shown for each year from 20 to 100 years of age in Figure 3. For the 358 causes of death, there was a bimodal distribution of D after the age of 20. The maxima were at age 41, where $D = 0.9839$, and age 77, where $D = 0.9602$. (For all three categorizations, there were similar patterns of dispersion with increasing age.)

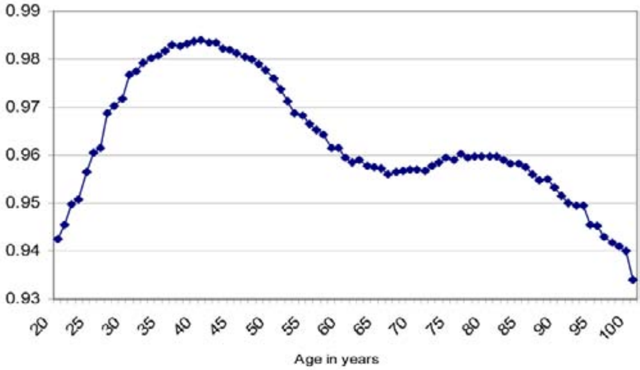

Fig. 3 Simpson's *D* calculated for each year from 20 to 100 years of age for 358 U.S. death causes 1999.

Discussion

The decline in the number of categories of causes of death by age, as well as the bimodal distribution of the dispersion measurement D by age, refutes the hypothesis of increased dispersion as a function of increasing age but opens up some questions for further research. There seems to be a consensus about the idea that persons in higher age groups have lower reserve capacities in many functions as well as higher vulnerability, resulting in a higher risk.

Events that are not fatal when encountered in a stage with high reserve capacity could be fatal when encountered with lower reserve capacity. As an example, falls by accident can result in femur fracture and femur fracture could cause death by embolism. The weaker femur structure in the more elderly shows less reserve capacity and increases the risk of embolism after falls. On the other hand, it is possible that reduced reserve capacity during aging hits a few vital functions more severely than other vital functions and thus reduces the variation in causes of death to these few, but vital, functions with more reduced reserve capacity (Smith 1997, Gessert et al. 2002).

In general, at least in higher ages, there are competitive causes of death. Is it the weak heart, the failing kidney, or the pneumonia infection that caused a death? The procedure for assigning a death cause is a result of professional, written standards and is in this respect a social construction. In many cases it is also probably true that death is caused by a combination of factors. If there is a practice of putting the causes in a specific order, e.g., always mentioning Alzheimer's as the underlying cause, then this can reduce dispersion as it disguises another probable cause of death with lower priority, e.g. pneumonia (Lakkireddy et al. 2004). It is also possible that there is a more exhaustive investigation of cause of death when the death is more unexpected or unusual, as in mid-life, more because of acute than chronic conditions, and more when it is associated with a greater interest in finding preventions of these conditions. If a person dies at 41 years of age, there is likely to be a higher motivation to establish the cause of death than when a more expected death occurs at 90 years of age. Thus it is possible that causes of death are assigned in a more superficial way in higher ages (Bordin et al. 1999, Leibovitz et al. 2001, Gosney 2005) owing to more commonly and well recognized social ideas of normal deaths among the elderly: Such practices would result in a decreased dispersion of registered causes of deaths for higher ages.

There was a second, smaller maximum during the higher ages when the majority of the deaths are occurring (Figure 3). There might then be a double influence: (1) more precise diagnostic practices in the middle age than older age (Leibovitz et al. 2001) resulting in a first maximum; and (2) a greater dispersion owing to higher vulnerability in ages where most of the deaths are taking place, resulting in a second maximum with the terminal decline as an even more accentuated lack of interest in the causes of death in very high ages.

It is a common phenomenon that aged persons are subject to stereotyping. These stereotypes consist of three elements: a concept, an emotion, and a habit or behavioral disposition (Millon et al. 2003). The term, "ageism," has been used to define circumstances in a society in which aged people are subject to discrimination by stereotypes (Butler 1969). In this case, the concept could be that old persons are going to die anyway, the emotion could be that it is less alarming when an old person dies, and the habit could be that it is not as important or worth the effort to establish the cause of death for an old person (Swift and West 2002). If there is a greater vulnerability resulting in a higher dispersion of what causes a person's death, but which is not reflected in the death certificates, then neglect of this variation in higher ages is an example of ageism (Butler 1969, Ory et al. 2003, Gosney 2005). Older individuals are treated more as members of a birth cohort than as individuals compared with younger individuals. When such a possible example of ageism is performed within a social institution it has been labeled as institutionalized ageism (Becker 1994, Nelson 2005, Townsend 2006). Death certificates are issued within a strict institutional framework, and if an increasing dispersion of causes is neglected, this is ageism, then it is an example of institutionalized ageism. Studying dispersion on the basis of sex, race, deaths in or out of hospitals, and deaths with or without autopsies could provide information about variation of assigned death causes. Sex should be studied because there are differences in patterns of morbidity between the sexes as well as gender attitudes that could affect the interest in finding a correct death cause. Race should be studied because there is the possibility of other patterns partly as the result of racial discrimination (Elo et al. 1996, Harwell et al. 2002, Rinaldi et al. 2003). The physician's information about the deceased varies if the death occurs within or outside a hospital which could influence the death certificate (Leibovitz et al. 2001, Johansson and Westerling 2002). Autopsy is a token of a greater interest in establishing the cause of death and also providing more information to decide on the cause of death (Smith et al. 1998, Ermenc 2000).

The three categorizations of death causes in 39, 113, and 358 categories are all constructed by the criteria that the aggregated information should be used to prevent disease, e.g. the vaccine-preventable diseases or frequent diseases that are costly in terms of health care expenditures or of public health importance (L'Hours 2003).

With this in mind, and with a possible concept of the fruitlessness of prevention in higher ages, the classification of deaths in higher ages may be made with less care than in younger ages. It might even be the case that possible measures of preventions are undetected because of a too superficial practice in assigning causes in the death certificates. It is the assigned cause that is recoded into 39, 113, and 358 categories in higher ages (Ory et al. 2003).

There is another interpretation of vulnerability increasing with age. The low vulnerability of the middle ages would lead to high survival even if the individuals were subject to life-threatening conditions. It might well be very specific conditions that are fatal in the middle ages, thus leading to the first maximum of *D* shown in Figure 3.

Conclusion

Neither of the aspects of dispersion investigated – the number of categories employed in describing death causes and Simpson's *D* – showed the expected increase in higher ages. Simpson's *D* showed a bimodal distribution. This result could be an accurate description of the distribution of death causes. Another possibility is that there is an increase in causes of deaths which is not registered because of practices consistent with institutional ageism. If so, knowledge of preventable causes of death may be hidden as a result of institutional ageism.

Appendix 1

The 20 titles covering the 358 causes of death:

I. Certain infectious and parasitic diseases: 55 entries
II. Neoplasms (cancer): 60 entries
III. Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism: 7 entries
IV. Endocrine, nutritional and metabolic diseases: 13 entries
V. Mental and behavioral disorders: 9 entries
VI. Diseases of the nervous system: 9 entries
VII. Diseases of the eye and adnexa: 1 entry
VIII. Diseases of the ear and mastoid process: 1 entry
IX. Diseases of the circulatory system: 36 entries
X. Diseases of the respiratory system: 23 entries
XI. Diseases of the digestive system: 23 entries
XII. Diseases of the skin and subcutaneous tissue: 2 entries
XIII. Diseases of the musculoskeletal system and connective tissue: 7 entries
XIV. Diseases of the genitourinary system: 14 entries
XV. Pregnancy, childbirth and the puerperium: 13 entries

XVI. Certain conditions originating in the perinatal period: 8 entries
XVII. Congenital malformations, deformations and chromosomal abnormalities: 9 entries
XVIII. Symptoms, signs and abnormal clinical and laboratory findings not elsewhere classified: 4 entries (including senility)
XIX. Not used for classification: 0 entries
XX. External causes of mortality: 64 entries

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Section IV

THE BREADTH OF APPLIED DEMOGRAPHY

Chapter 14
A Comparison of Potential Demographic Influences on Church Membership of Two United Methodist Congregations in San Antonio, Texas

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Introduction

The United Methodist Church (UMC) follows an episcopal organizational form. Churches are located within regions presided over by a bishop and pastors are appointed to local churches by the bishop based on the pastors experience, personality, and organizational needs. While church leadership plays an important role in church membership gains, if the church is located in an area of declining population or in an area of demographic transition, the potential for membership growth is made more difficult especially if the lay and clergy leadership do not effectively adapt church programs to meet the needs of the neighborhood. Applied demographers can assist local churches by helping them understand demographic processes affecting the neighborhoods in which they serve. The purpose of this paper is to compare the immediate geographic areas around two similar congregations to understand how area demographic characteristics may influence the membership and average weekly attendance of these two churches. Selected statistical techniques are utilized to provide an initial exploratory research into the demographic characteristics of the service areas of these respective congregations in order to understand the effects of these differences upon church membership and average weekly attendance. In addition, these comparisons provide an initial starting point for developing strategic plans for effectively responding to the needs of the populations living near each respective congregation.

Case Study Congregations

The two churches under study are both members of the Southwest Texas Annual Conference of the United Methodist Church. More specifically, these two churches are located in Northwest San Antonio, within five miles of each other. In addition

S.H. Murdock and D.A. Swanson (eds.), Applied Demography in the 21st Century, 237–249.

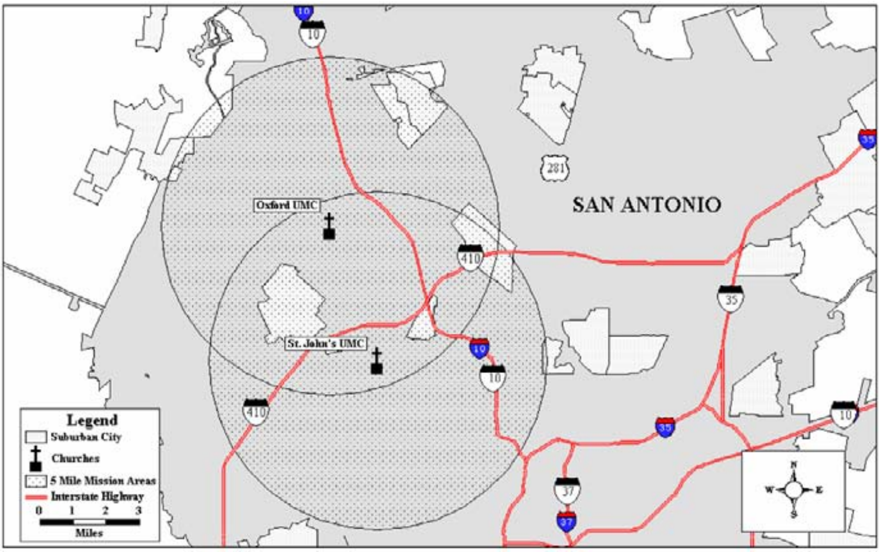

Fig. 1 Congregation locations and 5-mile mission areas.

to these two churches, there are 43 United Methodist Church (UMC) congregations in San Antonio (Southwest Texas Conference, United Methodist Church 2005). Oxford UMC is located at 9655 Huebner Road and had an official membership of 537 people with an average weekly attendance of 278 worshipers in 2004. The church has been located at the Huebner Road address since it was founded in 1957.

St. John's UMC was originally located in the Prospect Hill neighborhood of west San Antonio but was relocated to its present address of 2002 Bandera Road in 1954. In 2004, St. John's UMC had an average weekly attendance of 117 and a total membership of 419. While the two congregations are within five miles of each other, they are on opposite sides of a major freeway that operates as a psychological boundary between old and new San Antonio. St. John's UMC is just inside Loop 410, while Oxford UMC is a few miles outside of Loop 410.

Methodology

From a congregational and denominational standpoint, membership growth serves as one measure of success for a local congregation. Continued membership growth helps to ensure institutional survival. Like a retail firm, the location of a congregation can help determine the degree to which the church can grow. Denominational staff involved in planning new churches often utilize demographic information to help determine the best locations of new congregations. Unfortunately, this same information is often overlooked when reformulating programs for existing churches.

Table 1 Official church membership and average weekly attendance for case study congregations, 1990, 2000 and 2004.

St. John's UMC		Oxford UMC
	Church Membership	
696	1990	300
419	2000	537
297	2004	526
	Church Attendance	
182	1990	146
117	2000	278
113	2004	234

Source: Office of Congregational Growth, Southwest Texas Annual Conference of the United Methodist Church.

Statistics on church membership and average weekly attendance by year are reported to and maintained by the district and denominational offices of the United Methodist Church (UMC). To consider how neighborhood characteristics might effect local congregational growth, two congregations were selected for analysis on the basis of their proximity to each other, their general location within the city of San Antonio, and the differences in the trends of their average weekly attendance and membership. One congregation, Oxford UMC, has grown in membership and average weekly attendance while the other, St. John's UMC, has experienced relative decline in the same measures over the last 15 years. In order to understand the potential effects of differences in the demographic characteristics of the neighborhoods around the two case study congregations, comparisons were made using several descriptive techniques. The neighborhoods were defined as those areas within a five mile radius of each church location. These areas were defined as the "mission area" of each respective congregation. Although proximate to each other, significant differences exist that may have influenced changes in church membership and average weekly attendance between 1990 and 2000. Descriptive statistics were utilized to compare the size, racial/ethnic characteristics, age structure, and household income characteristics of these two mission-area populations. Finally, estimates of the number of people who attend church weekly were created in order to understand differences in the two mission areas and the potential "markets" for these two congregations.

For this study, a circle with a radius of five miles from each church location was drawn using a geographic information system. Ideally, member households would be geocoded in order to understand where current members live, but circles around the church locations were used for this study for three primary reasons. First, this research was intended to understand the effects of demographic characteristics of nearby neighborhoods on church membership and weekly attendance, regardless of where the current membership lives. Second, though people have the choice to attend churches outside of their immediate neighborhoods, the majority of members and worshipers in most churches come from within the immediate area. The author found no reference to an ideal size and extent for urban church mission areas after an extant review of the academic and popular literature, but rather general rules of thumb: when locating sites for churches, the Southwest Texas Conference of the UMC prefers not to place new churches within five miles of existing congregations (M. Lowry, personal communication, August 8, 2007). For this reason, the author chose a similar five-mile radius. Finally, the author was limited by time and resources to thoroughly delineate the respective mission areas using more advance techniques.

Census tracts were used for the demographic analysis. Data for a census tract were counted if the geographic center (centroid) of the census tract was found within the radius of the circle. For this paper, the census tracts selected for each circle will be referred to as the mission areas of the respective churches. The St. John's UMC mission area includes 89 census tracts, while the Oxford UMC mission area consists of 49 census tracts as defined by the 2000 Census. Due to overlapping mission areas, a total of 21 tracts are found in both mission areas. In order to compare the two mission areas, two measures of population size were utilized: total population and population potential, or Hansen's (1995) accessibility index. Population potential measures the degree to which populations are proximate to a given location. Population potential is measured as:

$$PP = \sum (P_j / D_{ij}),$$

where PP = population potential, P_j = population of census tract j, D_{ij} = distance between the church site i and the centroid of census tract j.

These two case study mission areas were also compared measuring changes in the total population between 1990 and 2000 relative to the changes in each congregation's average weekly attendance and official membership. The racial and ethnic characteristics and household income characteristics of these two mission areas were also compared. Median household income was estimated using categorical household income date from the U.S. Census.

Finally, both areas were compared based upon their age characteristics. Using information from the Gallup Poll (Wellner 2001) estimates of the total number of people who attend church weekly were created. Rates of average weekly attendance by age were applied to the age characteristics of each mission area to derive at the total estimated number of people who attend church on a weekly basis. Although ideally more refined estimates of potential attendance to mainline, and in particular UMC churches would be more desirable, these estimates provide a starting point for understanding the potential market for church attendance in the mission areas irrespective of denominational preference.

Table 2 Total population and population potential for the 5-mile mission areas of the case study congregations, 2000.

St. John's UMC		Oxford UMC
	Total Population, 2000	
354,110	5-Miles	265,481
	Population Potential, 2000	
129,415	5-Miles	97,338

Source: U.S. Census, 2000 as calculated by author.

Findings

Total Population

The populations for each census tract within each mission area were first summed to determine the total population within each church's trade area. On total population, the number of people within the mission area of St. John's UMC is about 25 percent larger than that of Oxford UMC. The total population for the Oxford UMC mission area was 265,481 in 2000 compared to 354,110 for the same period for St. John's mission area. This suggests that on population alone, St. John's UMC has a larger mission field.

The population potential was then calculated for each mission area. Distance was measured from each census tract centroid within each respective mission area to the church's location. The total population in each census tract was then divided by the distance and the results summed to determine the population potential. The total population potential for St. John UMC's mission area was 129,415 in 2000, while the total population potential for Oxford UMC's mission area was 97,338. From a population accessibility standpoint, the population potential of St. John's UMC mission area is still about 25 percent larger than Oxford UMC's mission area, thus suggesting that, all other things being equal, the membership and weekly attendance at St. John's UMC should be larger. If the rate of the proportion of United Methodists for Bexar County (2.95 percent) is applied to these respective areas, then approximately 3,818 United Methodists would be found in St. John's mission area, compared to 2,871 within Oxford's. Given that there are other UMC congregations within each mission area, on a per church basis, there are an estimated 718 United Methodists per church in the Oxford mission area (four UMC congregations within the area) and 764 United Methodists per church in the St. John's mission area (five UMC congregations within the area).

Population Change

Of the two churches, St. John’s has a larger mission area population as well as a larger measure of population potential, but in 2000 and in 2004, St. John’s membership and average attendance was smaller than Oxford UMC’s. In addition, St. John’s membership and average weekly attendance has been trending downward since the early 1980s while Oxford’s has trended upward since 1974 (with minor decreases only recently in the early 2000s). Population change could be another influence on membership and attendance changes in the two congregations. Indeed, in a study of congregations of a similar mainline denomination, area population growth was found to have a significant influence on membership and attendance growth (Thompson et al. 1993).

The population of the mission areas of the two churches was calculated for 1990 and 2000, and total population change was measured between 1990 and 2000. Some of the census tracts for 1990 were split and renumbered in 2000. Census tract reference maps from 1990 and 2000 were visually inspected and the data for these tracts were estimated based upon the relative sizes of those splits. In other words, if a census tract from 1990 was split into two equally sized census tracts in 2000, half of the population in 1990 was allocated to each one of those new census tracts.

The total population of the St. John’s UMC mission area was the largest of the two mission areas in both 1990 and 2000; however, its population only grew by 0.1 percent from 1990 to 2000 (a total of 211 people). On the other hand, the total population of the Oxford UMC mission area grew by 32.5 percent during the same period (an addition of 65,085 people during the 1990s). It would be expected that growing areas influence growth in the membership and weekly attendance of area churches as demand for services (in this case, spiritual services) increase with increasing population. Indeed, the church with the mission area with the largest population change also has higher rates of membership and average weekly attendance growth. The annualized exponential rate of change for the St. John’s UMC mission area was 0.01 percent, compared to the annualized exponential rate of change for the Oxford UMC mission area of 2.81 percent. During the same period, according to the Southwest Texas Annual Conference of the United Methodist Church (2005), Oxford UMC had an annual membership growth rate of 6.2 percent, compared to an annual average decline of −4.7 percent for St. John’s UMC.

While the indicators for total population and population potential favor St. John’s UMC, population growth appears to influence the membership and attendance trends for Oxford UMC. But could there be other demographic factors influencing membership and attendance differences between these two churches? Three additional variables were analyzed to understand demographic influences on church membership and average weekly attendance, the first two on a more descriptive basis and the latter through an analysis based upon standard rates.

Table 3 Change in membership, average weekly attendance and mission area population of the case study congregations, 1990–2000.

St. John's UMC		Oxford UMC
	1990	
353,900	Population of Mission Area	200,397
696	Official Church Membership	300
182	Average Weekly Attendance	146
	2000	
354,110	Population of Mission Area	265,481
419	Official Church Membership	537
117	Average Weekly Attendance	278
	Population, 1990-2000	
211	Net Population Change	65,085
0.1%	Percent Change	32.5%
0.01%	Annualized Percent Change*	2.81%
	Membership, 1990-2000	
-277	Net Membership Change	237
-39.8%	Percent Change	79.0%
-4.7%	Average Annual Percent Change	6.2%
	Average Weekly Attendance, 1990-2000	
-65	Change in Average Attendance	132
-35.7%	Percent Change	90.4%
-4.2%	Average Annual Percent Change**	7.2%

*Exponential rate of change, 1990–2000.
**Average annual rate of change calculated from yearly statistical data provided by the Office of Congregational Growth, Southwest Annual Conference of the United Methodist Church.

Race/Ethnicity

It has been said that Sunday is the most segregated day of the week in America. Although there are United Methodist Churches with predominately African-American, Hispanic, and Korean memberships, as a whole, the United Methodist Church's membership, like other traditional mainline Protestant denominations, is primarily middle- and upper-income Anglo (Smith and Faris 2005: 102). In fact, only eight percent of the Southwest Texas Annual Conference was reported as racial and ethnic minorities in 2002 (Office of Research 2002). In other studies of congregational growth of mainline Protestant churches, congregations located in areas of significant middle and upper income Anglos were found to grow more rapidly than other congregations. Could the underlying demographic characteristics of these two mission areas influence the membership and average weekly attendance records of these two churches?

For this analysis, data for race and ethnicity were combined. The data for Hispanics include all Hispanics regardless of race; the Anglo population includes the data for White Alone, Not Hispanic; the African-American population includes the data for Black or African-American Alone, Not Hispanic; the Asian population includes

Table 4 Population by race/ethnicity for mission areas of case study congregations.

St. John's UMC		Race/Ethnicity	Oxford UMC	
Population	%		Population	%
82,455	23.3%	Anglo	117,887	44.4%
251,381	71.0%	Hispanic	124,720	47.0%
11,604	3.3%	African-American	11,123	4.2%
4,548	1.3%	Asian	6,884	2.6%
4,122	1.2%	Other	4,867	1.8%
354,110	**100.0%**	**Total**	**265,481**	**100.0%**

Source: 2000 Census as calculated by author.

the data for Asian Alone, Not Hispanic; while the remainder of the population is included in the "other" category.

The populations of both mission areas had a majority of racial and ethnic minorities in 2000. As would be expected for a mission area in Bexar County, both areas had a large number of Hispanics in 2000. Seventy-one percent of the population in the St. John's UMC mission area was Hispanic in 2000, while 47 percent of the population in the Oxford UMC mission area was Hispanic in 2000. In terms of total population, there are almost 50 percent more Anglos in the Oxford UMC mission area than there are in the St. John's UMC mission area. Though the United Methodist Church does minister to people of different racial and ethnic backgrounds, people tend to seek membership in churches that consist of people of similar backgrounds. As a historically Anglo majority denomination, the United Methodist Church and its congregations likely attract new members who are Anglo. In addition, Hispanics are more likely to identify themselves as Catholic than any other religion (Keysar et al. 2001: 6). Like population change, Oxford UMC mission area's racial and ethnic characteristics appear to be more favorable for growth than that of St. John's UMC.

Income

Since the United Methodist Church's membership has traditionally consisted of predominantly middle and upper income Anglo populations, it is expected that a more affluent mission area would influence church membership and attendance positively. Data on household income was obtained from Summary File-3 of the 2000 Census. Median household income for each area was then calculated from the categorical data. Of the two mission areas, the most affluent is found around Oxford UMC. The median household income for the Oxford UMC mission area was $43,089, almost $10,000 more than the median household income of $33,234 for the St. John's UMC mission area. If household income is indeed a positive influence on United Methodist Church attendance and membership, then again, the Oxford UMC has a mission area with favorable demographic characteristics.

Table 5 Households by household income and median household income for mission areas of case study congregations.

St. John's UMC Households	%	Income	Oxford UMC Households	%
17,105	13.5%	<$10,000	9,221	8.6%
10,316	8.1%	$10,000-$14,999	5,610	5.2%
11,480	9.0%	$15,000-$19,999	7,118	6.7%
11,171	8.8%	$20,000-$24,999	7,063	6.6%
9,925	7.8%	$25,000-$29,999	7,284	6.8%
9,928	7.8%	$30,000-$34,999	7,887	7.4%
8,561	6.7%	$35,000-$39,999	6,844	6.4%
7,816	6.2%	$40,000-$44,999	6,350	5.9%
6,361	5.0%	$45,000-$49,999	5,701	5.3%
10,005	7.9%	$50,000-$59,999	9,854	9.2%
9,691	7.6%	$60,000-$74,999	11,172	10.5%
7,530	5.9%	$75,000-$99,999	10,537	9.9%
3,422	2.7%	$100,000-$124,999	5,519	5.2%
1,267	1.0%	$125,000-$149,999	2,413	2.3%
1,261	1.0%	$150,000-$199,999	2,340	2.2%
1,170	0.9%	$200,000 or more	1,994	1.9%
127,009	**100.0%**	**Total Households**	**106,907**	**100.0%**
$33,234		**Median Household Income**	**$43,089**	

Source: U.S. Census, 2000 as calculated by author. Median Household Income calculated from categorical data.

Population by Age

Age and the stages in the lifecycle are great predictors of church membership and attendance (Stolzenberg et al. 1995: 99–100). Generally, people in their middle ages are more likely to attend church as they are more settled down than younger people and usually have children attending church as well. In the early 20s, people are more mobile and less likely to attend a church until they settle down and begin to raise children. The two mission areas appear somewhat similar in age structure when comparing selected age demographics. On a percentage basis, the populations in the older age groups are slightly larger for St. John UMC's mission area, while the percent of people in the 20–64 age groups is slightly larger in the Oxford UMC mission area than in the St. John's UMC mission area.

Standard rates were used to estimate the number of people who attend church on a weekly basis for the two mission areas. These rates are national rates and were taken from the Gallup Poll (Wellner 2001) that estimated the number of churchgoers by selected age groups. These standard rates were applied to the corresponding populations by age group for the two church mission areas. The results provide an

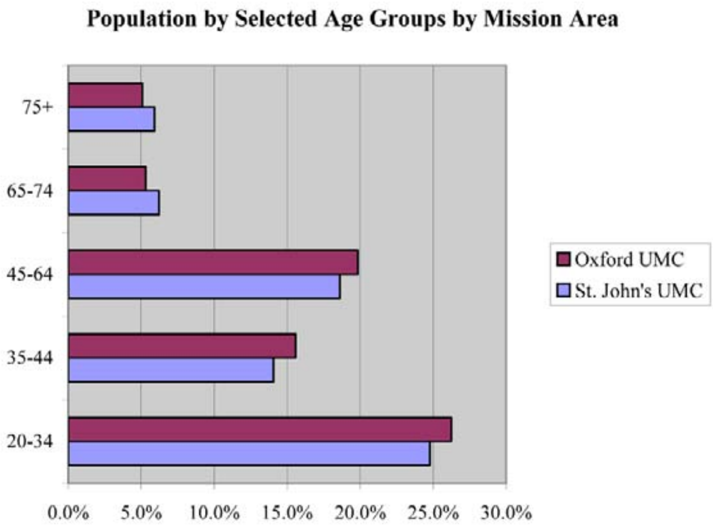

Fig. 2 Comparison of population by age for mission areas of case study congregations.

estimate of the number of people who attend church weekly for the area. While these rates will not provide a close approximation to the number of people who attended United Methodist Churches in the area, the goal is to understand how the age makeup of the area might be favorable or unfavorable to church attendance of any kind.

While the proportion of people in the younger ages is greater for the Oxford UMC mission area, the St. John's UMC mission area is still larger in total population and in the size of each age category. So at least on a numerical basis, there are still at least 25 percent more potential churchgoers in these age groups in the St. John's UMC Mission Area than there are in the Oxford UMC mission area. Unfortunately, attendance rates at more disaggregated age groups and by race or ethnicity were not available. Disaggregated rates might reveal additional differences, particularly when accounting for populations at younger ages.

There are an estimated 95,696 people who attend religious services on a weekly basis within the St. John's UMC mission area and 73,733 people within the Oxford UMC mission area. In order to estimate the membership per congregation for all religious institutions and thus compare the potential competition within each area, a list of religious institutions within five miles of each congregation was obtained from ReferenceUSA (2007). Excluded from the data were religious schools, administrative offices of churches, and specialized ministries such as convents and missionary programs. There were 125 congregations within a five mile radius of St. John's UMC and 68 within five miles of Oxford UMC. On a per congregation basis, there are 1,084 people who attend religious services on a weekly basis around Oxford UMC compared to just 766 people per congregation around St. John's UMC. Thus the competition appears greatest for St. John's UMC. This of course is only a rough

Table 6 Estimated number of persons attending church weekly for the mission areas of case study congregations.

		Mission Area			
	Standard Age-Specific Church Attendance	Population by Age		Estimated Number of Weekly Church Attendees*	
Age	Rates	St. John's UMC	Oxford UMC	St. John's UMC	Oxford UMC
20-34	33%	87,703	69,655	28,942	22,986
35-44	40%	49,800	41,381	19,920	16,552
45-64	40%	65,924	52,667	26,370	21,067
65-74	52%	22,060	14,080	11,471	7,322
75+	43%	20,913	13,503	8,993	5,806
			Total Estimated Weekly Attendees:	***95,696***	***73,733***
			Total Congregations in Mission Area:	***125***	***68***
			Attendees Per Congregation:	***766***	***1,084***

*Indicates the number of people who attend church of any kind.
Source: The Gallup Poll as reported in Wellner, A.S. (2001) and U.S. Census 2000 as calculated by the author.

estimate since we assume equal distribution of the population, no overlapping mission areas, and that people will be equally divided among all congregations within the respective mission areas.

Conclusion

This case study provides an exploration of selected demographic factors that might influence change in church membership and average weekly attendance for two United Methodist Church congregations in San Antonio, Texas. While the findings are not conclusive, there appear to be some factors that could attribute to the differences in the change in membership and average weekly attendance of these two congregations. The area around Oxford UMC is growing quite rapidly, has more Anglos, and is more affluent than the area around St. John's UMC. At the same time, the number of people in the St. John's UMC mission area is approximately 25 percent larger and more people are at ages during which attendance is greatest. Further analysis of the demographic characteristics of each congregation's membership and the competitive factors present in these two church mission areas is required to understand how much other factors may be influencing changes in membership and attendance. There are other churches within the mission areas of both churches, including other United Methodist Church congregations. Further analyses might reveal ways in which these churches can differentiate their missions from other churches within the area, meeting unmet needs present within their respective communities. In addition, demographic analyses can provide a basis for changing mission strategies of these two congregations, reflecting the needs of their respective mission areas.

Demographic data are consulted when planning new programs and establishing new churches – usually at the ZIP code level or in mission areas defined by radii. Interestingly, the author found no prescribed optimum size and scope for an urban church's mission area within the literature or in conversations with church leaders. Applied demographers are well equipped to assist these denominations in uncovering the scope of these mission areas and how they may have changed over time. On a national basis, people travel on average six and one-half miles to religious services (U.S. Department of Transportation 2001). Further research may uncover differences in this distance based upon urban and rural location as well as region of the country. In this research, membership address data for these two congregations could have been geocoded in order to define the current mission areas of these two churches had there been resources and time. Given that these two congregations were established in the 1950s, this analysis may have shown that a number of parishioners moved outside of the five mile mission areas but continued to maintain ties and membership within the local congregation. The findings may have also suggested mission areas larger or smaller than the given five mile radius.

Most denominations continue to plan for new churches and must make decisions about when to close older ones. A crude measure of competition with other United Methodist Church congregations and other religious institutions was utilized to compare the respective congregational mission areas. More in depth analysis of competition using techniques adapted from major retailers could help refine methods of analysis and provide church planners ways to formulate optimum locations for new churches or help determine closure of existing ones.

The information presented here can be used to provide a starting point for redeveloping established congregational programs. Applied demographers can assist in strategic planning by providing more analytical insight into neighborhood demographic characteristics than might be presented otherwise. The most difficult part of this role may be in the demographer's ability to communicate the results of these analyses to parishioners and congregational leaders so that they may understand how better to serve their neighborhoods without feeling that the characteristics of their neighborhoods may doom them to closure.

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Chapter 15
Linking Tax-Lot and Student Record Data: Applications in School Planning

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Introduction

This article is based on the experience of providing demographic services for a number of Oregon school districts, some growing rapidly and needing to build new schools, and others, such as the Portland Public School District, with shrinking enrollment and needing to make painful decisions about school closings. School districts make large investments in facilities to accommodate future student populations. Accurate enrollment forecasts can help keep districts from building over capacity and incurring excess costs or suffering under capacity and crowding. Knowledge about local housing markets and their impact on the mix of households can assist in producing realistic enrollment forecasts. One way to explicitly consider the effects of housing is to link students to their residential location, the tax-lot, where they reside. It is this theme that will be addressed in this paper.

Understanding local housing markets and how they change can provide useful information about changing school-aged populations. In the case of a school district that is growing, it is apparent that housing growth will generate new school enrollment. However, even in this simple case, one should be aware that new single family housing may generate as much as 50 times as much school enrollment per unit as downtown apartments. In districts that are largely built-out, changing housing tenure, household types, and ethnic composition in existing housing are the major factors influencing enrollment changes. For example, rental single family housing tends to house more students than does owner occupied single family housing. Gentrification where there are conversions of rental single family housing to owner occupancy may result in declining school enrollments.

The focus of this article is on kindergarten through grade twelve enrollments in the public school systems. A common reason for using the linked student – tax-lot data is to establish the ratio of the number of students to the number of housing units, by type of unit, subsequently referred to as the *yield* of students. The individual unit of land ownership is referred to in this article as the *tax-lot*, also commonly referred

S.H. Murdock and D.A. Swanson (eds.), Applied Demography in the 21st Century, 251–270.

to as a land *parcel* or *cadastre*. The Population Research Center, Portland, Oregon, which hosted the research described in this paper is abbreviated as *PRC*. Much of this research has been done for Portland Public Schools, Oregon abbreviated subsequently as *PPS*. Geographic information system technology is abbreviated as *GIS*. Most of the GIS analyses discussed in this article were done using Environmental Systems Research Institute ArcGIS software.

Most School Districts Track Housing Development

School demographers (or in smaller districts, school secretaries or assistant superintendents) commonly maintain databases on new housing developments in their district and on the number of pre-school and school-aged children living in these developments. They may get information on the numbers of children living in apartment developments from the manager or renting agency, and they may be able to use student addresses to count the number of their students living in single family subdivisions. They communicate with planners and developers in order to be aware of future housing developments. Their knowledge about student yield of apartments and single family subdivisions allows them to have “comparables” with which to assess new or planned developments. At one time it was common for districts to do a “school census” using volunteer help to locate and count the pre-school and school-aged students in their district. Over the past ten years, most medium to large school districts have adopted geo-based planning systems that require them to geo-code the addresses of their student. Most do this to support school bussing operations, but the data also serve other school planning purposes.

Related Research

Demographers and other social scientists have studied the linkages between housing and resident populations. Perhaps the best know work on the part of demographers is that of Myers (1990b). His chapter “Age Specific Population-per-Household Ratios: Linking Population Age Structure with Housing Characteristics” in *Housing Demography* examines in some detail the relationships between housing characteristics and the characteristics of those residing. For example he looks at specific housing types and year built and uses bedroom counts to estimate the population by age group. Most of his work was based on the Public Use Microdata Sample and looked at national trends, although this same analysis could be performed at county or PUMA areas with some limitations due to sampling error.

Also in *Housing Demography*, Gober (1990) surveys various theories of residential location. She first describes the “Neoclassical Trade-Off Model” based on space time location considerations and how they impact various household types, for example the dual career family without children who may opt for convenience over space. Second she describes the "ecological approach" with its beginnings in the social area analysis by Burgess, Shevky and Bell, and others (see review of this literature in Timms 1971, pp. 1–36). The social area analysts usually organized their analysis around three main factors: family, social, and ethnic status. The third approach that Gober described was the *life cycle approach*. This theory explained local changes in residence as a result of households adapting to their changing family and economic circumstances by changing residence, for example elderly empty nesters downsizing from a three bedroom home to a condominium. The notion of life cycle also was applied to housing, for example where aging garden apartments now provide housing for recently immigrating Hispanic families whose children often boost school enrollments. Elements of these three models are part of the author's intellectual heritage (see also Bourne 1971, Timms 1971, Guest 1972) and still provide valuable insights into shifts in household composition, but are not implemented in a practical way in most school enrollment forecasting models. See Plane (1994) for a discussion of housing based and cohort trend enrollment forecasting models.

The importance of the linkages between housing and school enrollment was recognized by the National Center for Educational Statistics (National Center for Educational Statistics 2002) when in the 1990s it developed the *School District Data Book*, now known as the *School District Demographics System* (SDDS), which provides special census tabulations for school districts. Some of these tables show cross tabulations of students and housing characteristics. Table 1 shows an example for the Portland, Oregon, school district. Since these data are from special tabulations of the 2000 Census they will subsequently be referred to as *Census data*. Table 1 shows that single family housing units on the average yield 0.335 students. By contrast, multifamily units with over 50 units in the development yield only 0.052 students per unit. It also shows that rental single family housing yields 0.394 students per unit, while owner occupied single family housing yields only 0.322 students per unit. These data are available from the SDDS only at the school district level. One can see how the values range by comparing yields from many school districts. These tables linking students and housing are not provided in Summary File 3, either for the 1990 or 2000 census, but can be tabulated for PUMA areas from the Public Use Microdata Sample.

Using Linked Student Record and Tax-Lot Data

Data similar to the above from the School District Demographic System can be generated from tax-lot files from local assessor's offices linked to student record data by residential location (Table 2). To determine the yield of students for various types of housing we divide number of students by number of units, after removing the units and students in units where we do not have a unit count. Table 2 shows the results of this (Tables 2a–2c), along with a simplified table from the 2000 NCES School District Demographic System data (Table 2d) for comparison purposes. Housing

Table 1 Cross tabulation of year 2000 student and housing characteristics for the Portland Public Schools District, Oregon. NCES School Demographic Data System.

A. Owner Occupied	Total	Single Family Detached	Single Family Attached	2-9 Units	10-49 Units	50+ Units	MH & Other
Children age 18 or under	55,555	53,745	715	375	50	35	635
Enrolled in public school	32,390	30,960	410	620	30	10	360
Households	105,715	92,915	2,590	6,255	1,345	1,135	1,475
Households with children	30,735	29,715	385	275	50	30	280
Occupancy Rate	0.937	0.965	0.919	...	...	...	...
Estimated Housing Units (HU)	99,102	96,285	2,817	...	...	...	...
Prop 18 & under in public school	0.583	0.576	0.573	...	...	...	...
Prop HH with 18 & under	0.291	0.320	0.149	...	...	...	...
Child per HH with 18 & under	1.808	1.809	1.857	...	...	...	...
Public school students / HU	0.327	**0.322**	0.146	...	...	...	...

B. Renter Occupied	Total	Single Family Detached	Single Family Attached	2-9 Units	10-49 Units	50+ Units	MH & Other
Children age 18 or under	32,884	14,275	1,195	9,860	5,425	1,940	189
Enrolled in public school	18,770	8,700	600	5,390	2,970	970	140
Households	84,025	20,670	2,055	23,895	21,420	15,625	360
Households with children	18,100	7,185	635	5,700	3,240	1,245	95
Occupancy Rate	0.921	0.936	0.919	0.915	0.925	0.898	0.894
Estimated Housing Units (HU)	91,280	22,083	2,235	26,002	23,151	17,405	403
Prop 18 & under in public school	0.571	0.609	0.502	0.547	0.547	0.500	0.741
Prop HH with 18 & under	0.215	0.348	0.309	0.239	0.151	0.080	0.264
Child per HH with 18 & under	1.817	1.987	1.882	1.730	1.674	1.558	1.989
Public school students / HU	0.206	**0.394**	0.268	0.207	0.128	0.056	0.347

C. All Units	Total	Single Family Detached	Single Family Attached	2-9 Units	10-49 Units	50+ Units	MH & Other
Children age 18 or under	88,439	68,020	1,910	10,235	5,475	1,975	824
Enrolled in public school	50,760	39,660	1,010	5,610	3,000	980	500
Households	185,785	113,585	4,645	26,195	22,765	16,760	1,835
Households with children	48,835	36,900	1,020	5,975	3,290	1,275	375
Occupancy Rate	0.941	0.960	0.919	0.915	0.925	0.898	0.894
Estimated Housing Units (HU)	197,352	118,353	5,053	28,621	24,602	18,669	2,054
Prop 18 & under in public school	0.574	0.583	0.529	0.548	0.548	0.496	0.607
Prop HH with 18 & under	0.263	0.325	0.220	0.228	0.145	0.076	0.204
Child per HH with 18 & under	1.811	1.843	1.873	1.713	1.664	1.549	2.197
Public school students / HU	0.257	**0.335**	0.200	0.196	0.122	**0.052**	0.243

Note: All data from School District Data System from National Center for Educational Statistics (NCES) except occupancy rate is from 2000 U.S. Census, Summary file 3 and American Housing Survey for the Portland Area. Single family owner and renter occupancy rates adjusted based on American Housing Survey. Values in bold text cited in narrative.

unit counts in may not be available for all tax-lots with housing, especially for older multifamily units. Housing tenure (owner/renter status) was not provided by the assessor's office but determined by comparing the *situs* address (the address assigned to the tax-lot by local government) and the mailing address for the tax bill.

The results for the 2002 tax-lot data are reasonably comparable to those from the 2000 special school district tabulation of the census. The yield of students for single family detached residential housing is 0.335 both in the Census and tax-lot derived data. Both show slightly higher yields for students in renter occupied than owner occupied single family housing, but the range of difference is greater in the

Table 2 Calculation of 2002 student yields from tax-lote data and comparison data from Census for the Portland Public Schools Area. Ratios with small denominators are shown as missing.

A. Students, no. of units known	Own	Rent	Total
Single family	30,635	9,060	39,695
Condo	111	90	201
Plexes	590	2,348	2,938
Apartments	48	2,095	2,143
Commercial	12	111	123
Other	27	27	54
	31,423	13,731	45,154
B. Units, no. of units known	**Own**	**Rent**	**Total**
Single family	93,625	24,806	118,431
Condo	4,352	3,099	7,451
Plexes	4,524	12,446	16,970
Apartments	1,196	27,225	28,421
Commercial	133	1,678	1,811
Other	3,379	7,204	10,583
	107,209	76,458	183,667
C. Enrolled / Unit from Tax-lots	**Own**	**Rent**	**Total**
Single family	0.327	0.365	0.335
Condo	0.026	0.029	0.027
Plexes	0.130	0.189	0.173
Apartments	...	0.077	0.075
Commercial	...	0.066	0.068
Other	...	...	0.005
D. Enrolled / Unit from Census	**Own**	**Rent**	**Total**
Single family - detatched	0.323	0.387	0.335
Single family - attached	0.146	0.268	0.200
Plexes	0.088	0.207	0.197
Apartments	...	0.097	0.092
Commercial	...	...	...
Other	...	...	...

Census tabulation. The results for *Plexes* (duplexes, triplexes, quads) are relatively close, as are the results for apartments. The tax-lot data show yields for commercial structures, which include some apartments and housing in mixed use structures classes not explicitly tabulated in the Census. The largest disagreement is for condominiums (tax-lots) or single family attached units (Census). It is likely that the identification of housing type by Census respondents and tax assessors is different. The difference also is greater since the number of condominium units in the district grew substantially from 2000 to 2002, with only a few students residing in the newly built condominium units. The tax-lot data suggest that one would find one PPS stu-

Table 3 Tax-lots by type of structure and availability of housing unit count data, Portland Public Schools area, 2005.

Type	No of Tax-lots	No Unit Count	Pct with No Units
Single Family Residential	119,219	0	0.0
Condominium	12,814	0	0.0
2-4 Unit Multi-Family	6,264	39	0.6
5-8 Unit Multi-Family	837	42	5.0
9-20 Unit Multi-Family	810	96	11.9
Court Apt 21-100 Units	206	49	23.8
Court Apt 21-100 W/Amenities	64	16	25.0
Court Apt Over 100 Units	30	13	43.3
Court Apt Subsidized Garden	80	33	41.3
Walk-Up Apt 5-20 Units	154	7	4.5
Walk-Up Apt 21 & Over	149	7	4.7
Walk-Up Apt, Subsidized	25	2	8.0
Elevator Apt High Rise	122	28	23.0
Elevator Apt Subsidized Hi Rise	98	33	33.7
Mfg Home, House boat	67	27	40.3
Other Property Types	1,493	1,180	79.0
Total	142,432	1,572	1.1

Notes: Tax-lot data are for February 2005 and are from Multnomah County.

dent for every 37 "condominium" units, whereas the census based data suggest one student for every five single family attached units.

It is safe to say that the variations in student yields from one type of housing to another vary in the same direction in the census and tax-lot data. For example, both sources show a lower yield of students for apartments with over 50 units compared to those with fewer than 20 units. It would not make sense to compare 2000 census data to 2002 tax-lot data to show change. It would make more sense to compare tax-lot data from successive years to show changes. Fortunately both the student record and tax-lot data are available annually, or as frequently as one would want to make the effort to access and process the data.

A set of tax-lot and student record data for 2005 was tabulated in a slightly different way. Housing tenure was not determined for these data. Table 3 shows the numbers of tax-lots with various types of residential uses. It also shows the number of tax-lots where unit count was unavailable, mainly for multifamily housing and a wide range of other structures with incidental residential use. Instead of using the broad structure type classifications used for the 2002 data, the more detailed property classes used by the assessor's office were used. The data show that the yield of single family units fell from 0.335 in 2002 to 0.307 in 2005 (Table 4), possibly reflecting the effects of gentrification, particularly owner to renter conversions of single family units. Apartments are broken into a number of classes and the student yields vary by type of structure. In general the student yields are higher for court, or garden, type apartments, except for those with over 100 units. Subsidized garden

Table 4 Students by structure type and yields per housing unit for structures where number of units known, Portland Public Schools area, 2005.

Type	No of Units	Students: Units Known	Students: Units Unknown	Students: Total	Students per Unit
Single Family Residential	119,261	36,670	0	36,670	0.307
Condominium	12,923	294	0	294	0.023
2-4 Unit Multi-Family	15,430	2,970	26	2,996	0.192
5-8 Unit Multi-Family	5,176	685	73	758	0.132
9-20 Unit Multi-Family	8,837	1,130	130	1,260	0.128
Court Apt 21-100 Units	5,250	847	78	925	0.161
Court Apt 21-100 W/Amenities	2,203	405	52	457	0.184
Court Apt Over 100 Units	2,451	181	47	228	0.074
Court Apt Subsidized Garden	2,368	752	231	983	0.318
Walk-Up Apt 5-20 Units	2,205	39	0	39	0.018
Walk-Up Apt 21 & Over	4,968	94	4	98	0.019
Walk-Up Apt, Subsidized	1,273	16	0	16	0.013
Elevator Apt High Rise	7,511	66	6	72	0.009
Elevator Apt Subsidized Hi Rise	6,043	296	7	303	0.049
Mfg Home, House boat	193	47	97	144	0.244
Other Property Types	14,768	109	207	316	0.007
Total	210,860	44,601	958	45,559	0.212

Notes: Tax-lot data are for February 2006. Student record data are for Fall 2005 and are from Portland Public Schools.

type apartments displayed student yields nearly as high as those for single family housing.

About Assessors Tax-Lot Files

Tax assessor's files are maintained for the purposes of determining the tax owed for each parcel tax-lot. The way in which these systems are administered varies from state to state and within states by counties. States normally provide guidelines for how local jurisdictions carry out the assessment of properties and collection of the resulting taxes (for an example, see Oregon Department of Revenue 2003). The professional associations for tax assessors, such as the International Association of Assessing Officers (IAAO), advocate standards and provide a vehicle for communication among tax assessors (see Renne and Cae 2003 for a review of assessing methods). Joint efforts between the IAAO and the Urban and Regional Information Systems Association (URISA) have facilitated the automation of the tax-lot database to the form in which it now exists in larger jurisdictions.

There are two distinct aspects to the tax assessor's tax-lot database – (1) the cadastral maps showing ownership, and (2) the data files describing the attributes of each property. Land surveyors map the legal descriptions of each property. At one time these maps were maintained on paper or film and were updated by hand.

Over the past 30 years they have been migrated from paper to CAD (Computer Assisted Design) drawings, and then into topologically indexed GIS (Geographical Information System) databases (Dueker 1987). The tax-lot may be mapped as a polygon for the property boundary or as a point centroid for the polygon. Each tax-lot has a unique identifier that ties it to the attribute data. In the past the attribute data were kept in paper ledgers, but now they are in database files where they are linked to their mapped location by a tax-lot ID and can be accessed using GIS tools.

The principal reasons for maintaining the tax-lot databases are the need to document the ownership of property and to determine the taxes owed. Taxes usually are based on the property classification, the value of the land and the property, and tax-rate schedules. However, in Oregon and some other states, property tax limitations have capped property taxes below that which would result from the appreciation of the value of a particular property. To some degree, this has diminished the benefits to the assessor of timely maintenance of these data.

As these tax-lot map and attribute data became widely available through GIS databases, it became apparent to planners and others that these data had considerable value beyond their use for tax assessment. GIS staffs in local government have become brokers between the assessor's offices and other users, such as planning, human resource, and utility departments. Today the tax-lot files form the basis for urban and regional planning databases in most medium to large cities and counties in North America. However many assessor's offices are experiencing declining budgets and find it difficult to support new demands placed on their staffs.

The variables describing properties will vary from one jurisdiction to another but the list below is a partial list of variables that that may be of interest to a demographer. What is easily accessible may depend on negotiations between the assessor's office, the GIS staff acting as a broker, and the needs of other local governmental entities desiring to use the data.

Property class Normally a distinction will be made between different types of property such as residential, commercial, industrial, or public uses. Within each class there will be further breakdowns such as residential into single family units, condominiums, duplexes, elevator apartments, and others. Commercial properties will include retail and services but also may include downtown commercial apartments, motels, and other locations where people may reside on a permanent basis. Apartments may be divided into solely private ventures and those with some type of public support, which may merit different treatment for taxation purposes. Usually there will be many more property class codes than a demographic researcher will want, and the codes will need to be aggregated into broader, meaningful classes.

Year built The year the structure or structures were built is usually available. However consider the example of a garden-type apartment initially built in 1960 with additional units added in 1964, and 1970. The tax record may show the year built as 1960.

Assessed value The assessed value of the property normally is shown as the sum of the value of the land and that of the structures. The two can change independently, for example the value of an older residential structure may decline but the value of the property, considering its redevelopment potential, may increase. The assessed value is usually determined by a combination of field inspections and mathematical modeling.

Sales Data for recent or at least the last sale and date of sale and amount of sale are available in Oregon. Not all states require disclosure of the sale value of a property.

Lot and building square feet The acreage of the lot is computable from the tax-lot maps and the legal description. The area of the structure in square feet representing useable space normally will be something desired by the assessor in determining taxes owed. Where counts of rooms are not available, building square feet may need to be used as a proxy.

Zoning Zoning class is designated by the local planning authority. The zoning class many not correspond to existing use. A residential property along a busy arterial may have been up-zoned to a commercial classification, resulting in a higher land valuation because of its potential use.

Rooms in structure One may find data showing some type of inventory of bathrooms and bedrooms and other features but these data are likely to vary from one jurisdiction to another. In the case of data from Multnomah County used for most of the examples in this paper, the county provided bedroom counts in a 2002 release of the tax-lot data but by a second release in 2005, it had stopped providing counts of bedrooms. From a school demography standpoint, this lack was unfortunate since the number of bedrooms proved a useful predictor for the number of PPS students residing in the dwelling.

Housing unit counts This is something very basic that one would like to have for demographic analysis. To know how many school-aged children live in a typical garden apartment complex, you need to have the count of students living in this complex and the number of units. You may find that the assessor's tax-lot files do not record a unit count, especially for older properties and commercial structures. The assessor may not need to know how many apartment units are on a property, instead using building square feet in the complex to assess market value. There may not be a mechanism in place in the normal work-flow of the assessor's office that provides the unit count and increments or decrements the count based on building permit data. In the case of the examples shown in this paper, we do have reasonably good housing unit counts, but the results came from efforts outside of the assessor's office, and there is no easy way to update and maintain currency of the counts.

Housing tenure Knowing whether a unit is owner or renter occupied is important for demographic analysis. We are accustomed to having tenure data from Census sources. The main problem in the tax-lot data is with single family housing units since most multifamily units are renter occupied. Renter occupied units tend to have a higher density of school-aged children. None of the Oregon tax-lot files that we have used provided owner/renter status. What they do provide is an owner address for mailing the tax bill and a *situs* address for the location of the property. One can compare mailing address and *situs* address and determine whether they match – if they are the same, it is owner occupied. It is a fairly time consuming procedure involving geo-coding the mailing address file against the *situs* address file, with several stages of matching to make sure those that have the same address, but are spelled or formatted differently, are counted as "owner." Some jurisdictions, such as those in California, provide a home owners exemption, and the assessor needs to know whether the unit is owner occupied. If owners cease to occupy a housing unit, they are expected to notify the taxing jurisdiction, but some may not, either purposefully or because of oversight.

About Student Record Data

Perhaps less needs to be said about the student record data. Accurate student addresses are needed in order to geo-code the students so their residential location can be mapped and linked to the tax-lot where they reside. Some addresses will be incorrect due to data entry errors or miss-statement by the student. However schools carry out frequent correspondence with parents, and addresses tend to be corrected over time. Often the individual tax-lot addresses in the tax-lot file are used as the reference file for geo-coding the student addresses, in which case the linkage between the tax-lot and the student follows directly from this effort. The student record data shown in the examples in this article include the following:

School The school or program that the student attends.

Attendance area Where the student resides, determined by using GIS tools to intersect attendance area boundaries with point location of students.

Age The school-aged population is generally age 5–18.

Grade level Recorded as KG-12, sometimes grouped into elementary, middle, and high school level, or whatever administrative groupings are appropriate.

Race For Oregon schools, Hispanic origin is treated as a race along with white, black, Asian, American Indian, and other.

Gender Some PPS programs are being organized by gender, so this category may be important for future analyses.

Other variables such as participation in free and assisted lunch programs and classroom performance could be added. Basically any characteristic of the student that links to the student ID can be used.

Linking the Tax-Lot and Student Record Data

Linking the student record and tax-lot data is a fairly simple matter using GIS tools. One can use a "nearest" function to match each student's location with the nearest tax-lot polygon centroid (in some cases simply any point inside of the tax-lot boundary). It may sound burdensome, but it is simple to do using GIS tools. An example of the results of such linkage is shown in Figure 1. Two of the cases were exactly co-located, and the third placed the student 57 feet from the nearest tax-lot centroid, likely because the student address was matched to the street address file rather than the tax-lot file. The result of the linking is a table of about 48,000 records where each tax-lot–student linked record looks like that in Figure 1, allowing us to cross tabulate student and tax-lot data.

Let us go on to look at some practical applications. Two are drawn from work for Portland Public Schools, Oregon (PPS), a large metropolitan school district with declining enrollment (Edmonston and Lycan 2002), and one is for the Bend-LaPine School district in central Oregon, one of the most rapidly growing areas in the country.

Example 1: Housing Tenure and the Yield of Students

The first example examines the yield of students from single family housing, comparing the student yield from owner occupied and renter occupied single family housing for the Portland Public Schools District (PPS). Previously we examined some results for the PPS as a whole, showing that the yield was significantly higher for rental single family housing (0.359 students/unit) than for owner occupied single family housing (0.323 students/unit). Here we will look at the student yields at a very geographically detailed level. We begin with the point locations of the 48,000 students referenced by housing type and the approximately 170,000 residential properties. We then calculate the ratio of students to housing units by type for a fine grid, 1/16th of a mile on each side, averaging the ratio over a ń mile radius, and map the results using a color gradation (Figure 2).

The results are mapped to facilitate visualization but could be shown in tabular form for any geography, such as census tracts or school attendance areas. What we find is that the yield of owner occupied single family units across the school district is relatively uniform, varying modestly around the district average of 0.323 students per unit. By contrast the yield of students living in renter occupied single family housing units varies widely above and below the district average of 0.359 students

Student Record Data	Student ID	850902	127863	949295
	School Attending	290	258	264
	School Name	Whitman	Kelly	Lee
	DOB	11/21/1996	5/8/1997	4/1/1997
	Age	6	5	5
	Grade	01	01	01
	Gender	M	M	M
	Race	B	W	A
	X Coord	7,664,928	7,666,899	7,666,717
	Y Coord	662,792	688,831	669,818
	Geo-coded from	TAX	PRE	PRE
	Elem Sch Att Area	290	258	264
	Middle Sch Att Area	263	263	254
	High Sch Att Area	220	220	218
Linked by Nearest	**Distance - Student to tax-lot in feet**	0	0	57
Tax-lot Data	Tax-lot ID	BQR8753	NTZ0593	XYZ0001
	Land Value	36,500	40,670	47,500
	Bldg Value	95,580	107,230	139,190
	Total Value	132,080	147,900	186,690
	Bldg Sq Ft	1,371	1,768	2,050
	Acres	0.040	0.120	0.130
	Year Built	2002	1956	1942
	County	M	M	M
	Units in structure	1	1	1
	Bedrooms	3	6	4
	Landuse	SFR	SFR	SFR
	Tenure	RNT	OWN	OWN

Fig. 1 Linking tax-lot and student record data.

per unit. There is a large area of older single family housing in the inner core of the district in which there are less than 0.100 students per renter occupied unit. Conversely, in patchy areas and in a band along the northern and eastern edge of the district, there are more than 0.500 students per unit in single family owner occupied housing. Many of these areas of single family rentals with high student yields house large minority populations. It is possible to track these trends on an annual basis to better understand some of the demographic trends that underlie shifts in school enrollments. Also, being better able to explain the mechanics of enrollment decline makes it easier to explain the process to parents who may be impacted by school closings and other responses by the District.

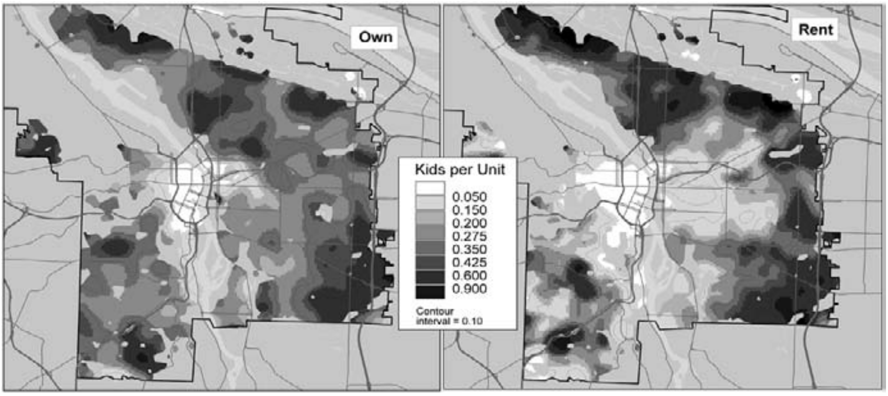

Fig. 2 Loading of students for single family housing. Portland Public School area, 2003.

Example 2. Estimating Enrollment Impacts Using Bedroom Counts

The second example also is drawn from our work with Portland Public Schools. In 2003 a large public housing development, New Columbia, was under construction in a low income area of the district. It was to replace, on the same site, an older public housing development (Housing Authority of Portland 2004). The original occupants were temporarily re-housed by the Housing Authority of Portland, with a priority to return when New Columbia was completed. Most of the new housing was to be rented but some of the units were to be sold rather than rented. The qualification process to purchase this housing was based on income and household size and tended to favor families with children. The housing was to sell for under $225,000 per unit, relatively inexpensive by Portland standards.

The question posed to PRC was what the enrollment impact would be of the returning families and of others who moved into the market housing. There was a hope on the part of the Housing Authority of Portland (HAP) that the development would increase enrollment sufficiently to justify building a new school within the development. The study dealt with several types of housing, but here we will only look at the housing available for purchase. HAP provided us with a schedule for construction of the development and the numbers of units with 2, 3, or 4 bedrooms available in each phase of the development. Our approach was to look for comparable housing and to determine the student yield of comparable units by number of bedrooms, also considering age and race of the students. Initially we considered using data for the surrounding high school attendance area, but the number of relevant units was too small so we used data for the PPS district as a whole. We selected single family owner occupied housing, built since 1990, and with assessed value below $225,000. These units and the students residing in them were then classified by the count of bedrooms in each unit (Table 5). The results of this effort provide us with student yields for housing according to vintage and number of bedrooms for single family housing priced under $225,000.

Table 5 Units and students by housing vintage and numbers of bedrooms for owner occupied single family housing valued under $225,000, Portland Public Schools area, 2005.

Units	Year Built				
Bedrooms	N/A	Pre 1940	1940-1989	1990-2003	Total
0	78	75	47	17	217
1	0	1,015	221	8	1,244
2	1	8,341	6,129	105	14,576
3	1	8,758	11,293	2,120	22,172
4+	2	5,958	2,586	348	8,894
Total	82	24,147	20,276	2,598	47,103
Students	**Year Built**				
Bedrooms	NA	Pre 1940	1940-1989	1990-2003	Total
0	51	22	29	2	104
1	0	370	72	2	444
2	0	3,274	2,357	40	5,671
3	0	3,710	4,811	1,300	9,821
4+	5	2,751	1,369	231	4,356
Total	56	10,127	8,638	1,575	20,396
Students/ Unit	**Year Built**				
Bedrooms	NA	Pre 1940	1940-1989	1990-2003	Total
0	0.654	0.293	...	...	0.479
1	...	0.365	0.326	...	0.357
2	...	0.393	0.385	0.381	0.389
3	...	0.424	0.426	0.613	0.443
4+	...	0.462	0.529	0.664	0.490
Total	0.683	0.419	0.426	0.606	0.433

Notes: Tax-lot data are from Multnomah County for February 2006. Student record data are for Fall 2005 and are from Portland Public Schools. The "NA" column represents tax-lots for which the number of housing units was unknown.

The tabulations show (Table 5) that a large proportion of the less expensive owner occupied single family housing in the district was built prior to 1940 and houses a large share of the district's students. While housing built prior to 1990 shows a mix of 2, 3, and 4+ bedroom units, nearly all of the housing built since 1990 consisted of three bedroom homes.

We divide the number of students residing in housing by vintage and bedroom count by the comparable count of units to get a student yield figure. Note that the yield for the strata of housing considered rises from 0.381 for two bedroom units to 0.664 for four bedroom units. These student yields are considerably higher than those for the district as a whole, reflecting the age and cost of the housing. Using figures for the numbers of units by bedroom count provided by the Housing Authority, we then can calculate that when the three phases of the development are completed we might expect there to be 129 Portland public school students in the

Table 6 Estimates of number of students in owner occupied housing in New Columbia owner occupied housing.

A. Housing Units	Bedrooms			
	4	3	2	Total
1st Phase Home Ownership	22	32	22	76
2nd Phase Home Ownership	19	30	19	68
3rd Phase Home Ownership	24	38	24	86
Total New Columbia	65	100	65	230

B. Students / Unit by Bedrooms		
4	3	2
0.664	0.613	0.381

C. Estimated No of PPS Students	Bedrooms			
	4	3	2	Total
1st Phase Home Ownership	15	20	8	43
2nd Phase Home Ownership	13	18	7	38
3rd Phase Home Ownership	16	23	9	48
Total New Columbia	43	61	25	129

Notes: Counts of planned units provided by the Housing Authority of Portland. Students per unit are from Table 5.

owner occupied housing in New Columbia. By linking October 2006 enrollment for the district to the current tax-lot files, we were able to determine that 80 PPS students resided in the single family housing in New Columbia compared to our estimate of 129. However only 128 of the planned 230 units were occupied in September 2006. If we extrapolate from the 128 occupied units to the full 230, we might expect to find about 143 students when the single family housing is fully built and occupied, slightly more than the 129 forecast.

Since the study was completed in 2003, Multnomah County ceased providing bedroom counts in the tax-lot files. They felt that it was not needed for the tax appraisal process, the counts were not accurate, and the data were expensive to maintain. They also pointed out that, conceptually, counting bedrooms is difficult since a "bedroom" often is used as an office or for other purposes. One can use the measure of "building square feet" as a substitute, but it does not directly correlate with bedroom count and is not as concrete in explaining the relationship between housing space and numbers of students.

Example 3: An Enrollment Forecast Linked to a Land Use and Density-Based Planning Study

The final example is drawn from an enrollment forecasting project for the Bend-LaPine School District. In this project we worked very closely with land use plan-

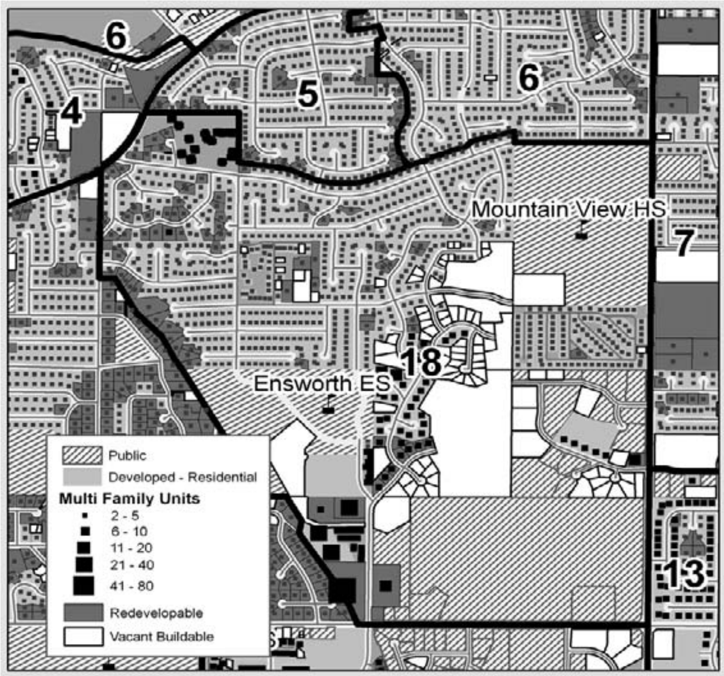

Fig. 3 Example of enrollment forecast planning area for Bend-LaPine, Oregon School District.

ners from the City of Bend and those for surrounding Deschutes County. The city was in the process of finishing a major comprehensive plan that included a complete inventory of existing land uses and vacant lands classified by zoning and potential for development. A population forecast was associated with the build out of existing vacant lands and conversion of under utilized lands. The forecast was not for a point in time, but for that time at which the vacant land in the area would be substantially exhausted. We were asked to link our small area enrollment forecasts to this planning model.

For our enrollment forecasting purposes we divided the school district into 25 planning zones, about two-thirds of them inside the urban growth boundary for the City of Bend. “Area 18” as shown in Figure 3 will be used as an example to illustrate how the student/tax-lot data were used in the enrollment forecasting process. It is an “attendance area fragment” from which students uniquely are assigned to one elementary, one middle, and one high school. This area consists of mainly moderate cost single family housing and a substantial number of multi-family units. Figure 3 shows the land use status for existing residential uses as well as vacant buildable and redevelopable tax-lots.

As a result of efforts by the city planners, we were fortunate to have highly accurate housing unit counts, including those for apartments and other miscellaneous housing units. We did not determine housing tenure. We multiplied the acreage of

Table 7 Estimated build-out enrollment for sample school planning area, "Area 18", Bend-LaPine School District, 2005.

	Planned housing density							
	Res standard	Res medium	Res low	Res high	UAR 10	SR 2.5	Other	Total
A. Development Status, developable acreage								
Dev. - Non Res.	0.0	0.0	0.0	87.2	0.0	0.0	0.0	87.2
Public + Rec.	44.4	29.6	0.0	0.0	0.0	0.0	0.0	74.1
Dev. - Res.	113.0	28.9	0.0	20.2	0.0	0.0	0.0	162.1
Vacant	14.6	37.4	0.0	18.7	0.0	0.0	2.3	72.9
Redevelopable	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Unbuildable	12.3	5.1	0.0	1.2	0.0	0.0	0.0	18.6
Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	185.0	100.9	0.0	127.3	0.0	0.0	2.3	415.5
B. Planned Density Range, units/acre								
Low range	1.2	7.3	6.0	21.7				
Median	6.0	10.0	8.0	35.0	0.1	0.4 ...		
High range	7.3	21.7	10.0	43.0				
C. Vacant and developable residential lands, acres								
Vacant	87.4	373.6	0.0	655.2	0.0	0.0	0.0	
Redevelopable	4.2	0.0	0.0	0.0	0.0	0.0	0.0	
Total	91.6	373.6	0.0	655.2	0.0	0.0	0.0	0.0
D. Enrolled / Unit	0.332	0.225	0.300	0.206				
E. Estimated Enrollec	30	84	0	135	0	0	0	249

Notes: Housing density data are from the Bend Buildable Lands Inventory, City of Bend, Oregon, June 30, 2005. Data on enrolled per unit are estimated from linked tax-lot and student record data using Fall 2004 student data.

vacant and buildable tax-lots by the median planned density to estimate the number of additional housing units that could be accommodated (Table 7). We then multiplied the number of additional units times an assumed value for enrolled/unit, resulting in an estimate of increased enrollment of 249 students. If the proportion of elementary school enrollment to total enrollment in area 18 remained the same, an increase of 120 additional elementary school enrollments would result by build-out time, about 20 percent of the capacity of a typical elementary school.

This forecast is not for a particular point in time, but is useful for determining how many more school sites would be needed by the time the available land inside the Bend urban growth boundary is consumed, likely in the next ten years. The build out forecast informed the models used to generate forecasts by grade and year, but were not mathematically integrated. The approach used was appreciated by the local school district and the city planners because it helped to integrate school and land use planning.

Conclusions

Building tables that link the characteristics of students with those of the housing unit where they live is both feasible and useful but can be time consuming. It has proven useful in a number of school planning applications where estimates of student yield from different types of housing were needed. It serves to link planning efforts by community land use and housing planners to facilities planning for school districts. It also can be useful in producing tables and maps that inform the school district's public about demographic trends in their district. Beyond producing enrollment forecasts, school demographers also have a responsibility to educate school administrators and the public about how their district is changing.

As the quantity of small area data from the census declines, demographers will need to depend on using linked sets of administrative records data to track trends. School enrollment and tax-lot data are useful to this end in that they provide some insights into changing ethnicity and age structure in the community, albeit only for school aged children, but some useful extrapolations can be made to the population as a whole. These data are not quite at the household level since a tax-lot can include a number of residential structures (such as an apartment development with a mix of 2 and 3 bedroom apartments) but they do approximate households for single family dwellings. The data can be aggregated up into various geographies such as census blocks, housing subdivisions, or school attendance areas.

There are a number of problems and limitations in using these data. The tax assessor's data are maintained for the purpose of determining citizen's tax bills and the assessor's allocation of resources supports this purpose. The classifications of housing units in tax-lot files are quite detailed and require that the user aggregate them in a meaningful way. Even with the best effort, the resultant data likely will not match the census classification of housing types. The student record data also presents some problems. The data are regarded as confidential by school districts and require proper security and efforts to avoid disclosure. The classifications of race and ethnicity generally will not match the census since they tend to treat Hispanic as another race. The student record data need to be geo-coded (address matched) to a coordinate location in order to link them to the tax-lots. Geo-coding is an imperfect process involving some human judgment and so not all of the linkages between student residence and tax-lot will be correct.

We have not adequately linked the housing based enrollment models discussed in this article with cohort progression models that carry students by grade level from one year to the next. There are some complexities in doing this that would require more discussion than space allows here.

If you are interested in making use of the tax-lot files for your community you will want to contact your local tax assessor's office or the office of the GIS coordinator. Many cities and counties are making these data available on-line to their citizens, although this access works best for a few properties and you no doubt will want thousands of tax-lot records for the entire community. You also should become involved with other organizations in your area who make use of these data and who advocate for more extensive and better data. Keep in mind that the assessor's office is funded to support the effort of fairly collecting tax moneys, not as a utility for planners and university researchers. While there may be a high return on investment in better and more widely available tax-lot data, the benefits may be mainly outside of the assessor's office while the cost is theirs to bear. You may be able to help persuade county commissioners, or others who hold the purse strings, to provide more resources to the assessor's office to meet this broader range of needs for their data.

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Chapter 16
Demography and Turnover*

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Introduction

In the managerial planning of a company's human resources, demography can be used in different ways: for example, to estimate the amount and composition of the workforce, in the attempt to better adapt the strategies of personnel management to demographic changes. This is true especially if we consider that company populations present features similar to the real populations: indeed, as the structure of a population is interested by various phenomena that determine changes in its amount and composition, similarly the pyramid of a company's personnel levels is the result of the formation of professional careers according to development rules given by the company's statutes (Santini 1995: 49–65). The flows inside and outside the company can be seen as migratory processes, in particular immigration and emigration.

The firm's populations are influenced by phenomena that could cause quantitative variations (hiring, dismissals, resignations, and deaths) as well as qualitative ones (inner movements: transfers, promotions, and retreats).

The study of the events' calendar (that is their temporal distribution) can be made with reference to the age of entering in the organization and the level of seniority. Moreover, as for the human populations, several phenomena can be analyzed from a cross-sectional point of view (contemporary analysis), observing at a specific time all the individuals that compose the organization and their characteristics, or from a longitudinal point of view (cohort analysis), individualizing a group of individuals (which is exactly the cohort) that have a definite characteristic in common (for example, the time of entering the organization) and following their evolution over time. In this way it is possible to analyze the careers of individuals, just as for hu-

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man populations it is possible to observe the biographies, being also able to compare directly the careers of two or more individuals.

It is possible to characterize three areas of concrete application of business demography (De Bartolo 1997: 192): the market's strategies, the decisions regarding the investments, and the management of the human resources. With regard to this last aspect, various studies have shown that demography can be a useful instrument of fundamental importance for the achievement of considerable objectives related to the managerial planning of human resources. Between the various uses of the demographic techniques, we can indicate some that appear of fundamental importance: (1) the analysis of the demographic composition of the population of a company; (2) the forecast of the consistency and the future composition of the manpower; and (3) the possibilities of adapting the strategies of personnel management to the emerged demographic changes.

Therefore, a company can be described on the basis of its workers' different characteristics (sex, age, length of service, level of education, etc.). The analysis of such characteristics is the first step to managing and planning human resources and to estimating the future needs of the company. This analysis comes along with the examination of the factors which determine the changes in the structure of the company population, among which the phenomenon of turnover has a special significance. Its level represents an indirect indication of the company's efficiency.

A correct management of human resources appears still more fundamental today in consideration of the verified existing relation between employee satisfaction and customer satisfaction. Many studies (including Schneider and Bowen 1985, Band 1988, George 1990, Reynierse and Harker 1992, Schneider et al. 1988, Johnson 1996, Rucci et al. 1998, Payne et al. 2000, Harter et al. 2002, Livingstone and Abbot 2003, Gelade and Ivery 2003, Homburg and Stock 2004), in fact, have marked such relation, showing that positive changes in the attitudes of employees (as a consequence of their professional satisfaction) lead to positive changes in the satisfaction of the customers.

Starting from all these considerations, the characteristics of turnover as a complex phenomenon will be examined in the present paper, along with some measures of this phenomenon taken from demographic analysis. Attention will be drawn to the turnover distribution according to length of service. It has been pointed out (Barber 1979) that an excessive company turnover represents an indirect indication of a company's inefficiency. In fact, to replace a worker, the company needs to pay an additional cost to carry out all the replacement procedures; moreover, the turnover often causes the loss of know how, which cannot be easily replaced with a new arrival. Finally, as this research is still in progress, the relation between business demographic heterogeneity and turnover will be examined by drawing on empirical cases found in the literature.

Demography and Management of Workforce

The demographic distributions which take place in a company can have an impact, both in theory and practice, different from the one obtained on the basis of the characteristics of each individual. For example, while there is no empirical evidence that shows the impact of sex on work performance or level of stress, there is, on the contrary, evidence that a different proportion of women and men in an organization can affect the form and the nature of social integration, especially in terms of psychological well-being, attitudes, and performance (De Bartolo 1997: 236).

The contribution of demographic analysis in a company can occur with regard to two distinct aspects: the descriptive analysis and the management. In the first case (Hugo 1990), the demographic characteristics of the company personnel are observed and then analysed by drawing on the characteristics of the local work market. In the second (Santini 1995), the company uses the methodologies and the procedures of demographic analysis to study and manage the company population: in order to do so the coming and leaving, which modify the total number (recruitment, dismissal, resignation, retirement, death), are analysed as are the factors which modify the qualitative composition (promotion, demotion, transfer). The objective, in this case, is to develop possible future scenarios or to manage temporary circumstances, for example the excess of personnel and the need to go back to ideal dimensions within a reasonable lapse of time.

Taking into account the link existing between demographic characteristics and workers' collective performance, the manager of human resources can try to reduce some undesired phenomena that occur in the workforce, among which a great emphasis is given to turnover (Daft 1992).

The Demographic Factors That Affect Turnover

An Analytical Framework

In the study of the workforce of a company, the analysis of the "losses" in the human resources (turnover-wastage) has received special attention on the basis of the significant effects that this phenomenon has on the companies: in fact, without an analysis of the losses, it is impossible to achieve strategies of recruitment, training, or promotion (De Bartolo 1997). The concepts, the methods and the instruments of demography are especially useful to analyse the wastage, as this phenomenon is a consequence of the impact of the demographic composition of the company by means of the following variables: cohorts' identity and conflict (Pfeffer 1983). Although in the present article, the two terms, "turnover" and "wastage," are used with the same meaning, a clear distinction exists among the two terms: both represent a loss, however in the case of turnover such a loss is replaced. Therefore, the term wastage refers to voluntary resignation, retirement, death, and dismissal, while the term turnover refers to promotions, transfers, etc.

The company turnover is often considered as a simple phenomenon and is therefore measured, as will be shown later, with elementary measures. As a matter of fact, it is a complex phenomenon, linked directly to the demographic characteristics of the company personnel: for example, it decreases when the length of service increases; it is higher for women; it diminishes with higher qualifications; it lessens with age. The first is the most important characteristic, so much so that it can be considered as a rule, and it is fundamental in many methods of prediction of the phenomenon. In the literature, in almost all the cases studied, the length of service is considered a fundamental variable which influences the company turnover (Wiersema and Bantel 1993, Gerhart 1990, McCain et al. 1983, Price 1977), as well as the organizational innovation in a company (Flat 1993), the social relations (Hambrick et al. 1996), and also the company performance (Keck 1997).

The analysis of the turnover according to length of service is a valid starting point to predict the future turnover; this is even more so for organizations that have existed for quite a long period of time and have a relatively stable workforce. For these organizations, the distribution of the company's manpower by length of service will be relatively similar year after year. In this case, the number for resignation in a given year may be a satisfactory prediction of how many will leave in the following year (De Bartolo 1997: 243).

The time of arrival in the organization (and thus the length of service) can be considered as the basic element to promote a feeling of similarity and attraction through the effect of the so-called cohort tie: it happens, in fact, that the individuals who enter an organization in the same period of time are able to better interact and share more experiences (Wagner et al. 1984). Apart from the length of service, there are further demographic characteristics which influence, according to the demographers, the turnover level. Many focused on "job satisfaction" (a factor which can favour the retention of the workers in the company), which may be hampered by differences in the characteristics of the individuals who belong to the company (Hackman and Suttle 1977, Mobley 1977). Some scholars (see Werbel and Bedeian 1989) focused on the existence of a link between age and turnover, which sends us back to the link with the length of service previously underlined.

The observations conducted so far are in accordance with the conclusions reached by many scholars of Theory of Organization (supported by studies in Psychology of Organization), which highlight how the demographic features of a company's workers (sex, age, length of service, education, etc.) can have an impact on their level of *similarity* and can influence their social cohesion and integration within the company (Pfeffer 1985). Workers who have the same age or same length of service share some characteristics that make them similar, thus contributing to a strengthening, for many aspects, of their relationships (De Bartolo 1997: 233).

Demographic heterogeneity is considered by many demographers of Organization as the principal cause in determining the company turnover, especially as such heterogeneity results in low levels of integration or attachment to the group (Williams and O'Reilly 1998, O'Reilly et al. 1989). The central element which links the group composition to the workers' attachment may derive from the paradigm of similarity/attraction (Berscheid and Walster 1978, Blau 1977), according to which people are attracted to those who resemble them (Tajfel and Turner 1986, Turner 1985, Byrne 1971, Becker 1957) and the levels of workers' interest in their job could be lower when there are different demographic features (Tsui et al. 1992: 554). The similarity between members of a group promotes social interaction, creation of friendly ties, and social integration (Festinger 1954), partly because the interaction among fellows is easier, partly because similarity leads to a positive strengthening of shared opinions and behaviours.

The demographic factors that affect turnover levels are, therefore, numerous and have to be considered within a larger group of processes that affect the phenomenon. Bowey (1974) listed 10 fundamental processes that may cause turnover, labelling them with the adjectives "push" (if they are factors of expulsion from the organization), "pull" (if they are factors of attraction outside the organization), or "neutral" (when they can be defined neither push nor pull): (1) higher salary (pull); (2) career advancement (pull); (3) alternative possibilities of work (pull); (4) interpersonal tensions and conflicts in the organization (push); (5) staff reduction as decided by the manager (push); (6) work dissatisfaction (push); (7) loss of new "unstable" recruits (neutral); (8) pressure due to job reduction (push); (9) pressure due to post change (push); (10) chance to hold alternative roles (pull).

The "push"-type factors depend on the organization and can hardly be controlled by the single worker, while the "pull"-type factors depend more on the will of the single individual. The demographic heterogeneity can be reasonably considered one of the causes of the processes as in points 4 and 6 of the previous list.

The reasons for resignation are often unknown, although an analysis of this may contribute to the implementation of prediction and control methods of turnover. An efficient way to understand these reasons would be to interview people who abandon. Although the study of the reasons for the resignation may help understanding which aspects of the organization can be improved, the long-term turnover trend can also be affected by external factors, such as the general situation of the work market, changes in the structure by age of the population, changes in the income level of the communities in question, and so on (Barber 1979: 47).

Some Case Studies on the Influence of Demographic Heterogeneity on Labor Turnover

Over time, various empirical studies have tried to demonstrate the influence of the heterogeneity degree on turnover in organizations. In the following, we will only cite a few of them which, together with those already quoted in the previous paragraph, allow us to support the thesis of the linear correlation existing between demographic heterogeneity and turnover. In 1993, Alexander et al. carried out a search for the Institute of Industrial relations of the University of Berkeley in California. They focused their attention on a sample of 383 community hospitals, examining the correlation between the nurses' rate of turnover and four dimensions of demographic heterogeneity individualized about the nursing staff of the observed hospitals. The authors tried to go beyond the simple measurement of the correlation degree to determine whether such correlation were of linear type or assumed the shape of a turned upside down U. Substantially the authors wanted to verify one of the two hypotheses:

H1: The larger the level of demographic heterogeneity in the organizations, the higher will be the rate of turnover (so the correlation is of linear type).

H2: The rates of turnover will be lowest in the organizations whose demographic heterogeneity is much higher or much lower, and highest in those organizations that show intermediate levels of demographic heterogeneity (turned upside down U correlation).

The first hypothesis is supported by various studies (Pfeffer 1983, Daft and Weick 1984, Hambrick and Mason 1984, Pfeffer and O'Reilly 1987). The choice of the second hypothesis to verify was based, instead, on an old study by Blau (1977), which affirmed that, in organizations of small dimensions, very high levels of heterogeneity can improve the communication, the interaction, and the social integration between the members of the organization itself, since the barriers to such interactions are broken off just from the small dimensions of the group (Blau 1977). The author therefore tried to verify if the turnover could be maximum in correspondence of an intermediate level of heterogeneity, while higher or lower levels of difference between the employees of the organization would not cause an increase in the number of resignations.

Alexander et al. (1993) showed three of the four dimensions of demographic heterogeneity considered in relation the nursing staff of the hospital to be positively and monotonically (in linear shape) correlated to voluntary turnover, while no empirical evidence was found for a curvilinear relationship (hypothesis 2). This study appears, therefore, consistent with previous research in the business organizational field that has demonstrated a linear relationship between demographic heterogeneity and turnover.

Moreover, the authors have discovered that, in addition to the real demographic factors, the process of *social construction* of the demographic diversity could explain a meaningful amount of the variance recorded in the observation of organizational turnover. Perhaps it is not only the dimension or the composition of the groups that lead to the reduction of the organizational communication, integration, and cohesion, but also the definition of demographic categories distinguished on the basis of the different experiences in the practice of the nursing profession. As an example, the dispersion degree which is shown on the basis of factors such as the different formation processes, can reflect dissimilarities in the philosophy of the nursing cares and lead, therefore, to an impoverishment of the communication and integration, causing high turnover between the groups in the nursing profession. Therefore what influences the rate of turnover is not the demographic characteristic in itself, but the social distance that such characteristic generates. Such results are significantly related to the process that ties diversity and turnover.

Sørensen (2000) examined how the demographic histories of top television station managers affect the rate of managerial turnover. This longitudinal study showed, just as the previous one had, that the individuals that had been part of mainly heterogeneous work groups demonstrated a greater impulse to abandon the organization than those whose career (biography) was not characterized by working experiences in demographically irregular groups. Regarding the study of Alexander et al. (1993), Sørensen goes beyond concluding that it is not the current composition of the group that influences the decision of the manager to leave, but all his working history: the effects of the demographic composition on the attachment to the organization would be cumulative, so they would manifest over time.

Many empirical studies at different times, have shown the positive correlation between demographic heterogeneity and turnover: some interesting bibliographical reviews of these studies can be found in Carrol and Harrison (1998) and Williams and O'Reilly (1998). In this last work, in particular, the authors identified and re-analyzed nine scientific studies published on the topic, all based on experiential observations in organizations at several levels, finding in eight of them clear support to the theory of the tie between demographic composition and turnover. Just one of the analyzed studies maintains the thesis that the relation does not exist (Wiersema and Bantel 1993).

Some Turnover Measures

As it has been previously observed, company turnover is a complex phenomenon. It is a consequence of many processes, as we have listed (Bowey 1974) and is classified in expulsion factors that operate in the company, called "push." There are expulsion factors which, on the contrary, operate outside the company, called "pull." Finally, there are factors which are neither push nor attraction, called "neutral" factors. However complex, the turnover is often measured by elementary indices such as, for example, the crude turnover rate, *TR*, a relation between the number of resignations recorded in a given period of time, usually a year, and the average number of workers present in the company in the same period of time. This index was introduced for the first time in 1950 by the British Institute of Management and was an important step in the measurement of wastage (Bramham 1987: 65).

The index, assimilated to the crude rate of mortality in demography, is strongly influenced by the high number of resignations of occasional workers: in other words, its value depends on the composition of the workforce according to length of service of each unit, since the probability to abandon decreases when the period of time increases. The crude turnover rate often hides more than it presents. It may be useful to find out where and why the turnover occurs, and therefore, it would be more significant to calculate such a measure for company sector, job category, age, sex, length of service, and motivations. Moreover, if we are interested in analyzing the organizational structure of a company it may be more useful to focus the research on the voluntary resignation, while if we wanted to emphasize unemployment, the analysis should be more focused on the unintentional turnover, which is caused by dismissals.

The calculation of TR does not take into account whether the workforce is increasing or decreasing: it is well known that the turnover is higher among the workers who have little service or are recently hired compared to the ones who have more service. It follows that if a company suddenly grows, there should be an increase in the company turnover, and this factor should be considered when comparing this phenomenon among companies and areas; moreover, this index does not say anything about the stability of the company workforce.

For example, we may assume that two companies, A and B, have a workforce of 100 people each at the beginning of the year and that in the following 12 months the first company loses 50 of its original 100 workers, while the second loses 10, who are replaced five times during the year. The TR of the two companies is for both equal to 50 percent, however, the first lost half of its initial workforce, while the second held 90 percent of this force. Therefore, the two companies are likely to need different strategies in the approach to the turnover issue (Harris 1964). As shown in the previous example, those who abandon are often replaced by other workers who also leave, and so on. As a consequence, the TR is not correlated to the workforce that stays. Therefore, if we are interested in measuring this latter aspect more than the TR, we should use an index that will measure the stability of the workforce.

Bowey (1974) has found, by analyzing set cases, that the TR is mainly a measure of the effects of the "pull" processes, while a stability index would measure the effects of the "push." Through a revision of case studies, Bowey found that among the processes that have an impact on the turnover in a company's staff made up of women, a higher correlation was found between the stability indices and the parameters of the "push" processes than between the turnover indices and the "push" processes; in the same study a higher correlation was found between the turnover indices and the "pull" processes than between the stability indices and the "pull" processes.

As a stability index, a percentage measure is often used between the number of workers who are in a company in a specific moment, for example, at the end of the year, with one or more years of service, divided by the number of these workers who were in service one year before in the same company (*LSI*); alternatively to this index, the median of the distribution of the resignation for length of service is proposed (Silcok 1955). This median value can be calculated, however, only if we have the distribution of the resignation for length of service and measure the time needed for an incoming group in an organization to halve due to resignation. More precisely, this index, as it measures the average duration of service of the workers who abandon, is distorted in favour of them, as the ones who stay are not taken into account.

However, this is an index easily calculated and interpreted that allows a comparison between different companies and incoming groups. At this point, we will examine in more detail some limits of the LSI index, which is the most employed among the stability measures. It is possible that two companies have the same value of LSI in the short term, for example, a year, while things can change if this index is

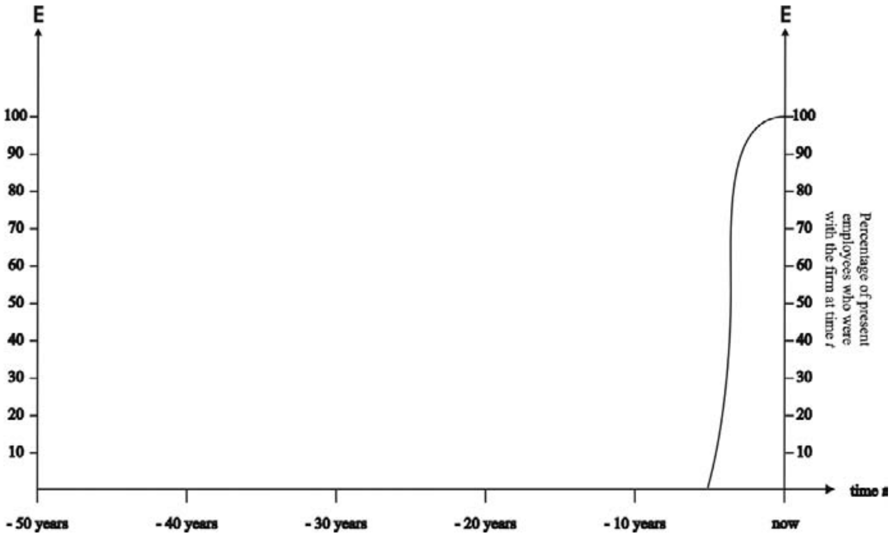

Fig. 1 Stability curve of an unstable firm. Adapted from Bowey (1974).

calculated over a longer period of time, for example, over five years. This situation is well illustrated in the following example. Let us consider two companies that have the same value of stability index calculated over one year. However, the first does not have workers with more than five years in service (Figure 1), while the second has workers with up to 45 years of service (Figure 2), half of them with a number of years in service slightly over 30. It is clear that the two companies, from the point of view of stability of workforce employed, are in a very different situation: the first is very unstable, while the second has a strong stability. Figures 1 and 2 allow us to understand this difference, which, on the contrary, is not highlighted if we employ the LSI index.

Indices which are similar to LSI were proposed by Hyman (1970). One is based on the percentage measurement of the incoming workers in a company who had "survived" after 13 weeks; another measures the survival after 26 weeks. These two measures, as well as others which are not reported here, do not add to the stability measure anything more than the LSI index. For an exemplification of the limits of the stability indices proposed by Hyman, see Bowey (1974: 42–45).

In order to overcome the LSI limits, Bowey (1969) proposes an index called Cumulative Length of Service Index (*CLSI*), which means building a stability curve starting from the current workforce, and considering how many were present in the company a year ago, two years ago, *n* years ago. It is clear that less or more stability depends on two factors: the concavity of the curve (Figure 3) and the value of the intercept on the time axis (Figure 4), beyond which there are no more workers in the workforce from among the ones initially considered.

The stability index proposed by Bowey is obtained as a ratio between the value of the area under the curve and the maximum value of stability for that company,

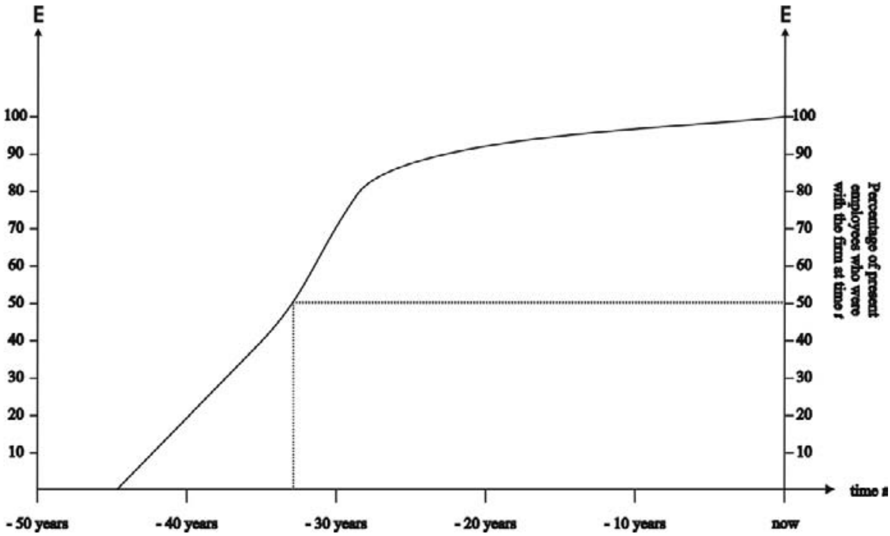

Fig. 2 Stability curve of a very stable firm. Adapted from Bowey (1974).

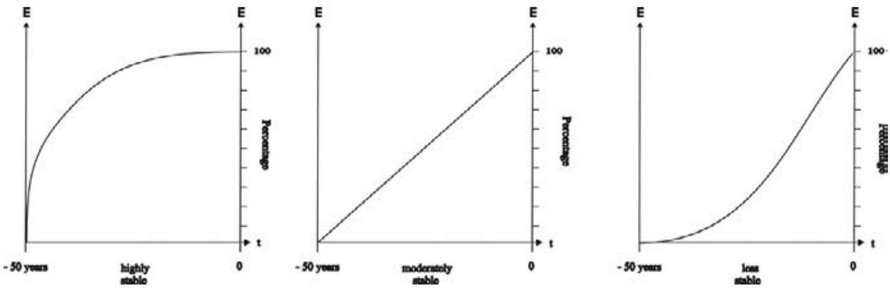

Fig. 3 Stability curves based on different concavity levels. Adapted from Bowey (1969).

equal to the rectangle that contains the same curve (Figure 5). Therefore, the index takes the following analytical form:

$$CLSI = (L_n/n \times N) \times 100,$$

where L_n is the hatched area and $n \times N$ is the rectangle area $ABND$.

Finally, it is possible to obtain a finer turnover index through the calculation of specific quotients for length of service: in other words, comparing the resignation in a given class of seniority service to the average number of workers who survived in that class. These quotients express the so-called *separation force*, a measure which gives the willingness to leave a given seniority class (De Bartolo 1997: 247–250). A synthetic index to compare the workers' separation force may be obtained through the addition of specific wastage quotients (direct standardization). It is also possible to obtain a wastage index if we know only the total number of outgoings in a given

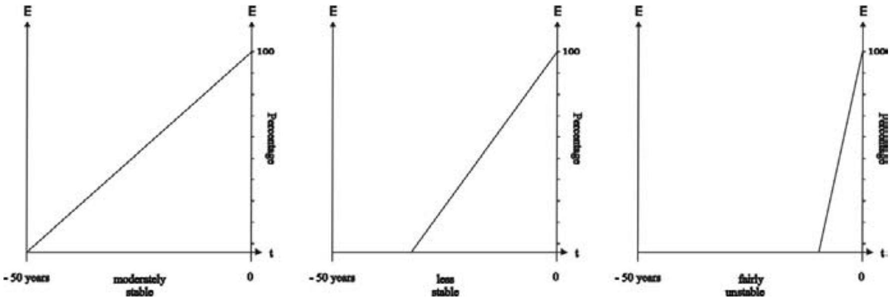

Fig. 4 Stability curves based on different intercept levels. Adapted from Bowey (1969).

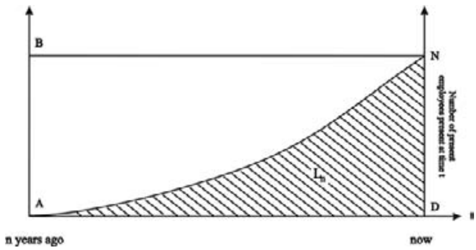

Fig. 5 Stability index proposed by Bowey. Adapted from Bowey (1969).

period of time and the population structure of the company's workers as for seniority. In this case, if we use a structure of specific standard quotients, we may compare the total number of outgoings to the theoretic number of outgoings that the company would record if the willingness to abandon were standard (in direct standardization). By employing the methods used in demography for the building of mortality tables and all the related measures, it is also possible to calculate the wastage probability and therefore build a survival table for duration of service (De Bartolo 1997: 249).

Conclusions

In the field of business demography, the study of turnover has been hardly explored so far. After an initial analysis of the literature related to demography and management of workforce, the present paper has focused on some factors that affect the business turnover in the attempt to identify which factors have a demographic meaning. For example, the relationships between turnover and age, turnover and gender, and turnover and length of service have been analyzed. In particular, it has been emphasized how a relation between demographic homogeneity/heterogeneity and turnover comes out from the literature: the higher the similarity among members of an organization, the lesser will be the presence of the phenomenon. This relationship is explained by employing the psycho-sociologic paradigms of similarity/attraction, according to which sharing demographic characteristics will determine sharing values, ideas, and points of view. This social contiguity would contribute to the creation of an atmosphere of satisfaction in the organization, thus reducing turnover rates.

Some measures of turnover-wastage and of stability of business workforce were critically examined, with the purpose to highlight the similarities with the measures typically used in the field of demography to study human populations: crude mortality rate, specific mortality rates, survival table, median value, etc.

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Chapter 17
Household Consumption in China: An Examination of the Utility of Urban-Rural Segmentation

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Introduction

With its population of nearly 1.3 billion people, China is the largest country in demographic terms (Hussain 2002). China is also one of the largest and fastest growing consumer markets in the world. The consumer electronics market alone, i.e., video, audio, and game console products, is forecast to grow by 61 percent from 2004 to 2009, reaching US$22 billion (Datamonitor 2005a). Similarly the personal computer market is expected to grow by 50 percent in the same period, reaching US$19 billion in 2009 (Datamonitor 2005b).

China is rapidly moving towards becoming a market economy. Unlike its earlier communist era, China is experiencing increasing inequality in income distribution (see, e.g., Fang et al. 2002, Khan and Riskin 2001, Meng et al. 2005). In 2003, the per capita income averaged RMB2,622 for people living in rural areas and RMB8,472 for those living in cities (National Bureau of Statistics 2005). Consequently, many researchers have focused on the urban Chinese consumer for their research. Urban households are reputed to constitute the major portion of the Chinese "middle class" and to have disposable incomes that enable them to enjoy the fruits of economic development and industrialization much more than their rural counterparts. Research addressing these urban consumers has tended to consider urban China as a homogeneous market segment, contrasting it with rural China (see, e.g., Cui and Liu 2000, Sun and Wu 2004, McEwen et al. 2006). Other researchers have examined the dynamics of urban China (Yusuf et al. 2006) or particular products in the urban China market segment (Dickson et al. 2004). While the importance of these authors' findings is not disputed, it is valuable to note that it is not necessarily correct to assume that the distinction between urban and rural consumers is static. This paper seeks to address this issue, first by reviewing the distinction between urban and rural Chinese consumers in terms of their demographic, socio-economic characteristics, secondly, by comparing the income, expenditure and savings patterns of urban and rural households, and thirdly, by ana-

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lyzing their expenditure and savings patterns and ownership of selected consumer durables, using income and urban-rural location as the basis for segmentation.

Literature Review

A search through various bibliographic databases for the past ten years has shown that, while there is a substantial body of research addressing the Chinese economy and society, there is, by comparison, a paucity of research on marketing, and in particular consumer behavior in China. Only a few papers were found that addressed the market segmentation of mainland China (see, e.g., Chen et al. 2005, Dickson et al. 2004, Sun and Wu 2004, Cui and Liu 2000). Other research papers dealt with specific expenditure categories such as food (e.g., Gould and Villarreal 2006. Min et al. 2004). On the other hand, a search of the research reported in Chinese identified some papers that dealt with marketing and consumer behavior issues in China. Some of this research has examined consumer classes and expenditure on different commodities (see, e.g., Song and Zhao 2003, Xu and Tang 2000). Most of these studies, however, were not based on nationally representative surveys.

As Sun and Wu (2004) note, “many studies have focused on a particular subset of the entire population, especially the urban consumer” (p. 245). Dickson et al. (2004) is one explicit example, examining urban consumers only, specifically, residents in Beijing, Guangzhou, and Shanghai. This focus, however, is not always explicit. For example, McEwen et al.’s (2006) reporting on aspects of a Gallup study notes the importance of location and considers “urban and affluent” consumers versus other consumers, or urban workers, suggesting an underlying urban versus rural mindset. While these and other authors provide useful insights into the Chinese consumer, few provide a comprehensive, national picture. Cui and Liu (2000) did address the nation as a whole, but their regional approach did not address the urban/rural dichotomy. Similarly, Sun and Wu (2004) address a specific subset of psychographic characteristics of urban and rural consumers (e.g., brand consciousness, ideal future image). Psychographic characteristics can illuminate consumers’ attitudes and behavioral intentions, however, they do not address the consumer’s actual consumption behavior. Given that it is the consumer’s actual expenditure that drives companies and economies, this aspect of consumers’ behavior is a central interest in determining the importance of market segments.

Cui and Liu (2000) examined a geographic segmentation of China based on seven regional markets, eschewing the urban versus rural distinction. Their findings included significant differences between the seven regions in terms of their education level, occupations, attitudes, and product ownership. Income was found to “be the main determinant in ownership of information appliances including pager, telephone, cellular telephone, and personal computer” (Cui and Liu 2000, p. 65). “Overall, South China leads the nation in ownership of luxury products such as CD player, camcorder, and VCD, while East China usually pioneers in ‘lifestyle’ products like microwave oven and vacuum cleaner” (Cui and Liu 2000, p. 65).

These findings, however, cannot be directly applied to differences between urban centres. Sun and Wu (2004) found differences in consumers' attitudes and brand consciousness and in the products that they identify as indicating a higher living standard. The product rated highest in terms of indicating a high living standard was the house for both rural consumers and urban consumers. For rural consumers the products rated second to fifth in terms of indicating a high living standard were color TVs, telephones, washing machines, and cars, but for urban consumers the corresponding products were personal computers, air conditioners, color TVs, and cars, respectively.

Having established that there are differences in consumers' attitudes and/or consumption behavior between regions, and between rural and urban locations, it would seem reasonable to suggest that similar differences exist between urban consumers in different geographic regions. While no study was found addressing this issue, limited support for regional differences between urban Chinese consumers is offered by the findings of Dickson et al. (2004). Investigating segmentation of the married adult urban Chinese (Beijing, Guangzhou and Shanghai) consumer market for U.S. fashion garments, they derived six significant segments. Four of these segments had identifiable geographic bases, amongst other factors such as age, household income, sex, employment status, and job type. Some research on consumption patterns in Beijing has recently been reported by Zhou (2004) and on Beijing and Shanghai by Zhang (2005) in Chinese academic journals.

It is generally acknowledged that rural areas are developing at a slower rate than urban areas. Cui and Liu (2000) note that "as the rural economy continues to develop, studies of rural consumers will make a significant contribution" (p. 67). Inherent in these statements, taken with the earlier statements indicating the expected growth rates of the Chinese economy as a whole, is a picture of rural and urban economies that are both in motion, but at different rates, suggesting that the differential between these economies is also changing. While research based on the urban/rural dichotomy continues to demonstrate significant differences between these segments, no research has been identified that examines trends in the differences between the urban and rural consumer segments.

Data

For the past two decades the National Bureau of Statistics in China has been conducting annual household income and expenditure surveys in both rural and urban areas. These surveys collect information on the socio-economic and demographic characteristics of the sampled households, their income and expenditure patterns, the major commodities purchased (by quantity and by expenditure), and the ownership rates of durable consumer goods. In addition to completing face-to-face interviews, sampled households are required to maintain a daily diary and transaction books to record all expenses and consumption in the household for a given year (Min et al. 2004).

Table 1 Number of households in the sample for selected years: China, household income and expenditure surveys.

	Number of sampled households	
Year	Urban areas	Rural areas
1995	35,520	67,340
2000	42,200	68,116
2003	48,028	68,190

Sample households in these surveys were selected using a multi-stage stratified sampling procedure. The exact sampling procedures used in earlier surveys were somewhat different from the more recent surveys, and their details are not readily available. Therefore one needs to be careful when comparing the survey data over time. For the purposes of this paper, the authors have mostly used the data reported in the 2004 Yearbook augmented with some data from the 1996 Yearbook. Data only for 1995, 2000, and 2003 are reported in this paper.

Table 1 shows the number of households covered in the three surveys. It may be noted that the sampling procedures used ensured probability samples that were large enough to enable the derivation of separate robust estimates, for both the urban and rural parts of China, for various regions, and for certain large cities such as Beijing and Shanghai. Unfortunately, no information was available on sampling errors and therefore it was not possible to test the statistical significance of the differences in various estimates.

It may be noted that while both urban and rural surveys used similar concepts and definitions, there was some ambiguity in describing the income levels in the two sets of surveys. In urban surveys, income quintiles were used, while in rural surveys the income categories used were: low income, lower middle income, middle income, higher middle income, and high income. For the sake of convenience in preparing Table 6 and Figures 1 and 2 in this paper, the authors have equated the first quintile with low income, second with lower middle income, and so on. Another difference in the two surveys was that in the rural surveys, total income and cash income were reported separately. The same convention was used for reporting rural expenditure. This is why the rural data for each of these components are presented separately in various tables and figures.

One of the major limitations of the data presented in this paper is the fact that there are no indications of the accuracy of the data. These are official data, and insofar as such data are used with caution, they could indicate broad trends.

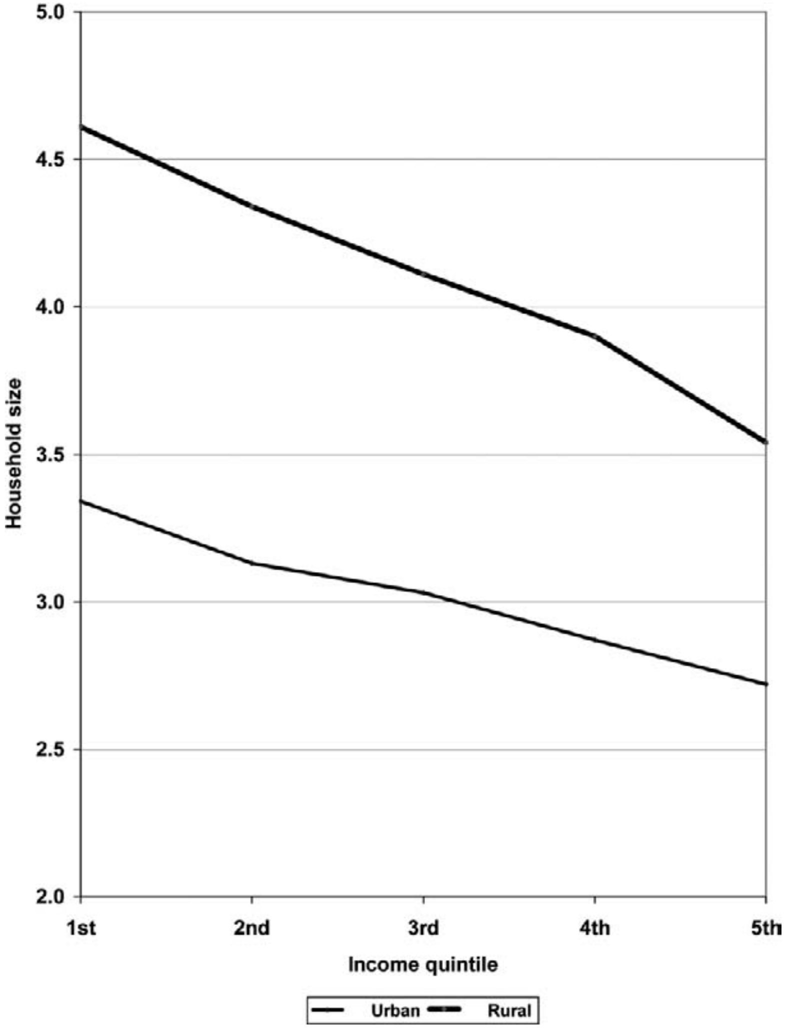

Fig. 1 Average household size by income quintile for urban and rural areas: China, 2003.

Findings

An Overview of the Demographics of China

China had a population of 1.211 billion in 1995, which had increased to 1.293 billion in 2003, showing an annual growth rate of 0.8 percent. During the same period the urban population increased at an annual rate of nearly 5 percent. As a result, the proportion of urban population increased by nearly 41 percent during the period

Table 2 Selected demographic indicators for China, 1995–2003.

Characteristic	1995	2000	2003
Total population (in millions)	1,211	1,267	1,293
Urban population (in millions)	352	459	524
Urban population as % of the total population	29	36	41
Total households (in millions)	301	339	361
Urban households (in millions)	109	147	174
Rural households (in millions)	192	192	187
Average household size in urban areas	3.23	3.13	3.01
Average household size in rural areas	4.48	4.20	4.10

Table 3 Household income, expenditure and savings in China, 1995–2003.

Characteristic	1995	2000	2003
Annual household income (in RMB):			
Average for urban areas	13,821	19,706	27,274
Average for rural areas (total revenue)	10,474	13,214	14,688
Average for rural areas (cash)	7,148	10,007	12,011
Annual household expenditure (in RMB):			
Average for urban areas	11,426	15,644	19,598
Average for rural areas (total expenditure)	9,580	11,140	12,402
Average for rural areas (cash)	7,915	8,990	10,403
Savings as % of income in:			
urban areas	17	21	28
rural areas (total)	9	16	16
rural areas (cash)	–11	10	13

under review (Table 2). Similarly while the estimated number of urban households increased by nearly 6 percent per annum, the estimated number of rural households experienced an annual rate of decline of 0.3 percent. The faster growth in urbanization was mainly a result of rural to urban migration, which has accelerated in recent years. For example, in cities such as Beijing, Shanghai, and Tianjin the proportion of people not holding the domicile ("hukou") in those cities was 31 percent, 11 percent, and 13 percent, respectively (National Bureau of Statistics 2005). Another interesting fact evident from this table is the steep decline in the average household size; the household size in 2003 was only 93 percent of what it was in 1995 in urban areas, and only 92 percent of 1995 levels in rural areas. This phenomenon can be largely ascribed to the success of China's one-child policy. Using the income-level data for 2003, it appears from Figure 1 that the well-off households, in both urban and rural areas, were smaller than their poorer counterparts, indicating thereby that the family planning program was much more effective among the relatively more affluent segments of the Chinese society.

Income, Expenditure, and Savings in China: 1995–2003

Table 3 shows that the annual household income increased in both urban and rural areas; though the annual rate of increase was much higher in urban households (8.5 percent) compared to the total income and cash income of rural households, which experienced annual growth rates of 4.2 percent and 6.5 percent, respectively. Another interesting point worth noting is that among the rural households, the cash proportion of income increased from 68 percent in 1995 to 82 percent in 2003. If this trend continues the contribution of non-cash income to the rural economy of China is likely to become negligible in the not too distant future.

Household expenditure increased in both urban and rural areas between 1995 and 2003 (Table 3). However, the rate of increase in urban areas was close to 7 percent per annum between 1995 and 2003, while in the rural areas it stayed at just over 3 percent, irrespective of whether or not it was cash expenditure.

Savings more or less doubled in both urban and rural areas. The negative cash savings of rural consumers in 1995 is interesting; the situation, however, was reversed from 2000. This phenomenon of increasing savings has been observed in some other studies (see, e.g., Qin 2003, Zhang and Wan 2004) and is particularly interesting given that McEwan et al. (2006) report both decreasing numbers of Chinese whose primary aim is to work hard and get rich, and increasing numbers who report their personal goals are self-satisfaction and self-expression. This contrast between measured behavior and indicated values suggests that a greater understanding of the Chinese culture and psyche is desirable.

Table 4 shows household expenditure in eight broad item categories. The changing consumption patterns over the years are worth noting. Perhaps one of the most dramatic features of this table is the drop in the proportion of total expenditure that was spent on food. This drop was found in both urban and rural households, though the drop in urban households was much more pronounced. Expenditure on all item categories, except clothing and household facilities and services, increased during the period under review. The increase in expenditure on many of the items, such as housing, education, and medical services, may be due to structural changes as China transitions from a socialist to an increasingly market economy. Consequently, there have been reductions in the coverage and level of government and employer subsidies for many of these items in recent years.

Trends in the ownership of selected consumer durable goods by urban and rural households in China during the period 1995 to 2003 are shown in Table 5. The table clearly shows the disparity between urban and rural households, but it also shows that the ownership rates have been increasing in both areas.

By 2003, three products – mobile phones, refrigerators, and washing machines – were each owned by around 90 percent of all urban Chinese households, while the corresponding proportion for rural households varied between one-sixth and one-third. The very high ownership rate for color television sets, in excess of 130 percent in urban areas and half of this rate in rural areas, is worth noting. The television market, however, has previously been influenced by factors that promote homogeneity. In 1958, Chairman Mao created China Central Television, which today has 16

Table 4 Percentage distributions of expenditure on broad categories for urban and rural households in China, 1995–2003.

Area/Expenditure category	1995	2000	2003
URBAN AREAS			
Food	50	39	37
Clothing	14	10	10
Household facilities and services	7	7	6
Medicine and medical services	3	6	7
Transport and communication	5	9	11
Education and culture	9	13	14
Housing	8	11	11
Other items	3	3	3
RURAL AREAS (TOTAL)			
Food	59	49	46
Clothing	7	6	6
Household facilities and services	5	5	4
Medicine and medical services	3	5	6
Transport and communication	3	6	8
Education and culture	8	11	12
Housing	14	15	16
Other items	2	3	2
RURAL AREAS (CASH)			
Food	41	36	35
Clothing	10	7	7
Household facilities and services	8	6	5
Medicine and medical services	5	7	7
Transport and communication	4	7	10
Education and culture	12	15	15
Housing	17	18	18
Other items	3	4	3

advertising supported channels. He also managed the affordability of television sets so that the majority of Chinese households own televisions, reportedly "tuning in" for about three hours a day (Madden 2006).

Among the consumer durable goods listed in Table 5, "motor cycle" was the only item which had a higher ownership rate in the rural areas compared to the urban areas. Although it is increasing at a very rapid rate, as is evident from the fact that the ownership rate in urban areas nearly tripled over a period of three years, motor car ownership is still quite low in China. Given that China has quite a booming automobile industry, these low ownership rates may seem surprising. Number of new registrations grew from just over half a million in 2000 to 2.16 million in 2004, an average growth rate of 34.3 percent per annum, yet this is a small number of vehicles in such a large population (Datamonitor 2005c). The increase in motor car ownership rate is at least partially contributing to atmospheric pollution and significant traffic jams, particularly in cities such as Beijing and Shanghai, despite their recent improvements in the infrastructure of roads, freeways, and highways.

Table 5 Number of selected consumer durable goods per 1,000 households in urban and rural China, 1995–2003.

Area/Item category	1995	2000	2003
URBAN AREAS			
Air conditioners	81	308	618
Cameras	306	384	454
Color televisions	898	1,166	1,305
Computers	*	97	278
Hi-fi stereo component systems	105	222	269
Mobile phones	*	195	901
Motor cars	*	5	14
Motorcycles	63	188	240
Refrigerators	662	801	887
Video recorders	182	201	179
Washing machines	890	905	944
RURAL AREAS			
Air conditioners	*	13	35
Cameras	14	31	34
Color televisions	169	487	678
Computers	*	*	*
Hi-fi stereo component systems	*	78	105
Mobile phones	*	43	236
Motor cars	*	*	*
Motorcycles	49	219	318
Refrigerators	52	123	159
Video recorders	*	33	35
Washing machines	169	286	343

*Data not available.

Segmentation by Income Levels in China, 2003

As pointed out earlier, income data in the urban survey were aggregated in terms of quintiles, while for rural surveys the information was available in five categories.

Table 6 shows the 2003 data for the average income and expenditure for both urban and rural households by each income quintile. It appears that for each quintile the average income and expenditure of urban households was more or less twice that of the rural households. The situation was even worse for rural households when one compares their cash income and expenditure with that of urban households. Among the rural households the cash component of total income and total expenditure increased for each quintile. For example, the proportion for cash income increased from 69 percent to 90 percent and for expenditure from 75 percent to 92 percent as one compares the lowest and highest quintiles.

The proportion of income saved in 2003 by both urban and rural households is also shown in Table 6 by income quintile. An interesting point to note is the high propensity of Chinese households to save, the only exception being the rural

Table 6 Income, expenditure, and savings of urban and rural households by income quintiles. China, 2003.

Characteristic/Area	Income quintile				
	1st	2nd	3rd	4th	5th
Average annual household income:					
urban	11,808	19,742	25,433	32,751	56,694
rural (total income)	7,253	10,094	12,844	16,467	28,288
rural (cash income)	4,990	7,334	10,049	13,624	25,565
Average annual household expenditure:					
urban	10,360	15,770	19,182	23,623	36,468
rural (total expenditure)	8,312	9,316	10,973	13,019	20,382
rural (cash expenditure)	6,197	7,140	8,903	11,032	18,737
Savings as % of income:					
urban	12	20	25	28	36
rural (total)	–15	8	15	21	28
rural (cash)	–24	3	11	19	27

Note: The information for rural households referred to the following five categories: (1) Low income; (2) Lower middle income; (3) Middle income; (4) Upper middle income; (5) High income. The authors have assumed these categories as equivalent to the corresponding income quintiles, i.e., 1st quintile = Low income; 2nd quintile = Lower middle income; and so on.

households in the lowest quintile who most probably lack the resources to engage in savings activity. This propensity seemed to increase substantially among the high-income earners. The urban-rural differential in savings tended to diminish considerably in the two top quintiles.

Expenditure patterns by income level are given in Table 7. Two main trends are worth noting. Firstly, the expenditure on food showed a negative gradient with income. Secondly, for most other items there was a positive association between income and expenditure. Thirdly, at each income level the rural households spent proportionally more on food but less on other items, except for housing where they spent marginally more than the urban households. The patterns were quite similar even when considering the cash expenditure by rural households.

Data on the ownership of consumer durable goods by income levels were only available for urban households (Table 8). An interesting fact to note from this table is the absence of some of the modern conveniences such as dishwashers. It appears that very few (around 0.6 percent) of the urban households in 2003 had dishwashers. The highest proportion was noted in Shanghai where it was 1.4 percent. In all other urban areas this proportion was below 1 percent (National Bureau of Statistics 2005).

Table 7 Expenditure patterns of urban and rural households by income quintiles. China, 2003.

Area/Expenditure category	Income quintile				
	1st	2nd	3rd	4th	5th
URBAN AREAS					
Food	46	42	39	37	32
Clothing	9	10	11	10	9
Household facilities and services	4	5	6	6	8
Medicine and medical services	7	7	7	7	8
Transport and communication	8	9	10	11	13
Education and culture	13	13	14	15	15
Housing	11	10	10	10	11
Other items	2	3	3	3	4
RURAL AREAS (TOTAL)					
Food	54	52	49	46	38
Clothing	6	6	6	6	6
Household facilities and services	4	4	4	4	5
Medicine and medical services	6	6	6	6	6
Transport and communication	5	6	7	8	11
Education and culture	10	12	13	13	12
Housing	13	13	14	16	19
Other items	2	3	3	3	3
RURAL AREAS (CASH)					
Food	38	37	36	36	32
Clothing	8	8	7	7	6
Household facilities and services	5	5	5	5	5
Medicine and medical services	9	8	8	7	7
Transport and communication	8	8	10	10	12
Education and culture	15	16	16	15	14
Housing	15	15	16	17	21
Other items	2	3	3	3	3

Note: The information for rural households referred to the following five categories: (1) Low income; (2) Lower middle income; (3) Middle income; (4) Upper middle income; (5) High income. The authors have assumed these categories as equivalent to the corresponding income quintiles, i.e., 1st quintile = Low income; 2nd quintile = Lower middle income; and so on.

Discussion and Conclusion

Considered *in toto*, there is evidence that in 2003 the urban consumer segment was more important than the rural consumer segment. The evidence is, however, equivocal. Considering the data in Table 2, the urban consumer represents 48 percent of Chinese households, which with their smaller household size, includes only 41 percent of the population. However, if income is considered, urban consumers receive 63 percent of the total income, as the average urban individual receives 2.5 times the income of his/her rural counterpart. One could conclude that for products associated

Table 8 Number of selected consumer durable goods per 1,000 households by income level: urban China, 2003.

Item category	Income quintile				
	1st	2nd	3rd	4th	5th
Air conditioners	166	366	542	723	1,223
Cameras	190	327	430	538	747
Color televisions	1,079	1,192	1,281	1,383	1,557
Computers	59	148	234	353	564
Hi-fi stereo component systems	132	210	275	308	402
Mobile phones	350	646	897	1,101	1,438
Motor cars	2	4	6	10	42
Motorcycles	159	221	252	253	306
Refrigerators	681	845	913	964	1,012
Video disc players	405	526	613	642	728
Video recorders	77	139	167	211	288
Washing machines	834	921	954	980	1,019

with individual consumption that are necessities or low cost, the rural segment has substantial appeal, distribution considerations notwithstanding. Given the comparatively lower adoption levels for many products in the rural segment compared to the urban segment, the rural segment may appeal as many of its markets are less mature than their urban counterparts. There is, however, evidence that, for some products at least, consumption is driven by income (Cui and Liu 2000, Yusuf et al. 2006). If income level is a driver of consumption, then the urban consumer is clearly the more affluent and hence the more appropriate market segment.

The change in importance of the urban consumer relative to the rural consumer is illustrated in Figure 2. While the urban sector still represented the minority of the population and households in 2003, it has grown substantially in both these dimensions over the preceding eight years. If the trend continues, it would be reasonable to expect the urban consumer segment to represent the majority of the population and households in the near future. In a static situation, one might expect development to eventually bring rural income levels up to near those of urban Chinese, increasing the importance of the rural segment, but the situation is not static. The rural segment population is diminishing relative to the urban population. Further, rural incomes are also diminishing relative to their urban counterparts, despite increases in currency terms (Table 3, Figure 2). In 1995, urban household incomes were 1.9 times that of their rural counterparts, increasing to 2.0 times in 2000 and 2.3 times in 2003. The urban consumer segment would therefore seem likely to increasingly dominate the rural consumer segment for the foreseeable future.

Finally, three important points emerge from the above analysis. Firstly, the Chinese urban market has been in a state of transition. It is growing in terms of size, income, and product adoption (for a substantial range of products) and in the proportion of the Chinese market that it represents. The growth of this market and the ease of distribution to urban areas, relative to rural areas, make urban China

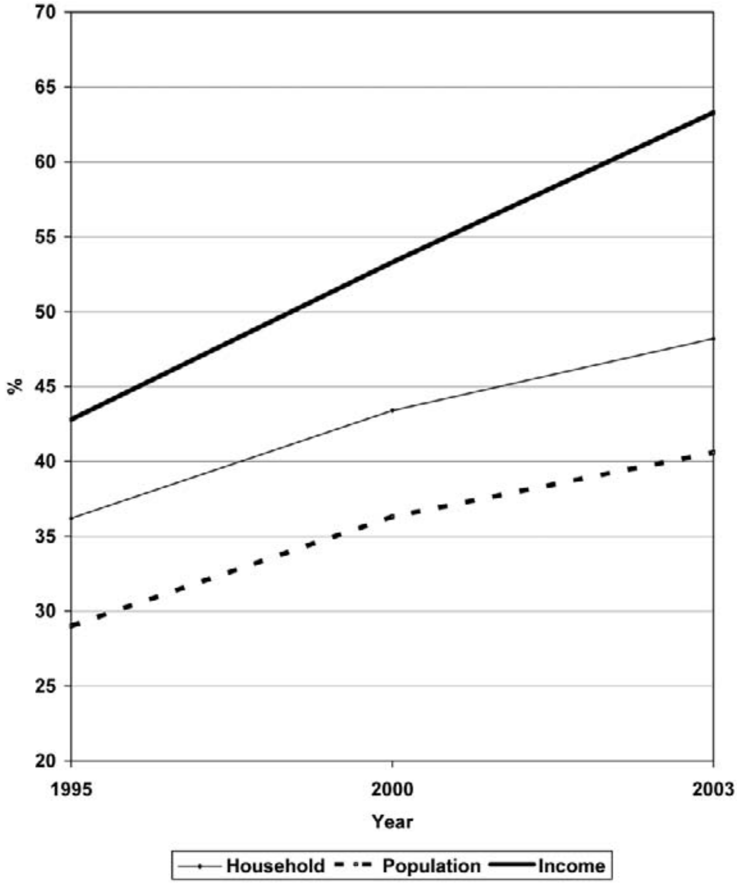

Fig. 2 Number of households, population and household income in urban areas as % of the national total, China: 1995, 2003.

an attractive market. Secondly, Chinese households save a significant proportion of their earnings. While direct comparisons may not be appropriate, it would appear that the market for savings products and services is certainly no less robust than the market for consumer durables. Thirdly, while urban Chinese have acquired a number of consumer durables, there are indications that as a result of increasing standards of living and easier access to modern communications media they are likely to become one of the largest consumer markets in the world. Successful marketing to this emerging market will require appropriate strategies, consistent with the Chinese culture and psyche. Marketing research has frequently used a rural versus urban dichotomy for segmentation. This dichotomy appears to be well-founded and likely to continue to be a valuable segmentation basis.

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Chapter 18
How Chinese Children Spend Their Time

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Introduction

According to an old Chinese saying, "Children are the future of the country" (Haizi shi zuguo de weilai), the central importance of children to the organization of family life in China has a long history. In recent decades, however, population policies have reshaped family organization regarding children by making "quality" children part of a national agenda. The government now calls on families to focus on the child quality rather than child quantity (e.g., one government slogan says, "Control the population quantity, while improve the population quality"). To achieve national goals, Chinese families are asked to limit fertility. Most often those in cities are allowed one child. There is greater variation in rural areas, but emphasis on small families with quality children remains. National leaders promote voluntary reduction in fertility, and adherence with one child policy limits, by encouraging citizens to produce fewer, quality children, thereby facilitating China's economic growth and modernization.

There is great variation in the popular images of childhood in China today. They range from images of "spoiled little emperors" indulged by parents and grandparents to "unwanted and abandoned baby girls." We do know that whatever their experiences, children in China are growing up in a time of transition, a time when socialism, and its associated ideals and practices, are being altered and replaced by global capitalist ways.

Results from both quantitative and qualitative studies (see Short et al. 2001 for a review) show that the one-child policy, insofar as it limits couples to one or two children, leads to greater involvement by parents in childcare. However, little is known about how this parental involvement is translated practically into the lives of children. This paper investigates the time use of children in China. Drawing on survey data from 2004, we describe children's time spent in work, play (including sports and TV/videogame use), doing homework, reading, and other activities, as well as the axes along which involvement in all categories varies. We describe variation

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among children and across communities. Finally, we explore in a regression context the correlates of time use.

A better understanding of children's time use has numerous advantages. First, time use among children has been linked to emotional, cognitive, and physical health. For example, more sedentary activity can lead to obesity and other chronic conditions (Dowda et al. 2001, Crespo et al. 2001, Eisenmann et al. 2002), while physical exercise improves both body strength and health (Pellegrini and Smith 1998, Byers and Walker 1995), and also academic performance (Shephard 1983). In addition, time spent reading has been associated with positive educational outcomes (U.S. Department of Education 1999, Snow et al. 1998) and higher scores on standardized achievement test in wording, vocabulary, reading comprehension, calculation, and applied problems (Hofferth and Sandberg 2001). Moreover, time spent studying outside of school (i.e., doing homework) has been associated with higher mathematics achievement and reading proficiency (Fuligni and Stevenson 1995, Keith et al. 1986). Furthermore, TV watching has been linked to both a decline in children's cognitive and/or academic development (Bachman and Schulenberg 1993, Leone and Richards 1989, Greenberger and Steinberg 1986, Keith et al. 1986, Timmer et al. 1985, Larson 1983) and also to growth in reading proficiency (Anderson et al. 1988), as well as to a decline in time spent in other important developmental activities (Koolstra and Van Der Voort 1996). In addition, computer use and play have been shown to provide beneficial effects in that they develop children's spatial skills (e.g., mental rotation, spatial visualization) and iconic skills (Greenfield et al. 1996a, 1996b, McClurg and Chaille 1987) and also improve their scores in mathematics and English (Rocheleau 1995), although more research is needed to establish the effects of computer use. Finally, the effects of housework (e.g., preparing food, washing clothes and cleaning) for children are ambiguous. For instance, some have found that housework has a neutral influence on children (e.g., Bianchi and Robinson 1997), while others have found that it has a beneficial influence, such as the development of children's skills in running their own households later in life and their sense of responsibility (Goldscheider and Waite 1991). Nonetheless, others have found negative influences of housework for children, such as diminishing feelings of competence (Call et al. 1995) and reinforcing restrictive gender roles (UNICEF 1991).

In addition to the above, from a social science point of view, a better understanding of children's time use is useful in that it can be a window into inequality. Variation in time spent doing household chores, or time spent in learning activities, for example, may inform our understanding of "unequal childhoods."

In a recent review of studies documenting time use among children across the world, Larson and Verna (1999) identified three needs: (1) the need for documenting children's time use in a larger number of countries, (2) the need for studies providing information on within-population variability in time-use, and (3) the need for more detailed information on time use, such as distinguishing between children's schedules during week days versus weekend days or activities done in school versus outside of school. By providing a description of children's time use in China that attends to variation across children, households, and communities, and attends to variation created by differences in school enrollment, season, days of the week, and other factors, our paper begins to fill the identified needs in a setting that is home to millions of children.

Due to the fact that in China six-year old children are legally required to enroll in a nine-year compulsory education program, most of the children in our sample (around 90 percent with small variations by age) were enrolled in school at the time of the survey. Thus, for children six to 17 years old, the variations in the amount of time spent in school activities, both physical activities and study activities, tend to be small. Moreover, previous research studies (Fuligni and Stevenson 1995, Anderson et al. 1988) have found that children's academic achievement depends, in addition to the time spent in school, on the way children spend their time outside of school. Therefore, despite the fact that activities in school take up a large proportion of children's time every day, we expect that it is the activities outside of school that would make the largest difference in the total time spent in various activities by different categories of children, and this is why we focus in this paper on children's time use outside of school only.

Finally, although other studies (e.g., Tudor-Locke et al. 2003) have used the China Health and Nutrition Survey (CHNS) to examine children's activities, our paper uses the newest available data for children's time use in China (2004), and also portrays a much more detailed analysis of children's activities, both in the larger number of activities we present and by exploring children's time in a multivariate context.

We start by reviewing what is currently known about children's time use, from the few studies that looked explicitly at this issue, focusing on a Chinese/Asian context whenever possible. Then we examine the factors that we expect to affect children's time use in China, followed by our results and discussion of policy implications.

Children's Time Use

The need to understand children's time use comes from the assumption that the way children spend their time affects their current and future lives in many ways. Understanding in detail children's time use is a necessary first step in understanding how time use affects children's development and their well-being in general. Many studies (e.g., Fong 2004, Larson and Verma 1999, Fuligni and Stevenson 1995, Russell 1997, Chung et al. 1993, Verma and Gupta 1990) have documented China/East Asia's traditional emphasis on children's academic achievement, rather than physical and health development. These studies have shown that Chinese children spend many more hours in academic pursuits, and a lot fewer hours/minutes in sports and other physical activities, compared to their American and European counterparts. Nevertheless, China is going through a transition period, and its traditional ways may be altered by Western influences. For instance, we may see an increased emphasis on sports for the children of well-to-do parents, due to its counterpart emphasis found in the American culture. Similarly, we may see an increased use of computers and TV watching among Chinese children, as a result of both market accessibility of TVs and computers, and also of western cultural influences that make these activities part of the everyday routine. Moreover, the market transition in China may strengthen or even bring back the strong emphasis on academic pursuits for children, since individual success is more and more dependent on personal qualifications rather than political connections, typical of the Maoist period.

While in a companion paper we examine how time allocated to various activities affects children's outcomes, in this paper we focus on the first step, that is, on understanding how children spend their time, and what is the amount of time spent in various activities. In this article, we address four key areas of children's activities: (1) time spent in paid work and household labor (such as cleaning, cooking, ironing, childcare, etc.); (2) time spent in extracurricular intellectual activities (such as reading, studying and doing homework); (3) participation in physical activities (such as sports and play), and (4) participation in leisure activities (such as watching TV and playing video/computer games).

Household and Paid Labor

In their comprehensive review of studies about children's time use across the world, Larson and Verma (1999) have found that economic development is associated with a decrease in time spent by children in household and wage labor. While in developing countries, children spend a substantial amount of their daily time in household and/or paid labor that increases with age, in developed countries, where universal schooling is an established norm, the amount of time children spent in household labor is greatly diminished. As Larson and Verma (1999) point out, "no study shows household labor in schooled populations to exceed one-hour per day" (p. 705).

While China is considered a developing country, it is experiencing extremely rapid development, being called by some "a greatest transformation of a piece of earth in history" (Balfour 2007). How is China's population, and especially the youngest members of this population, affected by this rapid development? While there is no doubt about the rapid growth of China's cities, we also know that there is another China, the rural China, where children may still be more like their counterparts in typical developing countries in terms of their time use than those in developed countries and in urban China. Regardless of the rural-urban differences in China, recent research (e.g., Tudor-Locke et al. 2003) has found that both paid employment among Chinese youth and engagement in household chores are not part of the activities of the typical Chinese child. For instance in 1997, fewer than 20 percent of children in China performed chores related to housework, and less than two percent performed any gardening or farming or assisted with small business ventures. Moreover, the "Chinese government prohibits employment of youth younger than 16 years of age, [. . .] and administrative requirements discourage workplaces from hiring temporary or short-term workers" (Tudor-Locke et al. 2003: 1097). Other studies (e.g., Alsaker and Flammer 1999, Fuligni and Stevenson 1995) have confirmed the low participation of Chinese youth in paid employment (around 25 percent) compared to the great majority of American teenagers (80 percent) that have part-time jobs. In addition, not only that a lower percent of Chinese children participate in household chores, but Chinese children also spent less time in these tasks when they do them (Stevenson and Stigler 1992).

Extracurricular Intellectual Activities

Most comparative studies on children's time use have found that East Asian children (including Chinese children) spend more time than their American and European counterparts, both in school and outside of school, in activities such as studying, doing homework, and reading for fun, although large differences between studies exist in the estimates of the average time spent in various activities (Larson and Verma 1999, Fuligni and Stevenson 1995). Many of these differences are due to different measurements between different studies. For instance, some studies include all time devoted to studying and reading in a week, regardless of whether this takes place in school or outside of school, while other studies separate the two. In a comparative study between American, Chinese (from Taiwan), and Japanese children based on data from 1990–1991, Fuligni and Stevenson (1995) found: (1) that Chinese and Japanese teenagers spend on average an hour or two longer than their American counterparts (9.2, 8.6, and 7.3 respectively) in a typical school day, (2) that Chinese and Japanese students take on average more classes each semester than American students do (7–8 versus 5–6), and (3) that Chinese students spend considerably more time in academic pursuits outside of school (25.5 hours per week in studying, taking lessons, and reading for pleasure) than both Japanese (17.2 hours) and American students (15.4 hours). Although informative for this article, it is important to emphasize that Fuligni and Stevenson's (1995) study was done in Taipei, a city in Taiwan in the early 1990s, and hence is not representative for Chinese children now, especially for those in the mainland. Nevertheless, other studies (Russell 1997, Chung et al. 1993, Verma and Gupta 1990) have confirmed that Asian children and teenagers spend a considerable amount of time in extracurricular intellectual activities, such as reading, writing, and studying, although the estimates vary among different studies as mentioned earlier.

Sports and Play

While participating in sports appears to be most common in North America, it is least common in East Asia. As several authors (Larson and Verma 1999, Fuligni and Stevenson 1995) have found and argued, as the pressure to succeed academically increases for Asian students, the time spent in sports decreases.

Although the estimates vary by study, in the 14 studies reviewed by Larson and Verma (1999) examining children's participation in sports in different countries, the time spent in sports by Asian children is less than half of that spent by U.S. children. Moreover, Fuligni and Stevenson (1995) found that fewer Chinese children (79 percent) participate in sports than American children (86 percent). In addition, the authors found that the Chinese children who do participate in sports do so for shorter time than U.S. children do, both in school and outside of school. While the American students spent on average 7.7 hours a week in sports at their high schools, and 4.9 hours a week in out-of-school sports, the times for Chinese students were only 3.0 hours a week in sports at school, and 3.4 hours a week in sports out of school.

Finally, a study mentioned before about Chinese children and using previous waves of CHNS data (Tudor-Locke et al. 2003) has found even lower rates of participation in sports. While 72 percent of Chinese children participated in sports during school, the reported median time spent in sports per week at school was between 90 and 110 minutes, while the time spent in sports outside of school was between 120 and 180 minutes, varying by gender and age (more about gender and age differences later in this paper). These differences between studies may be attributable to different measurements, but also to a different sample of students (e.g., Chinese children from Taiwan versus children from mainland China). Nevertheless, the lower participation of Chinese children in sports seem to worry most of the researchers mentioned in this article, especially with the apparent high increase in obesity among the population of Chinese children (MacLeod 2007).

In terms of play (non-structured play), "the frequency of play appears to be quite similar in the U.S. and East Asia until middle childhood, at which stage time devoted to play diminishes in East Asian societies" (Larson and Verma 1999: 719). Based on their review of several studies, Larson and Verma (1999) argue that increased devotion of time to schoolwork among Asian youth is at the expense of play, as it is of sports. Moreover, they show how, across societies, "play disappears as a category of activity in adolescence" (p. 719), although it is replaced in Western societies by talking (with peers and family). While in East Asia, children spend some time talking with peers and friends, this time is much shorter (e.g., not exceeding 45 minutes per day) compared to that of European and American adolescents.

Leisure Activities

The most studied category of leisure activity among children is watching TV. Tudor-Locke et al. (2003) have found that in 1997, about 80 percent of Chinese children and adolescents reported watching TV, and the median time spent watching was seven hours per week. Moreover, only eight percent of Chinese school-aged youth watched television more than two hours a day, and less than one percent watched more than four hours a day. When comparing children from different countries, many studies have found no clear differences in TV viewing between North American, East Asian and European children (see Larson and Verma 1999 for a review), although some studies found that Asian children spent more time watching TV than their American counterparts (Fuligni and Stevenson 1995), while others have found the opposite to be true (Lee 1994).

We have found no major study published in English examining patterns of using other media, such as computers, video games, and other electronic equipment, among Asian children, but informal accounts show that such use is becoming increasingly prevalent among children and adolescents in many countries, including Asian countries. We will explore in this study the prevalence of computer usage, video games, and other electronic media among contemporary Chinese children.

Factors That Affect Children's Time Use

Rural-Urban Disparities

Evidence from studies about the Western world (Goodnow 1988) suggests that household labor is more likely for children in rural areas (farm families) than in urban areas, and we expect this to be the case for China, too. We expect that the small percentage of Chinese children engaged in tasks such as gardening, farming, and caring for livestock (mentioned earlier in this paper) to be overwhelmingly from rural areas.

Moreover, although mainland China has a highly centralized curriculum development system, evidence (Ma et al. 2006) shows that there are urban-rural differences in the education system, with rural children generally performing more poorly than their urban counterparts. In their case study of urban versus rural schools, Ma et al. (2006) found that in urban areas teachers felt intense pressure generated by the national mathematics Olympiad, and thus tended to give more difficult mathematics problems to their students in the hope that above-average students would perform well in the competition. In urban areas, therefore, top students scored higher than their rural counterparts because they were pushed harder by their teachers to succeed.

Inequity in access to resources and opportunities might be the most important reason for why we expect to see rural/urban differences in time use among children. Becker's (2000) analysis of 1988 U.S. national-representative survey data shows that students' computer use at school depends on the number of computers available and whether the computers are located within the classroom or elsewhere. Consequently, because of the greater availability of computers in urban schools and homes, we expect both the likelihood and the time for computer use to be much greater for children in urban China than for their rural counterparts.

Age and Gender

Hofferth and Sandberg (2001) suggest that children's age may be the foremost factor that affects how they spend their time. As they grow up, children tend to spend less time in leisure activities such as sleeping, eating, and playing, and more time in studying, doing housework and watching TV (Hofferth and Sandberg 2001, Bianchi and Robinson 1997). Pellegrini and Smith (1998) suggest that children's time spent in physical exercise play is quite common in childhood, reaches its peak in the preschool and early primary grades, and then starts to decline. Moreover, Asian children substantially increase their time devoted to studying outside of school (homework, reading) with age (Larson and Verma 1999). Finally, some studies have shown that TV watching falls in early adolescence, while reading increases (Larson et al. 1989, Timmer et al. 1985).

Gender differences in children's time spent in different activities have also been widely witnessed. Fuligni and Stevenson (1995) found that, among U.S., Chinese, and Japanese students, boys spent much more time in extracurricular activities, but much less in studying and doing household chores each week than girls. The likelihood of participating in vigorous physical play has been shown to be greater for boys than for girls (Fabes 1994, Meaney et al. 1985, Pellis et al. 1996). In addition, Hofferth and Sandberg (2001) found the time spent playing declines at different rates in different activities for boys and girls as they grow mature. Their analysis shows that girls' time spent in reading increases faster than that for boys, whereas boys' time spent in sports increases faster than that for girls. Furthermore, several studies have found that whereas TV watching is more frequent for boys, the time spent reading is greater for girls (Bianchi and Robinson 1997, Larson et al. 1989).

Socioeconomic Status (Parental Education and Family Wealth)

Both parental education and income status have been strongly linked to how children spend time in different activities. Timmer et al. (1985) found that higher parental education was related to more time American children spent in studying and reading, but less time in watching TV. Fuligni and Stevenson (1995) found in their cross-culture study in Minneapolis (America), Taipei (Taiwan), and Sendai (Japan) that the likelihood of studying, attending lessons, and participating in extracurricular activities was much higher for the children whose parents have more years of education than for those whose parents have less years of education and that higher parental education status was associated with a decline in children's hours spent each week in watching TV and working. From the perspective of educational differences in parental time with children, extensive previous research suggests that well educated parents tend to spend more time with their children (Bianchi and Robinson 1997) and thus may lead to effective transmission of parental cognitive ability and academic expectations for children, which may translate into more time spent reading, doing homework, and participating in other academic pursuits for children.

Children in wealthy families may also have less difficulty in getting access to resources such as books and computers and therefore are likely to spend more time reading or using computers compared with those in poor families. Hofferth and Sandberg (2001) found that higher family income was significantly associated with less time children spent watching TV, though the effect was small. In addition, Bianchi and Robinson (1997) suggest that wealthy families are better-off in the ability and willingness to purchase reading materials, and thus children of these families may spend more hours reading than their poorer counterparts.

Maternal Employment

Although maternal employment status has often been considered one of most influential factors that affect children's time use and development, previous research remains inconclusive on the strength and the direction of this relationship. For example, some scholars argue that maternal employment may have negative effects on their children's educational achievement (Milne et al. 1986), whereas others failed to find such an association (Dawson 1991, Leibowitz 1977). Contrary to our common sense, Robinson (1993) found that the amount of time mothers spent with children in America in 1985 is almost as much as that in 1965, though there was a substantial increase in maternal employment during the same period. Similarly, Bianchi's (2000) study has shown that mothers' time spent with children remained relatively constant from 1965 to 1998, in spite of the noteworthy increase in women's participation in labor market in the same period. In addition, some scholars (Hofferth and Sandberg 2001) expect a larger amount of time mothers spend in the workforce is likely to reduce the time they spend reading with children or helping them complete homework. Bianchi and Robinson (1997), nonetheless, failed to find such a relationship in a sample of American children, whereas Zick and Bryant (1996) found that mothers with full-time employment throughout their children's childhood spend approximate 20 percent fewer hours in child care than unemployed mothers.

Single Parenting

The effects of single parenting on children's behavior and time spent in different activities may be not as simplistic as it is traditionally thought. The negative effects of living with single parents on children's behavior and development may be mitigated by some compensatory mechanisms (Demo and Acock 1988), and therefore children's time use in single- parent families may not differ noticeably from that in nuclear families. For example, although children living with single parents are expected to spend more time in household chores because they are likely to take on family responsibilities at a younger age than are children living with two parents (Longfellow 1979), Bianchi and Robinson (1997) failed to find such an association in their sample of young children in California. Nevertheless, Hofferth and Sandberg (2001) found that American children from single-female families still spent significantly less time in reading but more time in structured sports, after controlling for the employment status of the parent. The reasons for single parenting vary (divorce, out-of-wedlock birth, migrant parent, dead parent, etc.), and the implications of living with a single-parent for children's time use may be affected by these reasons.

We have found no studies examining the effect of single parenting in China, but in our study, single parenting is defined as one co-resident parent, and it most likely results from parental migration for work in this context. Several studies from societies where extended families and especially grandparents play a crucial role have suggested that children from families where a parent is absent for work are as well off as their two-parent families counterparts. For example, a study of children whose fathers were absent in Lesotho (Hlabana 2007) has found that father-absent children were doing better scholastically and emotionally than children whose fathers were present in the household. This finding was attributed to the fact that fathers who were present were "unemployable," since employable fathers were usually outside of the country working, and thus their families and children were economically worse off than father-absent families where fathers were sending periodic remittances. This latter study suggests that the relationship between single-parenting and children's outcomes is complex and context dependent and could be mediated by many factors.

Family Size and Birth Order

Previous research consistently found that a large number of siblings has a negative effect on children's educational achievement (Mare 1995, Blake 1989). One possible reason may be that more children in a family could reduce parents' time spent with each child and hence lead to fewer family resources invested in the cognitive development of each child. Hofferth and Sandberg (2001) show that American children in large families spend more time in sports and playing with their siblings than those in small families, which may lead to less time spent reading and studying.

The relationship between birth order and children's time use and their achievement remains unclear in previous research (Bianchi and Robinson 1997). For example, Zajonc and Markus (1975) argue that intellectual stimulation in the family tends to decline as a new birth occurs. Nevertheless, in the context of a developing country such as China, we expect that a higher birth order would imply more time spent in caring for younger siblings and doing housework but less time reading and studying, which may lead to higher social development but lower academic achievement, especially in a rural setting.

Data and Methods

The data used in this study come from the 2004 wave of the China Health and Nutrition Survey (CHNS), an ongoing panel study designed to examine the transition of health and nutrition status and family planning in the contemporary Chinese society. It covers both rural and urban areas of nine provinces in China and represents a diverse mixture with respect to socioeconomic, demographic, health, and nutrition factors. The first wave of data collection took place in 1989. Currently there are about 4,400 households in the overall survey. Our study focuses on school-age children from 6 to 17 years old and thus results in a total number of 2,191 observations in the final sample. Moreover, our study is cross-sectional as it includes the 2004 wave of the CHNS data.

In the CHNS 2004, questionnaires were administered to either the parents of the children (if the children were younger than 10 years of age) or the children themselves (for children 10 years of age or older), collecting reports of (1) whether children participate in a number of sedentary and physical activities in school, before or after school, and/or on the weekend, and (2) the usual time spent in activities on a typical week day and a typical weekend (recorded separately) for children who reported participation in various activities. Some activities were reported per day, while others were reported per week. To compute the time spent in an activity per day, we multiplied weekday time by five (5) and weekend day time by two (2), added them up and divided this weekly time by 7. To compute the time spent in an activity per week we multiplied the time spent each time in an activity by the number of times per week children were engaged in that activity.

For simplification purposes we have given short names to our dependent variables indicating various activities. The variable called "reading" refers to extracurricular reading (including books, newspapers, and magazines), writing, and drawing, for these three activities were classified into one category in the questionnaire of the CHNS 2004. In our descriptive analysis, we examined children's time spent watching TV, videotapes (including VCDs and DVDs), and playing video games separately. However, given the low percentage of participation in watching videotapes and playing video games, when fitting the regression models, we aggregated these three activities into one, indicating participation into either one of these TV-video related activities. Thus, the dichotomous dependent variable that measures whether a child ever participated in "TV & video" was coded "1" if the child ever watched TV or videotapes or played video games, and "0" otherwise. The continuous variable that measures the amount of time a child spent watching "TV & video" is the sum of the time that he/she spent in all of these three activities.

Similarly, we examined the percentage of participation and amount of time children spent in buying food, cooking, washing and ironing clothes, and cleaning the house for the family separately in the descriptive analysis. In the regression models, however, we combined these four activities into one category, known as "household chores." Therefore, the dichotomous variable that measures whether a child ever did "household chores" would be coded as "1" if he/she ever did any of these four activities, and "0" otherwise. The continuous variable that measures the amount of time a child spent doing "household chores" is the sum of the time that he/she spent in all of these four activities.

Most of the continuous variables that capture the amount of time children spent doing each activity such as reading and doing homework are measured in minutes per day. Time spent playing sports is measured in hours per week, while the time spent in childcare either in the same or another household and doing fieldwork is measured in hours per day, given the nature of these activities.

To capture rural-urban disparities, we used a dummy variable indicating whether children lived in an urban or rural area. Urban area here refers to a city or suburban community, whereas rural area indicates a town or a rural village, as per the classification scheme used in the CHNS 2004. We have also used a dummy for gender, while children's age is measured with a continuous variable. Both mother's and father's education are measured with ordinal level variables (that were later transformed into a series of dummies) with four categories, as follows: (1) no schooling (the reference category in our multivariate analyses), (2) primary school education, (3) junior high school education, and (4) beyond high school education.

To measure socio-economic status, we had two options. The first one was the reported annual incomes, but this measure turned out to be fraught with problems such as low validity and reliability, especially in rural China where people may not be able to convert all their revenues from different sources into monetary income. We decided instead to use a second option, a durable goods index that was created as an indicator of family wealth. In the CHNS 2004, every family either in rural or in urban areas was asked to report its ownership of a list of durable goods. We first summed up the number of these goods each family owned, and then divided all the families into quartiles based upon the total number of the goods owned and created a set of four dummy variables corresponding to each quartile (Adams and Hannum 2005).

Maternal employment status was captured by a nominal variable (a series of dummies in the regressions) with five categories: (1) unemployed, (2) professional, (3) unskilled worker, (4) farmer, and (5) other. Respondents were asked whether they were employed or not, and if they answered positively, they were inquired about the type of employment they have. Thus, for instance, farmers were categorized as employed or not, depending on how they answered the initial question regarding employment status.

Three measurements were used to capture family structure and size and children's birth order. First, we employed two dichotomous variables to differentiate (1) between children who live with both parents and those who live with only one parent, and (2) children who live with grandparents and those who only live with their parents. Second, a set of three dummy variables were used to distinguish among children who do not have siblings, those who have older siblings, and those who have younger siblings.

Finally, we added a community-level variable, the number of communication services available in the community, to indicate the level of development/urbanization of the village/town/locality/city where individuals live. The communication services include things like telegraph, telephone, internet, cell phone, fax, and postal ser-

Table 1 Summary statistics of the independent variables.

Variable	Mean	Std. Dev.	Min	Max
Residence				
Rural	0.7403	0.4386	0	1
Age	12.6563	3.3956	6	17
Male	0.5345	0.4989	0	1
Father's education				
No schooling	0.0096	0.0975	0	1
<=Primary school	0.1429	0.3500	0	1
<=Junior high school	0.3199	0.4666	0	1
>= Senior high school	0.1739	0.3791	0	1
Mother's education				
No schooling	0.0502	0.2184	0	1
<=Primary school	0.2154	0.4112	0	1
<=Junior high school	0.3145	0.4644	0	1
>= Senior high school	0.1273	0.3334	0	1
Maternal employment				
No job	0.2806	0.4494	0	1
Professionals	0.1035	0.3047	0	1
Unskilled worker	0.1393	0.3464	0	1
Farmer	0.3962	0.4892	0	1
Other	0.0285	0.1666	0	1
Family wealth quartiles				
1st (least wealthy 25%)	0.2150	0.4109	0	1
2nd	0.1803	0.3845	0	1
3rd	0.2305	0.4212	0	1
4th (most wealthy 25%)	0.1661	0.3723	0	1
Single parenting	0.0981	0.2976	0	1
Siblings				
No sibling	0.4774	0.4996	0	1
Has older sibling	0.3473	0.4762	0	1
Has younger sibling	0.2232	0.4165	0	1
Grandparents				
Living in household	0.3094	0.4624	0	1
Number of communication services	3.9428	2.1503	0	8
N = 2191				

vices, and capture differences between rural, semi-rural, small town and urban areas in terms of development.

Table 1 presents summary statistics of the independent variables. In our sample, around 75 percent of children were from rural areas (see Note 1), with an average age of about 13 years old. The sample is evenly distributed across genders, with the number of boys slightly higher (about 3 percent higher) than that of girls. Approximate one third of the children in the sample had fathers or mothers who had complete or some junior high school education. There were more children living in the families that fell in the poorest quartile and the second wealthiest quartile than the children living in the families that fell in the other two quartiles. About one quarter of the children had unemployed mothers, 36 percent had mothers who were farmers, 12 percent had mothers who were unskilled workers, and 10 percent had mothers who worked as professionals.

Nearly 10 percent of children were living with single parents, that is, one of the parents was absent from the family at the time of survey. Almost half of our sample had no siblings, while about 35 percent had older siblings and 22 percent had younger siblings. Finally, about one third of the children lived in extended families (with their grandparents, in addition to their parents).

Descriptive Results

Participation in Activities

Table 2 presents the percentages of children who are engaged in various activities by selected characteristics. The most common activities among Chinese children and teenagers in addition to schooling (which is not presented here since most children are enrolled in school) are TV watching (72.85 percent), playing sports (70.24 percent) and doing homework (63.69 percent), followed by reading (47.6 percent) and doing at least one of the household chores (31.26 percent). Playing videogames (7.38 percent), watching videotapes (13.44 percent), playing computer games and surfing the internet (11.58 percent), doing fieldwork (8.49 percent) and playing with toys (15.13 percent) were relatively uncommon activities, although some of these activities were quite common among some sub-groups of children.

Contrary to some other studies showing different patterns for TV viewing and reading or studying (doing homework), it appears that among Chinese children those activities are similar in that they are all more likely among urban, wealthier children, and those with more educated parents and no siblings. Gender is the only characteristic that differentiates this common pattern in that boys are more likely than girls to watch TV and girls are more likely than boys to read and to do homework, as other studies have previously found (e.g., Fuligni and Stevenson 1995). Children whose mothers are employed as professionals are more likely to read, do homework, play computer games, watch TV, and play sports, and a lot less likely to do housework or childcare, while children of farmers have the opposite pattern of activities. Interestingly, children from single-parent families are more likely to read, study, watch TV, and play sports, and also more likely to do fieldwork and house chores such as buying food, cooking, washing and ironing, cleaning, and childcare, compared to children living with both parents.

Playing sports is much more likely among urban, wealthier children and those with educated and /or professional parents and no siblings. Likewise, using the computer is much more likely among urban, wealthier children and those with educated parents and no siblings, but also among boys, while the opposite is true for housework, which is the most likely among girls and children with poorer, less educated parents. Playing with toys is age-dependent, as expected, with younger children being more likely to play compared to older children (21.81 percent versus 8.03 per-

Table 2 Percentage of children engaging in major activities by selected characteristics (CHNS 2004 data).

	Reading	Homework	TV	Videotapes	Video games
Total (percentage)	47.6	63.69	72.85	13.44	7.38
Residence					
Urban	66.08	76.1	79.26	21.27	12.13
Rural	41.12	59.49	70.78	10.73	5.73
Age					
6-12	54	82.82	89.22	14.41	7.47
13-17	42.82	49.44	60.65	12.72	7.31
Gender					
Male	44.32	62.08	73.19	15.54	11.27
Female	51.37	65.78	72.75	11.08	2.94
Father's education					
No schooling	42.86	52.38	85.71	0	0
<=Primary school	49.2	70.61	88.82	16.93	7.35
<=Junior high school	58.63	80.31	93.87	15.83	9.42
>= Senior high school	73.23	87.66	93.7	19.42	11.29
Mother's education					
No schooling	38.18	68.18	74.55	10	5.45
<=Primary school	52.75	73.52	92.58	15.89	7.84
<=Junior high school	62.41	82	93.18	17.85	10.16
>= Senior high school	80.29	91.04	94.98	20.79	11.47
Maternal employment					
No job	53.1	66.55	75.86	13.28	7.76
Professionals	70.09	78.97	80.37	21.5	7.48
Unskilled worker	55.9	70.14	73.96	16.67	11.11
Farmer	36.87	52.01	63.98	10.5	4.88
Other	44.07	71.19	77.97	13.56	16.95
Family wealth quartiles					
1st (least wealthy 25%)	47.98	72.82	88.75	7.86	5.94
2nd	54.94	78.73	93.92	12.41	7.59
3rd	62.57	81.98	93.86	20.99	10.3
4th (most wealthy 25%)	78.02	90.66	92.31	28.3	14.29
Parenting					
Single parent	57.21	82.33	87.44	16.28	10.7
Both parents	46.56	61.67	71.26	13.13	7.02
Siblings					
No sibling	57.46	74.76	82.79	15.87	9.27
Has older sibling	37.45	53.22	64.39	12.09	6.44
Has younger sibling	37.83	51.53	60.53	9.41	4.29
Grandparents					
Living in household	59.17	80.94	92.32	18.07	7.97
Not living in household	42.9	55.51	63.61	11.54	7.46
N=2191					

cent, respectively). Moreover, urban boys and those with no siblings are also more likely to play with toys than other groups of children.

Table 2 Continued.

	Computer	Sports	Buying food	Cooking	Wash & Ironing
Total (percentage)	11.58	70.24	11.66	10.11	11.34
Residence					
Urban	25.67	80.49	13.71	11.95	12.48
Rural	6.01	66.65	10.97	9.49	10.97
Age					
6-12	5.1	89.22	12.38	7.26	6.94
13-17	18.44	56.06	11.13	12.24	14.63
Gender					
Male	14.38	69.85	10.93	7.69	6.49
Female	8.43	70.69	12.55	12.94	16.96
Father's education					
No schooling	5	57.14	14.29	19.05	23.81
<=Primary school	5.5	85.62	15.65	16.29	18.21
<=Junior high school	10.4	87.87	15.83	13.55	14.41
>= Senior high school	18.95	94.49	11.55	7.09	10.76
Mother's education					
No schooling	7.55	79.09	16.36	13.64	20.91
<=Primary school	7.89	83.47	16.74	18.22	18.01
<=Junior high school	11.91	91.29	14.22	10.3	11.76
>= Senior high school	21.58	94.62	10.75	7.17	8.96
Maternal employment					
No job	15.14	72.41	8.45	5.86	7.07
Professionals	19.89	82.24	9.35	4.21	3.74
Unskilled worker	16.37	73.61	6.94	7.99	11.11
Farmer	6.24	61.05	13.19	13.31	14.29
Other	8.51	77.97	11.86	15.25	10.17
Family wealth quartiles					
1st (least wealthy 25%)	4.06	83.01	16.56	16.77	18.9
2nd	7.44	87.85	15.44	16.2	15.95
3rd	10.78	90.89	15.25	11.88	14.06
4th (most wealthy 25%)	27.02	93.96	10.99	5.22	7.14
Parenting					
Single parent	11.21	86.98	14.42	21.4	19.07
Both parents	11.64	68.42	11.36	8.89	10.51
Siblings					
No sibling	13.7	80.21	11.66	9.37	10.33
Has older sibling	9.75	60.45	11.43	9.86	11.43
Has younger sibling	7.38	59.1	11.25	12.88	13.91
Grandparents					
Living in household	10.76	88.62	13.8	11.24	11.52
Not living in household	12.32	62	10.33	9.18	10.77
N=2191					

Time Spent in Activities

Understanding how children spend their time implies not only finding the percentage of children engaged in each activity, but also knowing how much time children who engage in activities spend doing them. Thus we present in Table 3 the mean number of minutes/hours children spend in each activity. We have seen that most Chinese

Table 2 Continued.

	Cleaning	Childcare	Fieldwork	Playing toys
Total (percentage)	22.51	5.2	8.49	15.13
Residence				
Urban	24.96	3.08	4.57	21.56
Rural	21.7	6.03	9.86	12.58
Age				
6-12	23.27	7.22	6.19	21.81
13-17	21.94	3.08	10.21	8.03
Gender				
Male	16.91	2.72	8.37	18.86
Female	29.02	8	8.63	10.9
Father's education				
No schooling	23.81	4.76	38.1	10
<=Primary school	30.67	7.99	16.93	11.29
<=Junior high school	27.96	5	10.13	13.89
>= Senior high school	26.25	2.12	6.3	20
Mother's education				
No schooling	39.09	4.59	28.18	2.83
<=Primary school	29.66	7.84	16.1	11.73
<=Junior high school	27.87	5.25	7.55	17.89
>= Senior high school	20.79	0.72	3.23	20.22
Maternal employment				
No job	18.97	6.75	4.83	14.47
Professionals	13.55	1.65	0.93	23.2
Unskilled worker	21.18	6.61	5.9	16.81
Farmer	25.27	4.45	14.29	11.61
Other	28.81	4.26	10.17	23.4
Family wealth quartiles				
1st (least wealthy 25%)	29.09	6.6	15.71	7.69
2nd	29.37	6.33	12.15	12.53
3rd	31.09	4.58	10.69	19.16
4th (most wealthy 25%)	23.08	3.02	2.75	22.01
Parenting				
Single parent	36.74	6.51	12.09	14.42
Both parents	20.96	5.01	8.1	15.23
Siblings				
No sibling	22.18	2.67	5.54	18.55
Has older sibling	22.21	2.29	11.17	12.81
Has younger sibling	24.34	16.97	12.27	7.98
Grandparents				
Living in household	26.74	6.85	9.67	15.64
Not living in household	19.95	4.17	7.94	14.93
N=2191				

children watch TV, play sports, and do homework. Table 3 shows that, on average, children watch TV a little over an hour and a half a day (93.04 min/day), play sports

Table 3 Average time spent in major activities by selected characteristics.

	Reading*		Homework*		TV*		Videotapes*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total	47.61	41.48	98.12	81.69	93.04	73.63	46.24	34.99
Residence								
Urban	45.89	45.14	105.77	83.36	87.58	67.25	40.16	29.56
Rural	48.54	39.36	94.72	80.75	95.14	75.86	50.66	37.94
Age								
6-12	44.52	37.64	84.19	67.53	91.34	59.50	42.94	29.66
13-17	50.55	44.68	116.04	93.97	94.96	86.93	49.38	39.26
Gender								
Male	47.12	47.62	90.30	72.90	92.83	66.01	48.22	32.20
Female	48.08	34.50	106.51	89.47	93.28	81.46	43.28	38.81
Father's education								
No schooling	36.73	19.16	58.89	48.10	95.71	60.47	.	.
<=Primary school	51.71	49.53	94.19	76.22	103.77	89.57	51.01	42.63
<=Junior high school	46.99	34.88	98.14	84.07	96.46	73.98	51.65	36.49
>= Senior high school	45.62	33.65	101.39	79.95	81.74	67.29	40.84	30.87
Mother's education								
No schooling	52.60	34.39	84.82	52.58	95.54	99.53	65.00	66.86
<=Primary school	43.64	32.27	85.21	61.68	96.21	68.94	46.15	34.00
<=Junior high school	49.28	42.65	102.16	79.59	95.48	74.27	47.55	32.76
>= Senior high school	44.95	29.35	113.60	93.57	79.97	70.86	37.66	30.83
Maternal employment								
No job	50.58	34.64	106.40	86.92	91.22	65.07	45.54	30.04
Professionals	48.06	31.67	109.98	76.06	73.84	50.49	39.76	32.41
Unskilled worker	42.24	34.06	95.84	66.83	87.27	73.82	38.42	26.29
Farmer	44.52	33.03	87.34	61.76	98.29	70.12	48.56	34.55
Other	35.24	23.21	76.21	40.65	90.26	55.44	38.57	16.04
Family wealth quartiles								
1st (least wealthy 25%)	49.06	31.91	87.62	69.16	99.42	69.05	50.88	26.04
2nd	48.52	46.45	94.99	67.37	95.14	72.13	46.21	32.01
3rd	49.59	51.93	104.16	105.77	99.31	89.60	52.91	43.54
4th (most wealthy 25%)	43.60	29.49	104.30	69.54	74.20	48.30	36.61	26.76
Parenting								
Single parent	45.39	30.27	90.78	57.56	86.42	55.34	47.57	37.83
Both parents	47.90	42.77	99.21	84.66	93.93	75.71	46.05	34.65
Siblings								
No sibling	49.34	46.99	103.35	88.89	90.97	78.90	45.85	36.75
Has older sibling	45.49	32.66	91.73	75.58	93.12	67.84	47.18	32.75
Has younger sibling	44.59	31.04	89.55	59.59	97.36	63.44	42.24	29.70
Grandparents								
Living in household	42.60	36.14	91.44	71.86	89.80	62.23	42.28	26.80
Not living in household	50.67	43.63	102.62	86.21	94.23	79.13	48.69	39.69

Notes: SD = standard deviation; * Minutes per day; ** Hours per week; ***Hours per day.

for almost four hours a week (3.99 h/wk), and spend more than one and a half hours a day doing homework (98.12 min/day). Moreover, those who read for fun (47.6 percent) spend a little over three quarters of an hour a day (47.61 min/day) doing it, and children who do housework (31.26 percent) spend only 12.65 minutes a day doing household chores. Furthermore, the small percentage of children who use computers, play with toys, use videotapes, and play video games in China do so for

Table 3 Continued.

	Video games*		Computer*		Sports**		Buying food*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total	49.94	51.70	61.64	66.15	3.99	6.71	13.40	9.92
Residence								
Urban	52.16	64.67	59.08	67.17	4.71	7.17	14.40	8.44
Rural	48.42	41.03	65.76	64.75	3.69	6.49	13.06	10.39
Age								
6-12	41.61	31.88	36.70	27.95	3.71	5.35	11.48	7.96
13-17	57.41	63.87	69.03	72.20	4.33	8.05	15.00	11.09
Gender								
Male	55.42	55.45	72.29	78.11	4.53	8.13	12.83	9.97
Female	27.80	21.84	42.70	28.05	3.38	4.55	13.99	9.89
Father's education								
No schooling			1.43	.	2.48	1.56	3.00	.
<=Primary school	60.63	57.91	62.76	63.93	3.80	5.00	14.47	8.21
<=Junior high school	54.01	62.92	79.46	85.85	4.02	6.48	13.64	9.51
>= Senior high school	44.83	40.11	49.48	53.65	4.47	9.35	14.21	13.77
Mother's education								
No schooling	79.43	91.31	44.08	25.21	2.71	2.29	14.00	14.74
<=Primary school	56.79	46.87	64.60	78.96	3.91	8.90	15.10	12.17
<=Junior high school	49.20	60.30	67.32	72.07	4.29	6.48	13.07	8.11
>= Senior high school	40.03	26.82	55.31	55.91	4.34	5.97	10.04	7.14
Maternal employment								
No job	67.25	74.37	62.40	62.62	5.33	10.62	11.44	7.29
Professionals	32.45	20.62	60.61	67.96	3.99	3.62	10.38	7.73
Unskilled worker	39.13	27.13	63.01	68.26	4.13	6.69	16.36	15.83
Farmer	46.93	43.06	59.98	74.92	3.05	2.65	14.96	11.35
Other	27.14	20.55	59.29	81.90	5.81	10.74	11.40	10.60
Family wealth quartiles								
1st (least wealthy 25%)	59.47	85.40	76.83	99.64	3.43	5.46	13.90	12.07
2nd	48.02	35.68		48.64	3.81	8.97	14.24	10.28
3rd	54.49	52.75	79.74	84.56	4.17	5.70	13.02	7.40
4th (most wealthy 25%)	40.73	29.70	50.96	48.45	4.55	6.49	11.87	8.99
Parenting								
Single parent	50.16	39.06	58.54	52.80	3.35	4.72	9.08	4.99
Both parents	49.90	53.58	62.06	67.90	4.08	6.95	14.04	10.31
Siblings								
No sibling	43.95	38.44	59.64	62.86	4.05	5.63	13.19	9.77
Has older sibling	64.05	73.24	67.51	80.89	4.06	8.41	14.10	10.78
Has younger sibling	36.43	30.20	57.39	37.54	3.55	6.17	12.67	8.69
Grandparents								
Living in household	53.87	72.92	74.79	79.16	3.76	4.85	14.51	10.28
Not living in household	46.70	34.32	53.41	54.21	4.13	7.58	12.90	9.67

Notes: SD = standard deviation; * Minutes per day; ** Hours per week; ***Hours per day

over an hour (61.64 min/day), 42.78 minutes, 46.24 minutes, and 34.99 minutes a day, respectively. Interestingly, the few children who do childcare (5.2 percent) and fieldwork (8.49 percent) spend a long amount of time in these activities, 5.55 hours a day and 3.43 hours a day, respectively.

Children with no siblings and whose mothers have no schooling and are unemployed tend to read more than other groups of children. Therefore, although a

Table 3 Continued.

	Cooking*		Washing & Ironing*		Cleaning*	
	Mean	SD	Mean	SD	Mean	SD
Total	35.06	26.11	23.64	17.15	15.01	12.30
Residence						
Urban	33.42	25.18	25.92	21.55	17.71	14.98
Rural	35.71	26.53	22.83	15.28	14.00	10.99
Age						
6-12	32.05	26.21	22.28	21.09	13.01	10.32
13-17	36.37	26.05	24.10	15.63	16.64	13.51
Gender						
Male	33.35	24.34	19.66	9.90	12.63	9.55
Female	36.24	27.30	25.42	19.31	16.59	13.61
Father's education						
No schooling	45.00	21.21	28.75	22.50	7.67	4.04
<=Primary school	34.22	18.95	22.24	13.11	14.55	13.43
<=Junior high school	32.11	17.59	24.92	20.86	16.69	14.06
>= Senior high school	39.42	36.51	23.67	13.92	12.75	7.08
Mother's education						
No schooling	32.67	18.01	23.48	11.02	14.34	12.89
<=Primary school	35.13	26.61	22.40	16.93	14.69	11.73
<=Junior high school	31.52	23.90	25.61	19.73	15.87	13.02
>= Senior high school	28.95	19.26	21.50	12.61	13.98	13.15
Maternal employment						
No job	38.50	36.49	24.78	23.48	16.60	16.68
Professionals	48.13	55.93	18.83	10.78	18.77	16.64
Unskilled worker	24.76	11.99	22.58	10.64	14.19	8.48
Farmer	31.06	17.54	22.20	14.18	13.66	9.98
Other	28.57	9.45	21.25	10.31	10.77	7.69
Family wealth quartiles						
1st (least wealthy 25%)	38.83	27.05	24.42	18.92	15.80	14.24
2nd	34.91	17.15	22.37	12.78	14.29	12.14
3rd	28.80	25.49	24.31	19.29	15.77	12.54
4th (most wealthy 25%)	39.17	41.74	22.08	13.90	13.29	7.74
Parenting						
Single parent	35.95	20.07	21.34	12.75	12.95	7.95
Both parents	34.82	27.54	24.12	17.93	15.41	12.96
Siblings						
No sibling	33.24	25.09	24.90	19.15	15.37	12.31
Has older sibling	38.20	31.39	22.07	12.37	14.26	12.25
Has younger sibling	34.12	18.08	24.21	18.38	15.41	11.84
Grandparents						
Living in household	39.02	32.52	21.35	14.76	14.64	10.68
Not living in household	33.01	22.11	24.66	18.04	15.15	13.04

Notes: SD = standard deviation; * Minutes per day; ** Hours per week; ***Hours per day.

smaller percentage of children whose mothers have no schooling read, they do so for longer periods compared to other children, probably reflecting the exceptional status of these children. Moreover, girls, urban, wealthier children, and those with highly educated parents and no siblings spend more time doing homework compared to other children. Rural children, those with younger siblings, and those in two-parent families spend longer time watching TV, while the wealthiest children and those with highly educated mothers spend less time watching TV compared to other groups. Thus, although wealthier children with highly educated parents are more likely to watch TV, they also do so for less time per day compared to other groups, most likely indicating close parental monitoring.

Boys are not only much more likely to use computers, but they also spend much longer time using them compared to girls (72.29 min/day compared to 42.7 min/day, respectively). Boys, as well as wealthier children and those with highly educated parents, spend longer hours in sports per week compared to other children, possibly reflecting the Western influence on these children's activities. Finally, gender differences are the most striking in terms of household chores, with girls spending much longer time in all theses activities compared to boys. For instance, when all household chores are considered, girls spend on average 17.51 minutes a day compared to less than half (8.35) that time boys spend on these tasks. Moreover, girls spend 25.42 minutes per day washing and ironing compared to 19.6 minutes a day boys spend in these activities. Also, girls spend 6.22 hours a day in childcare compared to half that time boys spend in this activity.

Family and Children's Characteristics and Time Use

Some previous studies examining children's time (Hofferth and Sandberg 2001, Bianchi and Robinson 1997) used Tobit regression models to estimate the amount of time children spent in different activities, since these models correct for the fact that not all children participate in each activity. However, Tobit models rely heavily on the normality assumption, and the estimates are useless if the normality assumption does not hold (Smith and Brame 2003), which is the case in this study. Several diagnostic tests performed indicated that Tobit models are not appropriate for this study, since most of the variables measuring participation in activities are severely skewed. This was not surprising for us, since previous studies (e.g., Walberg and Tsai 1984, Greaney 1980) have also found that children's participation in various activities is highly skewed and unequal. Therefore, instead of fitting a Tobit model, we used two steps in our analysis. First, we used logit regression models to estimate the likelihood of engaging in each activity, and then used OLS regression models to estimate the amount of time spent in each activity conditional on the participation. For both steps (logit regressions and OLS regressions) and for each activity, we present two sets of models: (1) a simple additive model with all the covariates and no interactions, and (2) an interactive model with all the covariates and with the interaction between urban/rural environments and family structure on the one hand, and the interaction between urban/rural environments and family SES on the other hand. For simplification purposes, when we describe the results below, we refer to the coefficients/odds ratios from the additive models, since most interactions in our models are insignificant, and the results are fairly similar between the two sets of models.

Table 4 Logistic regressions of childrens' and families' characteristics on activities (CHNS 2004).

Variable	Reading				Homework			
	Model 1		Model 2		Model 1		Model 2	
Residence (Ref.=urban)								
Rural	0.55***	(0.07)	0.51**	(0.11)	0.65**	(0.10)	0.85	(0.19)
Age	1.04*	(0.02)	1.04*	(0.02)	0.83***	(0.02)	0.84***	(0.02)
Gender (Ref.=female)								
Male	0.70**	(0.07)	0.70**	(0.07)	0.83	(0.10)	0.83	(0.10)
Father's education (Ref.=no schooling)								
<=Primary school	2.21***	(0.41)	2.23***	(0.42)	3.21***	(0.67)	3.26***	(0.68)
<=Junior high school	2.37***	(0.39)	2.39***	(0.39)	4.16***	(0.80)	4.07***	(0.79)
>= Senior high school	3.55***	(0.68)	3.58***	(0.69)	5.96***	(1.38)	5.98***	(1.39)
Mother's education (Ref.=no schooling)								
<=Primary school	2.97***	(0.50)	2.96***	(0.50)	2.13***	(0.40)	2.16***	(0.41)
<=Junior high school	3.29***	(0.54)	3.28***	(0.54)	2.34***	(0.45)	2.37***	(0.45)
>= Senior high school	4.93***	(1.11)	4.94***	(1.11)	3.53***	(1.01)	3.36***	(0.97)
Maternal employment (Ref.=no job)								
Professionals	0.88	(0.19)	0.89	(0.20)	0.76	(0.21)	0.79	(0.22)
Unskilled worker	0.84	(0.14)	0.84	(0.14)	0.76	(0.16)	0.77	(0.16)
Farmer	0.76*	(0.10)	0.77*	(0.10)	0.67**	(0.10)	0.67**	(0.09)
Other	0.57	(0.18)	0.57	(0.18)	1.11	(0.45)	1.18	(0.48)
Family wealth quartiles (Ref.=1st quartile)								
2nd	1.64**	(0.24)	1.42	(0.43)	2.28***	(0.38)	3.76**	(1.48)
3rd	2.02***	(0.29)	2.17**	(0.63)	2.42***	(0.40)	3.02**	(1.02)
4th (most wealthy 25%)	2.97***	(0.53)	2.65**	(0.74)	3.91***	(0.89)	10.28***	(4.42)
Parenting (Ref.=both parents)								
Single parent	3.53***	(0.65)	2.63*	(1.08)	6.92***	(1.56)	2.78*	(1.29)
Siblings (Ref.=no sibling)								
Has older sibling	0.71**	(0.08)	0.71**	(0.08)	0.82	(0.11)	0.83	(0.11)
Has younger sibling	0.73*	(0.10)	0.73*	(0.10)	0.72*	(0.11)	0.72*	(0.11)
Grandparents (Ref.=not in household)								
Living in household	1.60***	(0.18)	1.61***	(0.18)	1.68***	(0.23)	1.65***	(0.23)
Number of communication services	1.01	(0.02)	1.00	(0.02)	1.01	(0.03)	1.01	(0.03)
Rural x Single parent			1.42	(0.62)			3.07*	(1.57)
Rural x Family wealth 2nd quartile			1.19	(0.40)			0.54	(0.23)
Rural x Family wealth 3rd quartile			0.91	(0.29)			0.76	(0.29)
Rural x Family wealth 4th quartile			1.20	(0.40)			0.25**	(0.12)
Pseudo R-squared	0.246		0.246		0.378		0.383	

Notes: Ref.=reference group; Standard errors in parentheses; *p<.05; ** p <.01; *** p <.001.

Family and Children's Characteristics and Participation in Activities

In Table 4 we present the odds ratios for the impact of family and children's characteristics, as well as urban/rural residence, on daily/weekly time spent in several major types of activities as follows: extracurricular intellectual activities (reading,

Table 4 Continued.

Variable	TV/video				Computer			
	Model 1		Model 2		Model 1		Model 2	
Residence (Ref.=urban)								
Rural	1.10	(0.22)	1.36	(0.39)	0.28***	(0.05)	0.19**	(0.10)
Age	0.86***	(0.02)	0.86***	(0.02)	1.31***	(0.04)	1.32***	(0.04)
Gender (Ref.=female)								
Male	1.33	(0.22)	1.32	(0.22)	2.24***	(0.40)	2.28***	(0.41)
Father's education (Ref.=no schooling)								
<=Primary school	6.84***	(1.88)	7.14***	(1.97)	0.38*	(0.15)	0.37*	(0.15)
<=Junior high school	7.97***	(2.05)	7.74***	(2.00)	0.57	(0.18)	0.56	(0.18)
>= Senior high school	9.27***	(2.79)	9.46***	(2.86)	0.96	(0.30)	0.92	(0.29)
Mother's education (Ref.=no schooling)								
<=Primary school	7.84***	(2.06)	8.08***	(2.14)	1.33	(0.45)	1.29	(0.44)
<=Junior high school	5.92***	(1.54)	6.13***	(1.62)	1.12	(0.35)	1.10	(0.34)
>= Senior high school	7.72***	(3.07)	7.16***	(2.85)	1.18	(0.41)	1.19	(0.41)
Maternal employment (Ref.=no job)								
Professionals	0.35**	(0.13)	0.36**	(0.14)	0.85	(0.24)	0.90	(0.26)
Unskilled worker	0.31***	(0.09)	0.32***	(0.09)	1.05	(0.26)	1.05	(0.26)
Farmer	0.45***	(0.09)	0.45***	(0.09)	0.83	(0.21)	0.84	(0.21)
Other	0.78	(0.45)	0.84	(0.48)	0.67	(0.39)	0.69	(0.40)
Family wealth quartiles (Ref.=1st quartile)								
2nd	4.31***	(1.14)	3.36*	(1.73)	2.03*	(0.65)	1.93	(0.90)
3rd	3.71***	(0.94)	7.79***	(4.38)	2.60**	(0.80)	2.17	(0.94)
4th (most wealthy 25%)	2.34**	(0.67)	3.88**	(1.68)	5.33***	(1.65)	4.47***	(1.84)
Parenting (Ref.=both parents)								
Single parent	5.94***	(1.61)	4.07**	(2.15)	0.99	(0.35)	0.51	(0.26)
Siblings (Ref.=no sibling)								
Has older sibling	0.91	(0.17)	0.92	(0.17)	1.02	(0.21)	1.04	(0.22)
Has younger sibling	0.49**	(0.10)	0.50**	(0.11)	0.93	(0.25)	0.94	(0.25)
Grandparents (Ref.=not in household)								
Living in household	3.42***	(0.72)	3.45***	(0.73)	1.19	(0.23)	1.18	(0.23)
Number of communication services	0.98	(0.04)	0.97	(0.04)	1.14**	(0.05)	1.14**	(0.05)
Rural x Single parent			1.65	(0.98)			2.86	(1.59)
Rural x Family wealth 2nd quartile			1.39	(0.82)			1.12	(0.72)
Rural x Family wealth 3rd quartile			0.39	(0.24)			1.46	(0.87)
Rural x Family wealth 4th quartile			0.44	(0.22)			1.47	(0.85)
Pseudo R-squared	0.576		0.578		0.252		0.255	

Notes: Ref.=reference group; Standard errors in parentheses; * p <.05; ** p <.01; *** p <.001.

writing, drawing, and doing homework), leisure activities (TV, video games, video tapes, and computer use), physical activity (sports), and housework (combined participation in cooking, buying food, washing, ironing, cleaning, and childcare). Since paid work and fieldwork are so uncommon among Chinese children, we did not consider them in the multivariate analysis. We have also excluded from our analyses playing with toys, since it is only applicable to young children.

Table 4 Continued.

Variable	Sports				Household chores			
	Model 1		Model 2		Model 1		Model 2	
Residence (Ref.=urban)								
Rural	0.66*	(0.12)	0.78	(0.20)	0.84	(0.10)	0.85	(0.19)
Age	0.80***	(0.02)	0.80***	(0.02)	1.07***	(0.02)	1.07***	(0.02)
Gender (Ref.=female)								
Male	1.05	(0.15)	1.04	(0.15)	0.56***	(0.06)	0.56***	(0.06)
Father's education (Ref.=no schooling)								
<=Primary school	6.96***	(1.70)	7.19***	(1.76)	3.93***	(0.75)	3.96***	(0.76)
<=Junior high school	5.64***	(1.25)	5.54***	(1.23)	3.20***	(0.54)	3.21***	(0.55)
>= Senior high school	13.61***	(4.05)	13.96***	(4.18)	2.53***	(0.49)	2.54***	(0.49)
Mother's education (Ref.=no schooling)								
<=Primary school	2.34***	(0.50)	2.37***	(0.51)	1.93***	(0.32)	1.92***	(0.32)
<=Junior high school	3.96***	(0.91)	4.06***	(0.95)	1.58**	(0.26)	1.57**	(0.26)
>= Senior high school	3.79***	(1.32)	3.45***	(1.21)	1.32	(0.29)	1.33	(0.29)
Maternal employment (Ref.=no job)								
Professionals	0.73	(0.25)	0.77	(0.27)	0.72	(0.15)	0.73	(0.15)
Unskilled worker	0.55*	(0.14)	0.56*	(0.14)	1.00	(0.16)	0.99	(0.16)
Farmer	0.81	(0.14)	0.81	(0.14)	1.17	(0.14)	1.17	(0.14)
Other	1.48	(0.76)	1.60	(0.81)	1.47	(0.45)	1.50	(0.46)
Family wealth quartiles (Ref.=1st quartile)								
2nd	2.65***	(0.53)	2.71*	(1.23)	1.60**	(0.24)	1.68	(0.51)
3rd	2.96***	(0.62)	3.84**	(1.66)	1.65**	(0.24)	1.99*	(0.55)
4th (most wealthy 25%)	3.85***	(1.08)	12.85***	(7.41)	1.23	(0.21)	1.15	(0.31)
Parenting (Ref.=both parents)								
Single parent	8.18***	(2.08)	3.45*	(1.76)	5.27***	(0.97)	4.16***	(1.55)
Siblings (Ref.=no sibling)								
Has older sibling	0.83	(0.13)	0.84	(0.13)	1.03	(0.12)	1.04	(0.12)
Has younger sibling	0.74	(0.13)	0.74	(0.13)	1.29*	(0.17)	1.30*	(0.17)
Grandparents (Ref.=not in household)								
Living in household	2.27***	(0.39)	2.24***	(0.39)	1.58***	(0.17)	1.59***	(0.17)
Number of communication services	1.05	(0.04)	1.05	(0.04)	1.00	(0.02)	1.00	(0.02)
Rural x Single parent			2.94	(1.68)			1.34	(0.53)
Rural x Family wealth 2nd quartile			0.95	(0.47)			0.94	(0.31)
Rural x Family wealth 3rd quartile			0.72	(0.35)			0.78	(0.24)
Rural x Family wealth 4th quartile			0.18**	(0.12)			1.20	(0.38)
Pseudo R-squared	0.502		0.507		0.121		0.122	

Notes: Ref.=reference group; Standard errors in parentheses; * $p < .05$; ** $p < .01$; *** $p < .001$.

Reading, writing, and drawing. Similar to our descriptive results, we find that when controlling for all the other characteristics, girls are more likely to read compared to boys. Table 4 shows that the odds of reading are 30 percent lower for males compared to females, and this difference is statistically significant at the 0.01 level. Moreover, also consistent with our descriptive results and with our expectations, “privileged” children are more likely to read for fun compared to other groups of children. Thus for instance, children whose mothers have above high school education have five times higher odds of reading compared to children whose mothers have no schooling, controlling for all the other variables in the model. In addition children from the 25 percent most wealthy families and children with no siblings are more likely to read compared to children from the bottom quartile of family wealth and those with siblings. Furthermore, children whose mothers are farmers had 24 percent lower odds of reading compared to those whose mothers were unemployed, probably reflecting the fact that unemployed mothers are a heterogeneous group with some proportion being highly educated, who tend to encourage their children to read. Interestingly but not unexpectedly for the Chinese population, children whose grandparents live in the household are more likely to read, compared to those in nuclear families. Finally, our most unusual finding is that children from single-parent households have 3.53 times higher odds of reading compared to children from two-parent households.

Doing homework. In contrast to reading, gender differences disappear when homework is considered and when other factors are controlled. All the other characteristics in our model, however, are significantly associated with "doing homework," except for our community level development variable, "the number of communication services." Thus, (1) rural children have 40 percent lower odds of doing homework compared to urban children, (2) older children have lower odds of doing homework compared to younger children, (3) the higher the parent's education and wealth, the higher the odds of doing homework among children compared to those whose parents have no schooling and those from the lowest wealth quartile, (4) children with siblings have lower odds of doing homework compared to children with no siblings, (5) children whose mothers are farmers have 33 percent lower odds of doing homework, compared to children of unemployed mothers, and (6) children from single-parent families and those living with their grandparents in the household have higher odds of doing homework compared to those from two-parent families. Finally it is important to note that the interaction between "single parenthood" and "rural/urban" is significant in the interactive model for "doing homework." Thus, compared to urban children living with two parents, (1) rural children living with only one parent are 7.25 times more likely to do homework, (2) urban children living with one parent are 2.78 times more likely to do homework, while (3) rural children living with two parents are 15 percent less likely to do homework.

TV and video. Interestingly, TV watching is the only activity where we have found no urban-rural or gender differences when other variables are controlled. Higher father's and mother's education are associated with higher odds of TV watching, while family wealth had an inverted "U" shape effect: the lowest odds of TV watching are among the children from families belonging to the lowest wealth quartile, but the highest are among the children from families belonging to the second wealth quartile and then the odds decrease as the wealth increases. Moreover, children whose mothers are unemployed and those who live with their grandparents are the most likely to watch TV compared to all the other groups. Interestingly, only children who have younger siblings (no effect for those with older siblings) have lower odds of TV watching (51 percent lower) compared to those with no siblings.

Computer surfing and playing computer games. Rural-urban residence, gender, age, and family wealth have by far the largest effects for "computer use." Rural children have 72 percent lower odds of using the computer compared to their urban counterparts, while boys have over 200 percent higher odds of using the computer compared to girls. Moreover, every one-year increase in age is associated with 31 percent higher odds of using the computer. Finally wealth matters a lot, with the wealthiest quartile having 5.3 times higher odds of using the computer compared to the bottom quartile. Not surprisingly, our community development variable has a significant effect, with children from the most developed/urbanized places being significantly more likely to use computers compared to their less urbanized counterparts, after adjusting for all the other covariates. Neither siblings, parent's education, nor family structure makes a difference in the likelihood of children using the computer.

Sports. No gender differences or sibling effects were found in the likelihood of participating in sports. However, all the other variables included in our model mattered for this activity, except our community-level variable. Thus, rural children have about 34 percent lower odds of participating in sports compared to urban children, while every one-year increase in age decreases the odds of sports participation by 20 percent. Compared to children whose fathers have no schooling, (1) children whose fathers' education was primary school have seven times higher odds of participating in sports, (2) those whose fathers' education was junior high school have 5.64 times higher odds, and (3) those whose fathers' education was high school or higher have 13.61 times higher odds (the largest effect of all variables) of sports participation. The effect of mother's education is smaller, but in the same direction, with children of the most educated mothers being the most likely to participate in sports. Moreover, family wealth had a similar effect as mother's education in that children in the top quartile had 3.85 higher odds of sports participation compared to those in the bottom quartile. Finally, children whose mothers were unskilled workers had 45 percent lower odds of participating in sports compared to those whose mothers were unemployed, while those living in extended families had more than 200 percent higher odds of sports participation compared to those in nuclear families.

Housework. No rural-urban differences were observed in the likelihood of doing household chores, after we controlled for other variables in the model. The effect of age is small but significant: with every one-year increase in age, the odds of doing household chores increase by seven percent. Moreover, gender differences persist after controlling for all the other variables in the model, with boys having 44 percent lower odds of doing household chores compared to girls. In addition, parents education has an inverted "U" shape effect with children whose parents have no schooling being the least likely to do housework, followed by those of the most educated parents, with those in the middle having the highest odds. Mother's employment status has no effect on the likelihood of performing household chores, while the family structure has by far the largest effect, with children from single-parent families having more than 5.27 times higher odds of doing housework compared to those from two-parent families. Moreover, those living in extended families have almost 60 percent higher odds of doing housework compared to those living in nuclear families. Finally, the only sibling effect is that those with a younger sibling have 30 percent higher odds of doing housework compared to children with no siblings.

Family and Children's Characteristics and Time Spent in Activities

The second step of our analysis was to test the impact of family and children's characteristics on the amount of time children spend in each activity, conditional on participation in activities, using OLS regression models. To improve the normal distribution of our dependent variables, we transformed them by taking the natural logarithm of the original variables, and used these new transformed variables in our models. The results are presented in Table 5.

Contrasting to the first part of our analysis, in the OLS models predicting time spent in each activity, conditional on participation, fewer covariates had a significant effect, and thus we only present selected interesting findings in our discussion, although all results are available in Table 5. The activities with the most significant effects are reading, doing homework, and doing housework.

Gender was the only covariate that made a significant difference for all activities, with girls reading and doing housework for longer compared to boys, and boys doing homework, playing computers, watching TV, and playing sports for longer compared to girls, conditional on participation in these activities and controlling for everything else. Also, rural children who read for fun read for longer compared to their urban counterparts, although urban children were more likely to read overall.

Children of highly educated mothers spend more time in sports and doing homework compared to other children. Wealthier children spend less time watching TV and less time in doing housework, while children whose grandparents are in the household spend less time in reading (although they were more likely to read overall) and more time in using computers. Neither maternal employment status nor family structure had an effect on the time spent doing housework.

Discussion and Policy Implications

Overall, our findings show that the largest differences between children of different categories, backgrounds, and socio-economic statuses are not in the time spent in each activity but rather in the likelihood of participating in activities. Thus, as expected we have found that the more privileged children, generally those living in urban environments in China and those with higher social capital (high parental education) and family wealth are more likely to read for fun, do homework, and use computers, activities that have been shown to be associated with higher test scores and other developmental benefits as well as improved life chances. Consequently,

Table 5 OLS regressions of childrens' and families' characteristics on activities.

Variable	Reading				Homework			
	Model 3		Model 4		Model 3		Model 4	
Residence (Ref.=urban)								
Rural	0.10*	(0.04)	0.27**	(0.10)	-0.02	(0.04)	0.07	(0.09)
Age	0.02**	(0.01)	0.02**	(0.01)	0.06***	(0.01)	0.06***	(0.01)
Gender (Ref.=female)								
Male	-0.10*	(0.04)	-0.10**	(0.04)	-0.15***	(0.03)	-0.15***	(0.03)
Father's education (Ref.=no schooling)								
<=Primary school	0.07	(0.08)	0.08	(0.09)	-0.10	(0.07)	-0.10	(0.07)
<=Junior high school	0.00	(0.07)	0.01	(0.07)	-0.11	(0.06)	-0.11	(0.06)
>= Senior high school	-0.05	(0.08)	-0.03	(0.08)	-0.15*	(0.06)	-0.15*	(0.07)
Mother's education (Ref.=no schooling)								
<=Primary school	-0.12	(0.08)	-0.11	(0.08)	0.06	(0.06)	0.07	(0.06)
<=Junior high school	-0.01	(0.07)	0.00	(0.07)	0.15**	(0.06)	0.15**	(0.06)
>= Senior high school	-0.01	(0.08)	-0.01	(0.08)	0.21**	(0.07)	0.21**	(0.07)
Maternal employment (Ref.=no job)								
Professionals	-0.02	(0.07)	-0.04	(0.07)	-0.02	(0.06)	-0.03	(0.06)
Unskilled worker	-0.18**	(0.06)	-0.19**	(0.06)	-0.08	(0.05)	-0.08	(0.05)
Farmer	-0.13*	(0.05)	-0.13*	(0.05)	-0.10*	(0.04)	-0.10*	(0.04)
Other	-0.36**	(0.13)	-0.36**	(0.13)	-0.18	(0.10)	-0.18	(0.10)
Family wealth quartiles (Ref.=1st quartile)								
2nd	-0.11	(0.06)	-0.04	(0.12)	0.03	(0.05)	0.10	(0.11)
3rd	-0.08	(0.06)	0.09	(0.11)	0.06	(0.05)	0.14	(0.10)
4th (most wealthy 25%)	-0.13*	(0.07)	-0.02	(0.10)	0.04	(0.06)	0.11	(0.09)
Parenting (Ref.=both parents)								
Single parent	-0.12	(0.08)	0.16	(0.15)	-0.08	(0.07)	0.08	(0.13)
Siblings (Ref.=no sibling)								
Has older sibling	-0.08	(0.05)	-0.09	(0.05)	-0.09*	(0.04)	-0.09*	(0.04)
Has younger sibling	-0.06	(0.06)	-0.06	(0.06)	-0.09	(0.05)	-0.09	(0.05)
Grandparents (Ref.=not in household)								
Living in household	-0.14**	(0.04)	-0.14**	(0.04)	-0.02	(0.04)	-0.02	(0.04)
Number of communication services	0.02	(0.01)	0.02	(0.01)	0.00	(0.01)	0.00	(0.01)
Rural x Single parent			-0.34*	(0.16)			-0.20	(0.14)
Rural x Family wealth 2nd quartile			-0.08	(0.14)			-0.08	(0.12)
Rural x Family wealth 3rd quartile			-0.24	(0.13)			-0.10	(0.11)
Rural x Family wealth 4th quartile			-0.17	(0.12)			-0.09	(0.11)
Constant	-0.46**	(0.14)	-0.60***	(0.15)	-0.25*	(0.11)	-0.33*	(0.13)
N	1009				1370		1370	
Adjusted R-squared	0.051		0.055		0.104		0.104	

Notes: Ref.=reference group; Standard errors in parentheses; * $p < .05$; ** $p < .01$; *** $p < .001$.

although China has a highly centralized curriculum development system, this study suggests that not all children benefit equally from it. As Bourdieu (1984: 23) explained, "academic capital is in fact the guaranteed product of the combined effects of cultural transmission by the family and cultural transmission by the school (the efficiency of which depends on the amount of cultural capital directly inherited from

Table 5 Continued.

Variable	TV/video				Computer			
	Model 3		Model 4		Model 3		Model 4	
Residence (Ref.=urban)								
Rural	-0.07	(0.05)	-0.03	(0.10)	0.05	(0.15)	-0.47	(0.44)
Age	-0.01	(0.01)	-0.01*	(0.01)	0.10***	(0.03)	0.10***	(0.03)
Gender (Ref.=female)								
Male	0.09*	(0.04)	0.08*	(0.04)	0.31*	(0.14)	0.33*	(0.14)
Father's education (Ref.=no schooling)								
<=Primary school	-0.01	(0.08)	-0.01	(0.08)	0.21	(0.32)	0.22	(0.32)
<=Junior high school	0.01	(0.07)	0.02	(0.07)	0.38	(0.25)	0.40	(0.26)
>= Senior high school	-0.09	(0.07)	-0.09	(0.07)	0.09	(0.26)	0.06	(0.26)
Mother's education (Ref.=no schooling)								
<=Primary school	-0.03	(0.07)	-0.03	(0.07)	-0.25	(0.29)	-0.27	(0.29)
<=Junior high school	0.00	(0.06)	-0.01	(0.06)	-0.04	(0.24)	-0.09	(0.25)
>= Senior high school	-0.05	(0.08)	-0.05	(0.08)	0.13	(0.26)	0.08	(0.26)
Maternal employment (Ref.=no job)								
Professionals	-0.13	(0.07)	-0.14	(0.07)	0.06	(0.20)	0.05	(0.20)
Unskilled worker	-0.07	(0.06)	-0.07	(0.06)	0.06	(0.19)	0.08	(0.19)
Farmer	-0.03	(0.05)	-0.03	(0.05)	-0.10	(0.23)	-0.17	(0.24)
Other	0.04	(0.11)	0.03	(0.11)	-0.67	(0.46)	-0.70	(0.47)
Family wealth quartiles (Ref.=1st quartile)								
2nd	-0.03	(0.05)	0.02	(0.12)	0.05	(0.28)	-0.12	(0.37)
3rd	0.03	(0.05)	0.08	(0.11)	0.27	(0.25)	-0.22	(0.36)
4th (most wealthy 25%)	-0.14*	(0.06)	-0.17	(0.11)	0.00	(0.26)	-0.25	(0.33)
Parenting (Ref.=both parents)								
Single parent	-0.11	(0.07)	0.24	(0.15)	0.23	(0.28)	0.06	(0.38)
Siblings (Ref.=no sibling)								
Has older sibling	0.01	(0.04)	0.01	(0.04)	-0.14	(0.16)	-0.09	(0.16)
Has younger sibling	0.07	(0.05)	0.07	(0.05)	0.23	(0.22)	0.19	(0.22)
Grandparents (Ref.=not in household)								
Living in household	-0.04	(0.04)	-0.03	(0.04)	0.39*	(0.15)	0.32*	(0.16)
Number of communication services	0.00	(0.01)	0.00	(0.01)	-0.01	(0.03)	-0.01	(0.03)
Rural x Single parent			-0.41**	(0.15)			0.16	(0.42)
Rural x Family wealth 2nd quartile			-0.06	(0.14)			0.33	(0.54)
Rural x Family wealth 3rd quartile			-0.05	(0.13)			0.96	(0.51)
Rural x Family wealth 4th quartile			0.08	(0.13)			0.46	(0.49)
Constant	0.55***	(0.12)	0.53***	(0.15)	-2.37***	(0.52)	-2.02***	(0.56)
N	1548		1548		183		183	
Adjusted R-squared	0.017		0.020		0.129		0.132	

Notes: Ref.=reference group; Standard errors in parentheses; * $p < .05$; ** $p < .01$; *** $p < .001$.

the family).” Thus, since “scholastic” culture can never quite duplicate the ease and depth of the cultural capital acquired by constant exposure at home, children with lower social and cultural capital will acquire a lot less from school, even within “a highly centralized curriculum system,” like that of China. If children do not prac-

Table 5 Continued.

Variable	Sports				Household chores			
	Model 3		Model 4		Model 3		Model 4	
Residence (Ref.=urban)								
Rural	-0.03	(0.05)	-0.08	(0.11)	-0.20*	(0.09)	-0.46*	(0.18)
Age	0.02**	(0.01)	0.02**	(0.01)	0.12***	(0.01)	0.12***	(0.01)
Gender (Ref.=female)								
Male	0.17***	(0.04)	0.16***	(0.04)	-0.41***	(0.07)	-0.40***	(0.07)
Father's education (Ref.=no schooling)								
<=Primary school	0.03	(0.09)	0.04	(0.09)	0.28*	(0.14)	0.27	(0.14)
<=Junior high school	0.02	(0.07)	0.03	(0.07)	0.24*	(0.12)	0.25*	(0.12)
>= Senior high school	0.00	(0.08)	0.02	(0.08)	0.10	(0.14)	0.09	(0.14)
Mother's education (Ref.=no schooling)								
<=Primary school	0.19*	(0.07)	0.18*	(0.07)	-0.18	(0.12)	-0.19	(0.12)
<=Junior high school	0.25***	(0.07)	0.25***	(0.07)	-0.21	(0.12)	-0.21	(0.12)
>= Senior high school	0.19*	(0.09)	0.18*	(0.09)	-0.28	(0.16)	-0.26	(0.16)
Maternal employment (Ref.=no job)								
Professionals	-0.03	(0.08)	-0.04	(0.08)	-0.02	(0.17)	-0.01	(0.17)
Unskilled worker	-0.12	(0.07)	-0.12	(0.07)	0.13	(0.12)	0.13	(0.12)
Farmer	-0.17**	(0.06)	-0.17**	(0.06)	0.06	(0.09)	0.06	(0.09)
Other	0.16	(0.13)	0.17	(0.13)	0.04	(0.23)	0.01	(0.23)
Family wealth quartiles (Ref.=1st quartile)								
2nd	0.00	(0.06)	-0.26	(0.13)	-0.08	(0.10)	-0.21	(0.22)
3rd	0.09	(0.06)	0.10	(0.12)	-0.08	(0.10)	-0.35	(0.21)
4th (most wealthy 25%)	0.12	(0.07)	0.06	(0.12)	-0.33**	(0.13)	-0.70**	(0.21)
Parenting (Ref.=both parents)								
Single parent	0.01	(0.08)	0.26	(0.17)	0.16	(0.13)	0.28	(0.28)
Siblings (Ref.=no sibling)								
Has older sibling	0.03	(0.05)	0.03	(0.05)	-0.11	(0.08)	-0.11	(0.09)
Has younger sibling	-0.08	(0.06)	-0.08	(0.06)	0.07	(0.10)	0.07	(0.10)
Grandparents (Ref.=not in household)								
Living in household	0.07	(0.05)	0.07	(0.05)	0.08	(0.08)	0.09	(0.08)
Number of communication services	0.01	(0.01)	0.02	(0.01)	-0.05**	(0.02)	-0.05*	(0.02)
Rural x Single parent			-0.30	(0.18)			-0.16	(0.29)
Rural x Family wealth 2nd quartile			0.33*	(0.15)			0.16	(0.25)
Rural x Family wealth 3rd quartile			-0.02	(0.14)			0.35	(0.23)
Rural x Family wealth 4th quartile			0.07	(0.14)			0.56*	(0.25)
Constant	0.41**	(0.14)	0.45**	(0.16)	-1.91***	(0.26)	-1.70***	(0.29)
N	1368		1368		590		590	
Adjusted R-squared	0.043		0.048		0.206		0.210	

Notes: Ref.=reference group; Standard errors in parentheses; * $p<.05$; ** $p<.01$; *** $p<.001$.

tice at home what they learn in school by reading, writing, doing homework, and studying, the inequalities with which they start will likely remain in place across generations.

Second, we have also found that “the privileged children,” that is, those from an urban environment, those who are wealthy, and those who have highly educated parents are also more likely to practice sports, which is the only activity tested in this study traditionally thought to be associated with physical (and mental) health. Realizing that health depends on a lot more factors than sports participation, this finding suggests that “the privileged children” are not only more likely to develop better intellectually, but also physically, based on the types of activities they participate in. As we mentioned in the introductory part, the traditional Chinese culture emphasizes children’s academic achievement, rather than physical and health development, and our finding may reflect an American/western influence on the wealthier and most educated Chinese parents who stress both the importance of intellectual pursuits and also of sports for their children. Moreover, although not as strong a finding as others, we have also found that the most disadvantaged children not only have a lower likelihood of participation in activities leading to intellectual and physical development, but they are also likely to do more housework compared to the privileged children.

Third, despite “the equality ideology” imposed by the socialist system in China, we have found profound gender differences that affect even the youngest members of this society. Thus, girls are not only significantly more likely to do housework compared to boys, but they also do so for longer hours. Furthermore, we have also found in China gender differences that are found in many other societies (Hofferth and Sandberg 2001, Bianchi and Robinson 1997), that is, girls are more likely to read compared to boys, and boys spend more time in sports and are more likely to use computers compared to girls.

Fourth, we have found that being an only child in China is “better” in that children with siblings are less likely to read, less likely to do homework, less likely to participate in leisure activities, such as watching TV or playing video games, and more likely to do housework (this latter activity only applies to those with a younger sibling). We suggest this finding is a function of “divided parental attention and resources.” Moreover, we have found that children of farmers are less likely than children of unemployed mothers to read, do homework, and participate in sports, probably as previously suggested a function of the heterogeneity among unemployed mothers compared to the overall under-privileged status of farmers in China.

Another interesting but not surprising finding was the overall beneficial effect of living with grandparents in the same household. Children who live with their grandparents are both more likely to engage in activities beneficial for intellectual development and academic achievement such as reading, doing homework, and using computers, and are also more likely to engage in sports. We attribute this finding to several possible explanatory mechanisms: (1) grandparents could help with childcare and child monitoring, (2) grandparents may relieve the parents of some of the housework tasks, and thus allow parents to engage more with their children, and (3) selection effects, as the presence of grandparents in the household may indicate both a better financial power of parental incomes in urban areas and also a better health status in the family (since grandparents should be alive to live in the household) in rural areas where traditionally it is expected to find grandparents in the household.

Finally, our most interesting but also puzzling finding is that children living with only one parent are much more likely to read, do homework, and participate in sports compared to children living with both parents. This finding is interesting because it contradicts a myriad of U.S. studies (e.g., McLanahan and Sandefur 1994, Robinson 1993, Longfellow 1979), which found that children in single-parent families have much worse outcomes compared to children from two-parent families (see Note 2). However, it is likely that the Chinese context is quite different in terms of the meaning of single parenting. While in the U.S., single parenting is likely to mean either an "out-of-wedlock birth" or divorce, in China, and especially in rural China, where divorce rates are much lower compared to many other countries (e.g., Zeng and Wu 2000), single-parenting is likely to be equivalent with parental migration for work, which is usually selective. Thus, rural parents who migrate for work into nearby towns or cities are likely to be better skilled than their counterparts who do not migrate, and this might explain why their children are doing better compared to those children living with both parents. This phenomenon, nonetheless, is unlikely among urban families, where parents are likely to work in their city of residence. Unfortunately, the limitations of our dataset do not allow us to find the reasons for parental absence. However, we have conducted our analyses separately for rural and urban children (results available upon request from the authors) and have found indeed that the higher likelihood of reading, writing, and doing homework among children in single-parent families is only significant for rural children, and not for urban children, which provides support for our argument. Nevertheless, this fascinating issue needs further research to disentangle the effects of an absent parent on children's outcomes, although this study has proved to be a powerful reflection of how these effects are highly contingent and context dependent.

Another issue needing future research is a study over time of children's activities. A panel study will allow us to observe how children's activities change as a function of economic, political, and cultural change of Chinese society, changes that were only implied but impossible to test in our cross sectional study. In addition, the newest wave of CHNS contains geocode data that would allow a test of spatial processes (through spatial autoregressive models) across geographic areas. For instance, children living in a village that is close to a big, developed city might be more likely to engage in certain activities than children living in another similarly developed village that is in a more remote area because of a diffusion or spillover process of cultural influence from the city to the village, in the presence or absence of a corresponding economic influence.

So far we have emphasized how family characteristics affect the likelihood of children's participation in various activities and how family inequalities are likely to be reproduced across generations. Nevertheless, despite powerful family influences, school context also matters. As evidence from other studies reviewed in the first part of this paper has shown, large gaps exist between school conditions in rural and urban China. Moreover, it is likely that some of the differences we have found between urban and rural children in terms of the likelihood of reading, writing, doing homework, or participating in sports are due to the school and community environment in which these children live, in addition to their family context. Thus, for example, rural children may be less likely to read because they have less access to books in their schools (e.g., lack of school library), or they are less likely to do homework because they are not given homework by their teachers. They are almost certainly less likely to use computers because of the limited access to computers and lack of resources. Moreover, they may not practice certain types of sports because of lack of specific equipment and facilities. All of these issues related to the school and community gaps in opportunities available to rural and urban children could be addressed by policies geared toward redirecting resources into the poor and rural areas where millions of Chinese children need them. In addition, society-wide policies are needed to address the strong Chinese gender bias that is affecting girls, who are doing most of the housework from early ages, even today in the middle of the unusually rapid modernization and change in the Chinese society.

General Notes

1. The large proportion of rural children in our sample is consistent with the population distribution in China, since 63.91 percent of the total population was living in rural villages according to China's 2000 Census.
2. There are several studies on children's time use in the U.S. that found no significant differences between children living with single parents and those living with both parents. For example, Timmer et al. (1985) found little difference in time use in other activities except TV watching and sleeping between children in single-parent families and children in both-parent families. Bianchi and Robinson (1997) failed to find the association between the number of parents and amount of time children spent reading, studying, watching TV, and doing household work.

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Section V

EDUCATING THE APPLIED DEMOGRAPHER

Chapter 19
Introducing Survey Methods to Professional Students in Applied Demography

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Introduction

Technical knowledge of survey design and administration, data management, and analysis is often needed in modern professional practice in both private and public sectors. Demography of health, both health status and health care, uses survey data for surveillance and planning. Public health surveillance "is ongoing, systematic collection, analysis, interpretation, and dissemination of health related data used to improve health" (CDC 2001). These data are increasingly used by local agencies. In most applied disciplines, the curriculum of a master's degree offers only a limited time for each topic. We have designed a single, introductory course in survey methods for students enrolled in a professional master's program. The course has three modules: modern questionnaire design and development methods, sampling practices of major health surveys, and analysis using modern survey software. By contrast, doctoral training for academic research often has one or more courses for each area of methodology, including questionnaire development, sampling techniques, total error measurement, and specialized analysis methods, as well as using surveys for the dissertation.

We originally designed our course for students in public health, where randomly sampled surveys are an increasingly common approach to measuring population health, locally and nationally. We designed the course both to serve future professional needs when these students enter into practice and to serve as a bridge from the introductory courses to a thesis. We anticipate that this course will also serve students in other professional programs, including applied demography, who require some training in survey methodology.

S.H. Murdock and D.A. Swanson (eds.), Applied Demography in the 21st Century, 337–345.

Environment and Background

Students in two programs at separate campuses in San Antonio may participate in our course. The University of Texas at San Antonio (UTSA) has a Doctor of Philosophy degree in Applied Demography. The University of Texas School of Public Health-San Antonio Regional Campus (SPH) has a Master of Public Health degree. Several faculties at the SPH are also faculty in the UTSA Applied Demography program and students there may take several courses in public health. Our course is designed to meet the needs of students in both these professional programs for training in survey methods.

The expectations for research skills among graduates of professional programs have changed. Increasingly, junior professionals are expected to tabulate or analyze data that has not been analyzed as needed. They might also be expected to contract for a survey needed by their agency. The skills needed both in the workplace and for students' research have changed in similar ways, requiring greater facility with modern statistical software.

Changing technology has shifted expectations for the conduct of survey-based research. Most obvious has been the increased use of complex sample design, that is, stratified, clustered samples with unequal probabilities of selection. The numbers and sizes of such surveys have increased. They are frequently done for local areas such as metropolitan areas or counties as well as for states and the nation. These designs require specialized software for estimates that are accurate and correct with respect to sampling errors. Survey analysis procedures are now available in several general-purpose statistical packages.

Somewhat less obvious are the changes in methods for the development and testing of questionnaires, interviewing, and modes of administration over the last 20 to 25 years. Computer-aided telephone or personal interviewing has reduced interviewer error and speeded the availability of data for analysis. Use of cognitive questionnaire development methods is increasingly the standard, and these methods have substantially increased the quality and interpretability of survey results.

Professional ethics support the expectation that surveys will be done according to generally recognized practice standards for design, data collection, analysis, and reporting (American Association for Public Opinion Research 2005, American Public Health Association 2002, American Sociological Association 1997, American Statistical Association 1999). Thus, the standards for students' theses and for their later professional work with surveys have become more rigorous. As surveys have come to be a more useful and important way to collect information about a local area, staff of local agencies have entered into design and analysis roles that were once exclusively the preserve of the Federal government or other national organizations or corporations.

Course Design

The central skills of survey design and analysis and the time available determined the structure and organization of our course. We wanted to include a substantial data analysis and reporting activity using theoretically appropriate methods and modern statistical software that implements sampling theory. It is apparent that realistic and sophisticated analyses require some depth of knowledge in sample design, including stratification, clustering, and unequal probabilities of selection. The analysis projects also build on students' knowledge of total survey error and the design and methods of data collection to reduce errors. Other elements of course design follow from other goals, such as our desire to build teamwork, to have students learn how to use software resources and about standard methods used in health surveys, and to introduce the students to the relevant ethical norms in both research and professional practice.

The three major modules are Data Collection and Instrument Development, which uses about 3.5 weeks, Sampling, which uses about 3.5 weeks, and the Analysis Workshop, which uses the remainder of the course, about 8 weeks. Additional topics include introductions to the National Health Interview Survey (NHIS) and the Behavioral Risk Factor Surveillance System (BRFSS) and survey ethics; each has no more than one class session, though further discussion often occurs in the course of the Analysis Workshop.

We teach the course jointly. Both of us studied survey methodology. One of us trained as a biostatistician (David Smith) and one trained as a sociologist (Stephanie McFall). We have experience with the analysis of major national health surveys such as the NHIS, the BRFSS, and the National Long-Term Care Survey. Stephanie McFall has primary responsibility for modules on data collection methods and instrument development. David Smith has primary responsibility for the sample design module. Each of us has taught previous classes devoted to these separate topics. We share responsibility for the analysis workshop.

We use *Survey Methodology* (Groves et al. 2004) as the principal source of readings, assigning about two-thirds of the chapters. The authors are leading experts in several branches of survey methodology. Their book introduces students to cutting edge issues in survey research. Useful features include spotlights of key words and suggestions for further reading. The centrality of the text's Total Survey Error framework unifies what may otherwise appear to be disconnected decisions about design and analysis. There is, at present, no other text that covers this range of material with the level of scholarship that is necessary.

We assign some supplementary readings of recent research reports, technical documentation of specific surveys, and codes of ethics of professional associations. The research reports, recently published papers from the peer-reviewed literature, vary from year to year. They are assigned and reviewed in class as examples of good survey practices. Codes of ethics of the American Public Health Association and the American Association for Public Opinion Research are assigned as readings. The codes are reviewed in class with respect to their relevance to survey research and survey practice. The documentation of specific surveys is reviewed in class, and all students are expected to read parts of the documentation for both the BRFSS (http://www.cdc.gov/brfss/) and the NHIS (http://www.cdc.gov/nchs/nhis.htm), regardless of which they choose for their analysis problem (Botman et al. 2000, Centers for Disease Control and Prevention 2006, National Center for Health Statistics 1999, National Center for Health Statistics 2000).

The first module, Data Collection, summarizes the survey process with a focus on the types of error that can be introduced at each stage of the process. In relation to data collection, we examine the advantages and disadvantages of different modes – personal or face-to-face interviews, telephone, and other self-administered modes – using examples. The textbook has an emphasis on the use of technology to reduce error, for example combining personal and self-administered modes to reduce social desirability effects related to sensitive topics.

We also concentrate on instrument development since improvement in the questions asked is a cost-effective method for reducing error. Following Sudman and Bradburn (1982) as well as others, the broad question categories are demographic characteristics, sensitive and non-sensitive behaviors, and subjective domains, such as knowledge, attitudes, and behaviors. The assignment for this module is to construct and revise a brief instrument to address a research question. Each instrument includes a memorandum describing the purpose of the survey, concepts and considerations in measurement, population, and other decisions. Students receive a critique from an instructor and a peer, which they use to revise the instrument for final submission.

The second module, Sampling, introduces students to the basic sample design and selection issues and their effects on analyses. Random sampling is introduced with samples of beads from an urn and from an artificially created and listed population using a printed random number table. Clustering and stratification are introduced using exercises with the 254 counties in Texas and a small number of variables from the U.S. Census. A laboratory exercise uses several standard methods to enumerate and sample one respondent from households. The basics of random digit dialed sampling of telephone numbers are introduced using the BRFSS technical documentation and of geographic household samples using the NHIS. Unequal probability sampling is introduced both through the laboratory exercise and by samples of Texas counties. The computations for these exercises are usually done with a spreadsheet. The variation in estimates from samples selected by each student is discussed in class.

The selection of statistical software packages that include routines that properly weight and incorporate features of sample design is growing. We selected Stata (http://www.stata.com) because it is reasonably priced for students, has available materials for training, and is used in the biostatistics classes taught at the San Antonio Regional Campus. With the site license available, Stata can be purchased by graduate students as a one-year or perpetual license. Stata is available in three versions, but surveys are large enough that the smallest and cheapest version (Small Stata) is not adequate for the students’ analyses. Students who do not choose to purchase the software can use it in the computer laboratory. We keep full documentation for students and a small collection of Stata-related literature. In addition to the online help files, which come with the program, there is ample instructional material on the Internet. Students have found material from the UCLA Stata portal particularly useful (http://www.ats.ucla.edu/STAT/stata/).

The Analysis Workshop

The goal of this module is for students to write a brief but complete paper with introduction, methods, results, and conclusions featuring an independent analysis. The results include estimates of means or proportions and some relational analysis such as regression or logistic regression. We introduce this module with published and unpublished case examples to illustrate the process.

Students are expected to select a research question that can be addressed using either the NHIS or the BRFSS. Recently we have also allowed students to select a problem from the Department of Defense sponsored Survey of Health Related Behaviors (DOD-HRB) that is sampled from active military personnel. (Several students have been military physicians who have a professional interest in this survey.) The number of surveys is limited for several reasons. The NHIS and BRFSS are examples of the two main types of surveys commonly used today: a geographically stratified sample of households with personal interviews and a random digit dialed telephone sample and interview. Each is conducted in accordance with contemporary professional standards and both have thorough, detailed technical documentation. A substantial body of applied research has been produced from each survey. There are abundant resources on the internet for each, including the official web sites, which have extensive documentation on purpose, questionnaire design, sample design, and the resulting data. Finally, permitting only a limited number of surveys is intended to build communities of students confronting similar technical issues and data management problems.

The NHIS is a multistage personal interview survey. In recent years it has oversampled African American and Hispanic households. It collects information on the health status of each household member and obtains additional information from one randomly selected adult and child. In the classroom overview we discuss sample structure and size, interview process, and the basic sequence of question domains. Useful documents on the website include the summary survey description, the questionnaires and codebooks, and the interviewer manuals. Since the survey is lengthy and complex with voluminous documentation, it takes effort to identify whether specific questions were asked in a given year or whether they were asked in the same way over several years. Thus, the NHIS has a more complex design and presents a greater challenge to the novice user than the BRFSS.

The BRFSS uses telephone interviews of adults and is conducted by states with funding and oversight by the Centers for Disease Control and Prevention (Holtzman et al. 2003, Figgs et al. 2000). The purpose of the BRFSS is to identify health behaviors related to chronic conditions and to yield estimates for each state. Households are sampled and contacted by telephone and one adult is interviewed in each household. Telephone numbers are randomly selected, as is each interviewed adult. In recent years, the BRFSS has used stratification within states to obtain estimates of larger metropolitan areas or counties, a feature useful for management and planning. The questions are organized into core questions that are asked by each state, optional modules selected by states and state-added questions. The quality of these questions has been tested and reported (Nelson et al. 2001). Again, in a classroom overview, we discuss sample structure and size, interview process, and the basic sequence of question domains.

The Department of Defense DOD-HRB tracks Healthy People 2010 goals for the military population (RTI International 2006). (Since most national health surveys exclude military personnel, it has value as a complement to those other surveys.) The DOD-HRB is sampled from active military personnel around the world and is self-administered. The sample design includes stratification by branch of service, rank, and location. Rare subpopulations (e.g., women, Marines, and senior non-commissioned officers) are oversampled. Students using this survey have summarized its design and primary results for the class.

Case Study: Prostate Cancer Screening

Early in the class, we have one or two sessions that describe one student's experience as a case study for students to use in their own work. Because the process modeled in the case example is similar to the recommended analyses for the student projects, we discuss this case example in detail. This particular project, published as a peer-reviewed report (Norris and McFall 2006), preceded the development of the class.

We use a theme of how the analyst moves between theoretical conceptions and the data available in the survey (Aneshensel 2002). In this case example, the student's initial research question was, "Is prostate cancer screening by prostate-specific antigen (PSA) related to the performance of other positive health behaviors?" To make the question more specific, she listed positive health behaviors. Moving to the data sources, she found that the BRFSS has a greater emphasis on health behaviors than the NHIS. Consequently, she reviewed the availability of listed health behaviors in the BRFSS by year and state. She also considered how to operationalize level of performance for each health behavior, that is, what would constitute a healthy behavior versus a not healthy behavior. Back at the conceptual level, she modified the question to ask whether PSA use is associated with performance of healthy lifestyle behaviors (e.g., physical activity) or clinically mediated behaviors (e.g., influenza immunization). Working at both levels she identified control variables such as health insurance.

The session also introduces how to make use of the sample design information in the analysis. The design structure of the BRFSS varies somewhat by state. Some states stratify geographically and use different sampling densities within strata. The data for all states include weights based on probabilities of selection with post-stratification to age, sex, and race in most states. We show how to specify the design structure for samples with these characteristics. Finally, the student specified and computed a variable to identify members of the subpopulation that she used. As a check on this variable, the student compared the sum of the weights for the sub-population to the Census estimated population of men aged 50 or older. With the subpopulation indicator, the analyst can use the sample design information for the full sample while focusing on the sub-population. (Many student projects employ the full population and do not require this step.)

Materials for the class include sample files of commands ("do-files" in Stata) to prepare the data for analysis: assign missing values, recode categories, particularly missing data categories, and lab variables and values. In preliminary analyses to describe the sample, we illustrate the difference in results for survey and non-survey procedures. The basic outline of the analysis for the case study is: (1) describe sample characteristics, (2) conduct bivariate analyses, e.g., tables of rates of focal variable and PSA use, and (3) conduct multivariable analyses, e.g., survey logistic regression analyses.

Three Years' Experience

We have offered the course three times to students in public health in the Spring terms of 2004, 2005, and 2006. The respective enrollments were three, seven, and six students, for a total of 16.

The analysis problems selected by students used all three of the surveys permitted. Four used the BRFSS, and six each used the NHIS and DOD-HRB surveys. The last survey was only used by students getting an MPH as part of the Aerospace Medicine Residency program. The populations studied vary with eight using topics about adult civilians, two using topics about children, and six using topics about military personnel. Four students used the BRFSS as their data source, six used the NHIS, and six used the DOD-HRB. Most of the students selecting the BRFSS used data from Texas, but some used data from all states and one used data from her home state.

Problems selected by students include such behaviors as smoking cessation during pregnancy and current smoking status. Psychological status problems included suicidal thoughts and quality of life. Chronic conditions problems included asthma and successful control efforts among persons with hypertension. Health service problems that were selected included health insurance and emergency department visits by children.

There is growing awareness among students of the utility of this course as a stepping stone in meeting the thesis requirement. In its initial offering, two of the three students were already engaged in their theses. Since then all the students have enrolled before starting their thesis research, though some had already chosen a research topic that would use survey data. Of the 13 students from the 2005 and 2006 sessions, 10 have completed their master's theses using national health surveys.

Comments from students indicated that they valued the experience with the statistical software, both in terms of data management and statistical analysis. One mentioned specifically that he or she enjoyed "reaching beyond toy problems." Others remarked positively about the final presentations they made in the Analysis Workshop and about the value of peer tutoring and shared problem solving.

We have selected two quotations by students from the standard course evaluation reports of our University. One student particularly valued the Analysis Workshop:

> The initial portion of the class (survey design) was interesting but less applicable to me. The second part of the class was very helpful. Not only did it solidify the concepts I learned in biometry, but it also gave me a basis for analyzing my thesis data.

This comment shows how students seeking a professional degree consider their future professional role:

> ... what ultimately makes me feel this class was excellent is the sense of personal accomplishment I feel in completing it. Also, in my workplace and in interactions with other professionals, I have found that the material ... is highly valued and appreciated.

Lessons Learned and Future Plans

We have learned several lessons that we have incorporated in subsequent class sessions. An important one is a move from more open class sessions to much more defined sessions, both in terms of topical material and assigned responsibility for presentations. We have moved to more standardized work products. We introduce the Analysis Workshop earlier and earlier each time, to the point where we are now opening our description of it in the second week of class. We have moved to provide support to students for some more difficult analysis issues, such as subpopulations or subdomains, since they have shown themselves to be capable of taking on these more complex problems with appropriate coaching.

We plan to include doctoral students with the expectation that they show more advanced skills. For example, we expect them to prepare and present a mini-module on an advanced topic, such as imputation for missing data, or lead a laboratory session on cognitive questionnaire testing.

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Chapter 20
The Academic Training of Applied Demographers: History, Evolution, and a Description of the First Ph.D. Program in Applied Demography

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Introduction

Applied demography has grown substantially as a subfield of demography and may, in fact, claim to be the largest single specialization represented in such organizations as the Southern Demographic Association and the Population Association of America (Swanson et al. 1996, Swanson and Pol 2003). In fact, one might legitimately debate whether applied demography or demography is the base discipline since the development of demography has been driven as much by attempts to address pragmatic issues as it has been to address alternative philosophical or conceptual debates. Thus Malthus work although often seen as an attempt to address the broad theoretical link between population and resources was also an attempt to address the practical question of whether government attempts to limit poverty could be successful in the long term. Similarly the voluminous body of research in fertility of the post World War II era was driven as much by an attempt to manage the explosive population growth in developing countries as it was by a desire to understand the basic determinants of fertility change (Bogue 1969), and the current increased emphasis on demography and health and mortality is a product, at least in part, of the recognition of the implications of aging populations and of governmental support of research on health brought forth by public and political recognition of these demographic realities (Pol and Thomas 1997, Sanderson and Sherbov 2007). Finally, it might be argued that one of the major demographic data entities in the United States, the U.S. Bureau of the Census, is an applied demographic entity with its major data collection elements being justified by policy and administrative requirements rather than purely scientific ones.

As Swanson and Pol (2003) note, however, there is a tendency to view applied demography as a new phenomena dating back primarily to the founding of applied groups in the Population Association of America in the mid 1980s or to more recent texts in the area (see Rives and Serow 1984, Murdock and Ellis 1991, Kintner et al. 1995) including some quite recent efforts (Siegel 2002).

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Part of the failure to recognize a unique role for the long-standing form of demographic work associated with applied demography has been the lack of separate training and graduate education programs in applied demography. Outside of the occasional offering in regular demography curricula, the major graduate applied programs have been at Bowling Green University, Portland State University, The University of Southern California, and Florida State University. All of these are Master's level programs, and thus within the profession of demography there has been a tendency to see applied demography as requiring only a master's level of education. In fact, it might be argued that part of the slow recognition of applied demography in professional associations has been associated with the lack of advanced degree programs in applied demography.

So, what is the level of education and training required for an applied demographer? This work delineates the rationale for, and describes the content of, an applied demography program developed and recently implemented by the authors and others at The University of Texas at San Antonio. The intent is not to suggest that this is in anyway the only, or even the best, curriculum for such a program but rather to begin a discussion of what educational knowledge and skills most enhance the career success of demographers involved in applied demographic analyses.

Rationale for a Ph.D. in Applied Demography

There are several factors that argue for the development of a Ph.D. level of training for an applied demographer. First is simply the fact that the acquisition of the levels of knowledge and skills noted below require the hours of coursework and training provided by the number of hours included in a Ph.D. Discussions with students in masters' programs invariably reveal that students feel that the courses they completed did not cover a sufficient number of the topics on which they needed knowledge. The overall expansion of knowledge required to operate successfully in the applied sector requires the level of training involved in a Ph.D.

Second is the fact that the level of scientific expertise and the theoretical basis for the writing of a dissertation is as essential for applied work as for the more purely academic. The perception that somehow one does not need the mastery of the underlying theoretical bases of demography to work in the applied sector is belied by the reality of such work and belittles the creativity that those in the applied sector know is essential for their success.

Third is the fact that those who hire applied demographers increasingly demand a Ph.D. Thus in our analysis of research divisions in major state agencies we found that a majority had Ph.D.s as their research directors and many also had Ph.D.s as associate directors. Similarly an analysis of those involved in demographic analyses in regional planning authorities revealed a strong preference for analysts with a Ph.D.

Finally, the general requirements of the host disciplines within which demography has been but one of several specializations are growing as their knowledge bases increase such that demographic specializations are increasing condensed and "crowded" into smaller numbers of courses. The intellectual effort needed to master an acceptable amount of the existing base of demographic knowledge is at a level such that a good mastery of basic sociological, economic, or other disciplines at the master's level is usefully combined with a full Ph.D. level of demographic education and training. We would argue that for demography as a whole, and for applied demography in particular, it may be time for the development of programs that are separate from their initial host disciplines. In fact, demography has always had its own theories and methodologies; the major characteristics that are normally used to delineate a separate academic discipline.

The Necessary Skills of Applied Demography

It can be argued that applied demographers' knowledge and skill requirements are not significantly different from those of all demographers; that is, knowledge of the basic demographic processes of fertility, mortality, and migration and of the unique demographic methods for the analysis of populations and population processes. The applied demographer is likely both to have unique emphases within such areas and to have to develop an additional set and depth of knowledge and skills in several areas.

Coupled with the skills of all demographers, applied demographers must have more developed knowledge in at least five areas (no rank is implied by the numerical ordering): (1) highly developed computer analyses expertise in major languages such as SAS, STATA, and SPSS and of GIS and other methods for geographic and spatial analyses; (2) detailed knowledge of techniques for estimating and projecting small-area populations both in general and specific to particular uses (such as methods for projecting school enrollment, health service demands, etc.); (3) extensive knowledge of data sources and uses and of modes for the collection and adjustment of incomplete data and data symptomatic of change in population size and characteristics; (4) highly developed statistical skills for completing the activities noted in (3) and for the analysis of error and other functions critical to evaluative analyses; and (5) knowledge of the basic terminology and methods of substantive areas likely to be of importance in the public and private sectors in which applied demographers work (e.g., areas such as economics, marketing, finance, public policy analyses, evaluation research, and human services delivery). Each of these five areas is discussed in more detail below.

Nearly all students who progress through a standard masters or Ph.D. program have some experience with standard statistical software, but the skills needed by the applied demographer exceed those provided by such basic training. Those employing applied demographers will expect them to not only be able to use such software for data analysis but also to construct data sets from raw data, effectively merge complex and irregular data sets, provide outputs in a variety of forms, have knowledge of numerous graphics systems, and be able to perform complex statistical diagnoses of alternative data sets and analysis techniques. What has come to have particular importance in demographic analyses today is extensive knowledge of GIS and of techniques for the spatial analysis of demographic and related data. Training not only in how to use but also in how to analyze spatial patterns has come to have increasing importance for the applied analyst. Because of the utility of GIS and other forms of spatial display to convey patterns within data bases, these methods have come to form expected parts of the arsenal of applied demographers. For all of these forms of computer analysis applied demographers are increasingly expected to be able to operate independently of systems analysts and ideally to have basic knowledge of computer hardware as well as multiple software systems.

Although most demographers have some training and knowledge of population estimation and projection methods, few standard demographic curricula outside of applied programs provide detailed training on population estimation and projection techniques, especially those used in small population areas such as counties, places, school districts, etc. Acquiring this knowledge generally requires working with demographers completing (or who have in the past completed) such estimates and projections, so that knowledge of how small-area data are collected, how they must be supplemented, and their relative strengths and weaknesses are understood. Similarly, it requires acquisition of knowledge about how many of the unique problems related to small areas might be handled. For example, what are the best raking techniques for insuring that a particular cohorts' populations for a set of sub-areas (e.g., counties) sum to that for the larger area (e.g., the state)? When completing projections what are the options for dealing with cohort values of zero in small areas so that rates for that cohort throughout the projection period will not be zero? What should be done when the short-term patterns for the only data available for a small area (e.g., in births, deaths, or migration) lead to unreasonable population characteristics in long-term projections? What compromises can be made, and which should not be made, to meet the needs of a data user? These are all issues that generally require some hands-on work with small-area data estimation and/or projection methods.

Demographers in purely academic settings often become experts on the strengths and weaknesses of the particular data sets that they use for their professional work and publications. For applied demographers, the difference is that they are often required by their need to perform a variety of widely different functions to learn the strengths and weaknesses of multiple data sets and types of data. For example, an applied demographer working in a consulting firm may need to know health data strengths and weaknesses for certificate of need studies for hospitals, the potential limitations of educational data for school enrollment projections, the utility of various types of business data (e.g., scan data or credit card receipt data) for business marketing studies, and the strengths and weaknesses of traffic and commuter data for transportation planning. The need to know data sources and how to use various forms of data effectively is a skill that is simply magnified in importance for applied demographers.

It is a widely held belief that applied scientists are doers rather than theorists, and although many of us in the applied world would argue that good theory is essential to completing good applied demography, it is evident that good statistical theory and other skills are increasingly essential to applied demographers. Again, what is needed is, in part, a function of the wide range of activities pursued by applied demographers. Thus knowledge is needed not only of the strengths and weaknesses of specific statistical techniques such as multiple forms of regression analysis, survival models, and hierarchical linear models but also of sampling theory, techniques for the detailed analysis of the quality of data, and similar procedures. This knowledge is not lacking in other demographers, but the success of an applied demographer is perhaps more often determined by his/her own knowledge of such factors.

A Description of the First Ph.D. Program in Applied Demography

The program at The University of Texas at San Antonio was designed with careful attention to the professional needs noted above and to the demographic, socioeconomic, and geographic characteristics of the university's market area. San Antonio is the seventh largest city in the United States with a majority of its population being members of Hispanic and other non-Hispanic White racial/ethnic groups. It is also a city whose residents have relatively low incomes and limited socioeconomic resources. A preliminary analysis of the demand for the program indicated that many of those with the academic backgrounds appropriate to the program would need to work as well as attend school so the program was designed so that students could take as few as six hours per semester.

The program was also designed to take into account the strengths of other academic programs in the San Antonio area. First the program was designed to make maximum use of existing courses and faculty within The University of Texas at San Antonio. In particular, faculty in the Department of Sociology and its courses were included in the curriculum as well as those in Statistics. In fact, the faculty of the program includes three Ph.D. level Statisticians. In addition, the San Antonio area has several other major academic institutions. The University of Texas Health Science Center at San Antonio and a regional campus of the University of Texas School of Public Health are both located in San Antonio and have significant numbers of demographers and social scientists in related areas (such as health economics, biostatistics, epidemiology, sociology of health and medicine, community medicine, program evaluation, and psychology). Although the Ph.D. degree in Applied Demography is formally awarded by The University of Texas at San Antonio, it is a joint program of the three institutions with faculty members from all three institutions serving as committee members for students. There are a total of 17 faculty in the program with 8 having specializations in demography, 3 in statistics and biostatistics and the remainder in a variety of health and policy areas (such as policy evaluation, epidemiology, biostatistics, health policy, sociology of health and medicine, public and community health, and other areas).

The program is a standard Ph.D. with 60 hours beyond the masters. Students must complete a minimum of 48 hours of coursework and 12 hours of dissertation with exams taken at the completion of the coursework. As shown in Appendix A, the coursework reflects the needs noted above.

The students must complete a basic curriculum in demography with an introductory social demography course (SOC 5143 or PH3998), must complete both a basic and advanced methods course in demographic methods, a basic GIS course, and courses on the basic demographic processes. The introductory course not only overviews the major demographic processes and their general demographic affects, it also examines the impact of demographic factors on socioeconomic characteristics of populations and subpopulations. It also includes extensive work on locating and using basic demographic data as well as basic information on census taking and data collection and processing issues.

The core courses in research and statistics include two general Ph.D. level general methods courses aimed at ensuring that the students who come from diverse academic backgrounds have a common base of research knowledge, two semester long courses in statistical computing (to master SAS, STATA, and data management and evaluation techniques), and three courses from a list of statistical courses that provide both background knowledge and training in such methods as life table analysis, survival modeling, time series forecasting, and other statistical techniques with demographic applications.

The program requires students to follow one of two tracks, applied demography and health or applied demography and public policy. Students complete a minimum of 12 hours in their chosen track and are encouraged to complete additional courses.

Students who do not have an applied background must also complete a non-credit semester-long internship in an applied setting in either the health or policy area. A faculty advisor for internship placement arranges for such internships and supervises the formation and completion of the internship. An internship "contract" between the student and the internship entity is completed so that all involved know what is expected of both the offering entity and the student. The faculty advisor is responsible for ensuring adherence to the "contract."

Finally, students must complete qualifying exams and a dissertation in their chosen specialty area. Because a majority of the students take six to nine hours per semester the average time for completion of the degree is expected to be approximately five years.

The program is weaker in several areas than we would like. For example, although we would like the students to have more training in the area of geographic and spatial analysis, there is simply a paucity of courses offered by any institution in the area. Similarly, we have recognized that the level of training in the basic demographic methods may be inadequate and have developed additional courses in the area of immigration and separate courses in fertility and mortality which are pending approval for inclusion in the next university graduate catalogue. Similarly, we wish to see additional course offerings in both of the tracks to further strengthen the program. We fully expect that as the program matures there will be significant changes in the program as initially designed.

The Process for Admission and the Characteristics of the First Students Admitted to the Program

The initial students were admitted using a holistic set of criteria; that is the factors considered for admission were GRE scores, GPA at the undergraduate and graduate levels, an evaluation of the relevance of their undergraduate and graduate training to a Ph.D. in applied demography, an assessment of professional goals and capabilities based on three hours of personal interviews by a minimum of two members of the admission committee, an assessment of a submitted writing sample (a graduate paper or publication), and letters of recommendation relative to their potential success in graduate training. Consideration was also given to the student's socioeconomic background if other factors placed them on the cusp for acceptance.

The demographic characteristics of the first students in the program at the beginning of the second year showed its students to be a mature and diverse population. Of the 23 students in the program as of the fall of 2007, 14 were women and 9 were men, 10 were non-Hispanic White, 9 were Hispanic, 2 were African American, and 2 were international. Their mean age was 34.4 years. Of the 23 in the program, 6 were full-time graduate students taking at least 9 hours per semester while 17 were taking 6 hours per semester. These characteristics clearly show that the program is addressing the needs of the area and the broader need to produce a body of professionals that reflect the characteristics of the population of the state and the United States.

Summary and Conclusions

Applied demography may be argued to be as old as demography itself with demography having relevance to major policy actions throughout its history. Since its recognition as a separate area by the Southern Demographic Association and the Population Association of America, applied demography has come to have increasing visibility in the discipline of demography. The number of its adherents has been increasing rapidly and a number of excellent master's level programs have developed across the United States (and elsewhere). We argue, however, that the next stage in the maturation of Applied Demography is the development of a Ph.D. level of expertise with a specialization in Applied Demography.

The program we have described in the Department of Demography and Organization Studies at The University of Texas at San Antonio must clearly be seen as experimental at this stage of development because it has not yet graduated its first student nor have any attained employment in applied areas. However, if we are correct in our assessment of the market for such persons and the nature of the training that they should be provided, the establishment of this program may mark the beginning of yet an additional stage in the maturation of the field of Applied Demography.

Appendix A: Coursework and Other Degree Requirements for the Ph.D. in Applied Demography, Department of Demography and Organization Studies, The University of Texas at San Antonio[1]

The Applied Demography degree requirements comply with general University requirements. All prospective students must have a Master of Science or Master of Art degree from an accredited university in demography/sociology, geography, economics, biology, health administration, health policy, public policy, public health, political science, statistics, mathematics, business, or similar fields. Students who have not earned a qualifying masters degree will be required to complete the equivalent courses in the appropriate discipline area before admission to the Ph.D. program in Applied Demography.

The Applied Demography Program requires students to complete a minimum of 48 hours of organized coursework and a minimum of 12 hours of dissertation credits for a total of at least 60 hours beyond the Master's degree. All students will be required to complete the core courses listed below and a set of courses in their chosen track. This table summarizes the distribution of hours expected in the Applied Demography Program.

Course Type	*Hours Required*
Core Demography Courses	Minimum of 15 hours
Research and Statistics Courses	Minimum of 21 hours
Demography Tracks (Health or Policy)	Minimum of 12 hours
Dissertation	Minimum of 12 hours

Listing of Courses

A. Core Demography Courses (15 semester credit hours)

a. 12 semester credit hours selected from the following:

DEM 7013 Basic Demographic Methods of Analysis
DEM 7023 Advanced Methods of Applied Demographic Analysis

SOC 5143 Demography and Community Trends
or
PH 3998* Demography and Public Health

[1] Material in this appendix taken directly from the Handbook for the Ph.D. in Applied Demography, Department of Demography and Organization Studies, The University of Texas at San Antonio.

EES 5033 Geographic Information Systems
or
POL 5913 Design and Management of Geographic Information Systems

b. 3 semester credit hours selected from the following:

DEM 7033 Fertility and Mortality
DEM 7043 Migration
DEM 7053 International Migration

B. Core Research and Statistics Courses (21 semester credit hours)

a. 12 semester credit hours of the following required courses or their equivalents:

Statistical Computing (6 hours selected from this category)

DEM 7203 Software Applications for Demographic Analysis
DEM 7213 Advanced Software Applications for Demographic Analysis

Research Methods (6 hours selected from this category)

DEM 7243 General Research Methods for Demographers I
DEM 7253 General Research Methods for Demographers II

b. 9 semester credit hours selected from the following:

DEM 7223 Advanced Methods for Life Table Analysis
DEM 7233 Applied Forecasting Methods in Demography

STA 5313 Theory of Sample Surveys with Applications
STA 6833 Analysis of Categorical Data
STA 7013 Advanced Applied Business Statistical Methods
STA 7023 Applied Linear Statistical Models
STA 7033 Multivariate Statistical Analysis

C. Demographic Tracks
A minimum of 12 semester credit hours are required in the track area selected. Both tracks require completion of an approved internship.

1. Applied Demography and Health Track
A minimum of 12 semester credit hours are required from the following courses:

DEM 7403 Health Care Organizations, Professionals, and the Government
DEM 7063 Applied Demography in Policy Settings

PH 1120* Introduction to Program Evaluation
or
PH 3740* Community-Based Health Assessment

and at least one of the following courses:

DEM 7073 Disparities in Health and Health Care
FAPR 4100** Medical Economics
PH 1110* Social and Behavioral Aspects of Community Health
PH 2610* Introduction to Epidemiology
SOC 5133 Sociology of Health and Health Care

(OR)

2. Applied Demography and Policy Track

A minimum of 12 semester credit hours are required from the following courses:

DEM 7063 Applied Demography in Policy Settings
DEM 7413 Public Policy and Corporate Change
SOC 5103 Complex Organizations

SOC 5043 Evaluation Research
or
PH 1120* Introduction to Program Evaluation

and at least one of the following courses:

MKT 5003 Introduction to Marketing
POL 5853 Economic Geography

PAD 5323 Public Policy Formulation and Implementation
or
PH 3915* Methods of the Economic Evaluation of Health Programs

Note: *Denotes courses that are to be completed at The University of Texas School of Public Health San Antonio Regional Campus.
**Denotes courses that are to be completed at The University of Texas Health Science Center at San Antonio.

D. Doctoral Dissertation (minimum 12 semester credit hours)

DEM 7911–7916 Doctoral Dissertation

The entire program of study must be approved by the student's dissertation advisor and graduate committee, and must be submitted to the Dean of the Graduate School through the Dean of the College of Public Policy for final approval.

Admission to Candidacy. Advancement to candidacy requires that a student complete University and Applied Demography requirements. The student must request a graduate committee comprised of five members and designate one faculty member as chair of that committee. This faculty member must be a member of the graduate faculty of UTSA. A degree plan must be submitted by each student to his or her specific graduate committee and must be approved by the committee before the end of the second semester of enrollment. The student may seek candidacy by taking and passing written and oral qualifying examinations. The written examination is administered by the graduate faculty of each track. The oral qualifying examination will assess issues not adequately addressed in the student's written examination. The student will also submit and undergo an oral examination in defense of the student's dissertation proposal. Written qualifying examinations are scheduled twice a year, whereas oral examinations may be scheduled at any time. However, oral examinations are administered at the discretion of the student's committee and must meet the time line and requirements of the University. All students must schedule a defense of their dissertation at which all members of their committee are present to examine the student and issue a pass/fail evaluation of the student's work. The Chair of the student's committee is responsible for overseeing the final corrections of the student's dissertation.

Dissertation. Candidates must demonstrate the ability to conduct independent research by completing and defending an original dissertation. The research topic is determined by the student in consultation with his or her Dissertation Chair. A dissertation committee, selected by the student in consultation with his or her Dissertation Chair, guides and critiques the candidate's research. The completed dissertation must be formally presented and defended to, and approved by, the student's Dissertation Committee. Awarding of the degree is based on the approval of the Dissertation Committee. The UTSA Dean of the Graduate School certifies the completion of all University-wide requirements.

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CONCLUSIONS

Chapter 21
Applied Demography in the 21st Century

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The chapters in this volume have examined a large number of issues in applied demography from such major emphases in the field as population estimation and projection to the most recent data developments (e.g. the American Community Survey). The entries in this volume show the breadth and depth of the field, delineate its strengths and point to areas where there are remaining concerns, but do so as it relates to the specific issue addressed in each work.

In this last chapter we draw upon such works to identify the major characteristics of applied demography today and then examine areas of continuing challenges and opportunities. We do not claim that we have adequately covered all of the dimensions that currently define this expanding field or noted all of its challenges and opportunities. However, we believe it is appropriate to attempt to identify major trends and to raise the level of discussion of what applied demography is, and what it may become, in the 21st century. In discussing these issues we do not wish to repeat the discussions in previous works such as those by Rives and Serow (1984), Murdock and Ellis (1991), Siegel (2002), Swanson and Pol (2005) or others. Rather we wish to simply highlight those characteristics and issues that are particularly important at this point in time. We begin by discussing what we believe are the key characteristics of the field today, followed by a discussion of future challenges and opportunities.

The Current State of Applied Demography

Applied demography is a diverse field but continues to have several defining characteristics that are worthy of delineation. Among the most important of these is that applied demographers continue to be about doing the work that needs to be done. That is, applied demographers continue to develop their craft as a means of addressing the applied questions that they are asked to address by business, government, nonprofits, and their own science. How can school projections be improved? How

S.H. Murdock and D.A. Swanson (eds.), Applied Demography in the 21st Century, 361–367.

do we make data more understandable to lay users? Can we combine short-term and long-term forecasting to extend the utility of projections for detailed program administration? Should marketers be concerned about rural and urban differences in populations in rapidly developing economies? Who is more likely to perceive the risks of exposure to various diseases and hence who most needs to be educated about such risks? All of these issues were addressed in this text and make the point that applied demography is, above all else, applied.

Although the fact that applied demography is applied may seem so obvious as not to merit mention, what flows from this general characteristic is critically important because it leads applied demographers to work across disciplines, across diverse forms of data, and with widely varying geographic areas of analysis; that is, to pursue knowledge from whatever source is necessary to serve a client, a customer, a data user, etc. Although some might argue that this leads to breadth without sufficient depth, such an interpretation fails to differentiate the focus of applied efforts relative to non-applied enterprises. Compared to academic demographers, applied demographers tend to be very specialized relative to the specific questions they must address, but tend to be less specialized relative to the concepts or methods used to address a specific question. Applied demographers must address pragmatic issues and must use all perspectives and methods available, whatever their disciplinary or conceptual origins, to address such issues. This leads to a certain level of versatility that is displayed by most applied demographers.

Compared to academic demographers, applied demographers tend to have very focused audiences that are external to the field of demography; academic demographers tend to have audiences made up of other demographers. As such, academic demographers tend to be interested in contributing to the general body of knowledge of colleagues across the country (Swanson et al. 1996). Further, applied demographers, although interested in the broader academic audience as well, nearly always serve a specific user: that is a private sector client, a public decision-maker, or a specific set of nonprofits. As a result, applied demographers tend to place greater emphasis on how to address the issues of concern to specific bodies of users such as company CEOs, school administrators, elected officials, and others.

Nearly all the remaining characteristics of the current state of applied demography flow from the above noted general orientations. Thus, it is clear that the nature of the work pursued by applied demographers continues to be centered on the present and future making population estimation and projection key areas of work (for additional description of this emphasis, see Murdock and Ellis 1991, Swanson and Pol 2005, Siegel 2002) in applied demography. As several works in Section II of this volume show, applied demographers must know how to complete estimates and projections, how to make them more accurate, and how to assess their uncertainty continue to define large parts of the activities of applied demographers. Although of only some interest to the discipline of demography as a whole, estimates and projections are at the core of applied demography (Smith et al. 2001, Swanson and Pol 2005, Murdock et al. 2006).

Because the clients of applied demographers usually want specific knowledge about specific geographic areas rather than generalized knowledge about generalized areas, interest in small areas and small area data remain key foci as well. The nature of applied demography is such that census tracts, school attendance zones, traffic grid areas, tax parcels and similar specific units of geography continue to be of key concern. Whereas general demography tends to focus on the behavior of total populations within nations, metropolitan areas, and counties, sub-county analyses have increasingly become the norm in applied demography (Siegel 2002).

As a result of the small area geographic focus, applied demographers increasingly possess GIS expertise. Although some may yet have rudimentary skills, there are few who do not see it as an essential tool for communicating geographic specific demographic data to decision-makers. Therefore we would argue that the current characteristics of applied demographers increasingly include skills in GIS technology and analysis.

As suggested by its need to use whatever knowledge is available to address a pragmatic issue, applied demography is also characterized by disciplinary diversity. Concepts and methods from business, statistics, biomedicine, geography, sociology, psychology, economics, and other perspectives, are all used by applied demographers. As a result, the disciplinary tent for applied demography remains broad, expansive and open. Most academic demographers are trained in sociology, with lesser numbers coming from economics, geography, and political science. The disciplinary backgrounds of applied demographers include all of these fields and more (e.g. business administration, planning, and public policy).

In sum, applied demographers are currently characterized by interest in addressing pragmatic questions in specific (generally small) geographic areas for specific clientele who need to make decisions impacting current or future periods of time. They show particular foci on population estimates and projections and on GIS applications while employing multiple sets of disciplinary knowledge to address such questions. Although all of these have been delineated previously (see Murdock and Ellis 1991, Siegel 2002, Swanson and Pol 2005, Swanson et al. 1996) they merit repeating here because they still define much of what is applied demography today.

Two more recent characteristics should also be added to any discussion of the current state of applied demography. One of these is that applied demography and its adherents have moved to the forefront in the development of key data bases and related methods. Whether one examines work directly related to agency estimates or the need to estimate the effects of disasters such as hurricanes or attacks such as 9-11 (see the chapter by Stone in this volume), examines the need for better and more complete analyses of immigration (Swanson 2006), or examines the data use requirements of the American Community Survey (see the papers by Hogan and Becker in this volume), it is apparent that applied demographers are playing major, if not dominant roles. The special expertise of applied demographers is both increasingly recognized and required by all in the demographic community. Each of these areas affects the accuracy and utility of decennial and other data in ways that impact all professional demographers who use such data. We argue that applied demographers have come into their own in terms of being recognized for their unique knowledge of specific methods and their data use expertise.

We also believe that despite its growth as a field of work, and its recognition among data use professionals, applied demography appears to be unsure of itself. The traditional tension between applied and basic demography noted by Swanson et al. (1996) still seems to apply. As a result, some applied demographers continue to be tentative in referring to themselves as applied demographers and some in the general profession continue to suggest that applied demography is somewhat less than professional demography. Similarly, many applied practitioners seem uncertain of their acceptance in general demography and yet lack the time and other essential resources necessary to establish a separate identity. We do not wish to suggest what stance applied demography should take relative to such issues but believe that it remains an undercurrent affecting the development of the discipline and that the resolution of such issues is likely to be critical to the future of applied demography in the coming years.

Opportunities and Challenges for Applied Demography in the 21st Century

Applied demographers also face a number of challenges and opportunities that we believe are likely to be created by expanding data, methods and technology. Among the most important of these is simply the volume and technical features of data provided by such new data sets as the American Community Survey (ACS). The works by Hogan and Becker in this volume addressing the ACS clearly recognize the challenges but it is also clear that applied demographers have yet to master them. Although demographers have wished for access to annual data on socioeconomic characteristics for small areas for years the volume and technical aspects of these data may be so extensive as to not only push the reporting and interpretation capabilities of many state and local applied demographers, but even go beyond them. This was evident in the first comprehensive data releases from the 2005 ACS that occurred in 2006. Local officials were overwhelmed by such data, the press wanted vast amounts of data summarized in a succinct fashion and applied demographers often found insufficient time to analyze the data before another wave was released. The reporting and analysis problem was not due to computer limitations or other technical factors but simply the time necessary for human analysts to digest the data. This will likely become easier as profiles and other standard data products are produced but the applied problem of what should be reported for what areas at what frequency has yet to be adequately resolved.

This issue is aggravated by the fact that the use of three and five-year averages reported on an annual basis show substantial variation for small areas (mainly due to sampling errors resulting from smaller sample sizes, but also due in some part to non-sampling error) particularly if year to year averages are reported (Swanson and Hough 2007). How well are small areas served by reporting such data annually? How well will local officials (mayors, county commissioners, city councils, etc.) understand such variation and how will they use data with wide annual fluctuations for making decisions on infrastructure and other factors? As noted by Swanson and Hough (2007), there is a high level of "interpretation burden" placed on these users and while the answers to such questions are not clear, it will be applied demographers who will be at the front lines in assisting local persons to use small area data. Although it may be unlikely that such can be achieved, the use of commonly agreed upon criteria would be immensely helpful for local users. Applied demographers who understand local users should play a leading role in such development.

Additional challenges will be faced by applied demographers in the sphere of use of multiple data sets. Given increased data base management technologies, very large capacity data storage, increasingly sophisticated GIS and related geographic-based software and the fact that demographic factors impacts are evident in a large number of types and forms of data, it is clear that applied demographers are likely to be required to learn how to effectively integrate a wide variety of data forms. However, the ability to create comparability between census, commercial, institutional, governmental, and other data for a given level of small-area geography creates both empirical and use challenges. Although many of the relationships between demographic change and other factors are well established, it is less clear how changes in many commercial indicators such as store sales, number of units in governmental appraisal districts, changes in non-educational institutional populations are related to changes in populations and subpopulations. Clearly, there is an empirical need for analyses to establish these relationships if multiple data bases are to be effectively used to measure demographic change and related events. Similarly, there is simply insufficient knowledge in the applied demographic community of how to effectively use many of the commercial and governmental data bases that may soon be made compatible with standard census and other data. The demographic community will have to be convinced of the internal and external validity of such data bases and it is likely that applied demographers will be among the first to introduce such data combinations to a skeptical demographic audience.

The continuing miniaturization of computer chips and other technology is likely to also challenge applied demographers. Whereas traditional practices have allowed applied demographers to meet with clientele, obtain an assessment of their needs and complete an appropriate report or product, users of applied demography are likely to increasingly require user interfaces with interactive products. For example, the ability to show the instantaneous results of an alternative projection scenario created by users' interactive selection of parameters is likely to be expected by an increasing number of users as a means of assessing model sensitivity. Users served by applied demographers whether in the private or public sectors are likely to require more interactive products and more options in the form and types of products delivered to them. Having the skills necessary to provide such products will require substantial upgrading of skills and products by experienced applied demographers and the imparting of additional forms of knowledge in graduate training programs for applied demographers.

Coupled with the use of new data bases and new technology will be the need to develop new methods for population estimation and projection. Current methods use very specific data bases such that the very names of the methods (e.g., the Housing

Unit Method) convey the dependence of the method on the data used. The demographic processes (measured by fertility, mortality and migration data components and the use of component methods), the households and housing units in which populations live (as used in housing unit methods), and the services with which populations interact (as measured by such factors as school enrollment, vehicle ownership, voting registration, driver licenses, and employment, and used in regression-based procedures) have been the most common parameters used in population estimates and forecasts to provide the basis for projections. How may other forms of private sector and public data be used to estimate and/or project populations? Clearly the empirical and integration skills noted above will be necessary for the development of new methods. Although we do not yet have sufficient knowledge of what methods may be developed, we are certain that new methods including continuous population estimation methods will flow from the availability of new data and data integration methods.

The expanding range of data, methods and technology promise to place unprecedented demands on applied demographers who, in turn, are going to play key roles in the development of these same factors. These factors also are likely to create new roles for applied demographers as data, methods and technology consultants. With demographics receiving increased attention as the population diversifies and ages, private and public sector managers will increasingly require assistance in knowing what to do to understand these and other trends and to identify their likely impacts. The data, methods and technology for the use of new data and methods are expanding faster than the total number of knowledgeable users and applied demographers who shall be required by their professional activities to remain current in these areas, and by their applied emphasis to have experience in explaining these factors to users. Thus, applied demographers are likely to be in increased demand. Without such consultants the explosion of data, methods and technology for their use is likely to lead to data misuse and substantial errors in data interpretation.

Finally, we believe that an opportunity exists that is key to growth of the discipline of applied demography. This is the need to more systematically and completely identify the roles that applied demographers can play in the private and public sectors. In large part, the areas where there is demand for applied demographers have been in some academic settings, in governmental entities closely associated with census data, and in selected other areas where individual demographers have created a niche for themselves. Outside of universities, state data centers, state population estimation or projection programs, and state and local planning entities, the positions for applied demographers have been created largely by the individual demographer. There has been no systematic process to identify areas of employment for applied demographers. Although examples are provided in business (Pol and Thomas 1997) and other areas (Kintner et al. 1994), we have not, as a profession, identified employment opportunities and worked with businesses and others to promote the employment of applied demographers in such positions. If the aging population of applied demographers is to be replaced by other applied demographers, and the field is to expand such an effort is merited.

In sum, then, the state of applied demography is robust, its challenges and opportunities extensive, and its future potentially bright. However, applied demography must be supported and promoted both within the profession of demography and in the workplaces for applied demographers. Applied demographers would do well to systematically prepare a plan, including a plan of action to ensure that in the last decade of the 21st century, applied demography will have a larger number of professionals and play an even more important role in assisting decision makers and in developing the science of demography than it did in the first decade of the 21st century.

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