Models of Intraurban Residential Relocation

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To Margie and Graham

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PREFACE

Most of the research incorporated in this monograph was initially undertaken as part of the author's Ph.D. dissertation submitted to the School of Urban and Public Affairs, Carnegie-Mellon University. The research was funded through a Doctoral Dissertation Grant from the U.S. Department of Housing and Urban Development. The dissertation was a winning entry in the 1979-80 Ph.D. Dissertation Competition of the North American Regional Science Association, funded through a grant from the Economic Development Agency of the U.S. Department of Commerce. Revisions and extensions of the initial research were conducted at the University of Wisconsin-Milwaukee.

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Models of Intraurban Residential Relocation

1 INTRODUCTION

Intraurban residential relocation is the central dynamic process affecting the formation and change of urban residential structure. United States Bureau of the Census figures reveal that nearly 13% of the total population annually changes residence within county jurisdictions in the United States. Yet it is not the sheer magnitude of the process alone that suggests the importance of residential relocation in shaping urban residential structure. So many significant urban phenomena, such as social and racial segregation, neighborhood change and decline, and suburbanization, all operate largely through the intraurban residential relocation process. Knowledge of the underlying determinants generating intraurban residential relocation patterns is essential for understanding the dynamics of urban residential structure and the analysis of impending public policy issues surrounding these urban phenomena.

The objective of this investigation is to advance our understanding of the process of residential relocation and its modeling from theoretical, empirical, and policy perspectives. The basic premise underlying this effort is that further insight may be gained by the explicit economic treatment of residential relocation as a process of housing consumption adjustment within local housing markets.

The most significant characteristics of housing, which in combination distinguish housing consumption from that of the realm of conventional goods and services, are its multidimensional heterogeneity, extreme durability, and locational immobility. These features of housing jointly produce the unique "localization" of housing consumption. Because housing lacks the portability of conventional commodities, housing consumption must take place at a particular site in a specific spatial context. The heterogeneity of the physical housing stock contributes to the locational specificity of housing consumption as particular dwelling types are unlikely to be ubiquitously distributed over an urban area. At the same time, the heterogeneity of housing is enhanced by the locational immobility of the physical dwelling since the general social, environmental, and public service attributes of the locational neighborhood are encompassed within any housing bundle. Finally, the extreme durability and relative nonmalleability, or nonconvertability, of the physical dwelling further enhance the localization of housing consumption in the sense that households, in general, must *relocate* to adjust their consumption of housing over time. In this way, the localization of housing serves as an integral factor interlinking the formation and change of urban residential spatial structure.

Despite its key functional role in housing markets, residential relocation has received little attention in the economic analysis of housing markets. The economic literature on housing has largely been wed to a static long-run equilibrium view of housing and land markets. Household relocation in this context is merely viewed as a costless mechanism to ensure that prices adjust so as to reflect locational and other advantages and that equilibrium prices are sustained. For the most part the study of intraurban household relocation has fallen in the domain of geographers, demographers, and sociologists. Although these works have retained the view of relocation as a housing adjustment process, the roles of prices, income constraints, and supply and demand factors in economic paradigms of housing markets are generally given little more than cursory attention. The emphasis of these works is placed on the behavioral processes involved in relocation and the constraints that impair the workings of the conventional economic paradigms. The view taken in this book is that the economic and behavioral perspectives on relocation both have merits, which together should contribute to advancing our understanding of residential relocation and related policy issues.

This book differs from most monographs and review articles on the subject of residential mobility in its emphasis on the various modeling approaches to the study of residential relocation. Excellent summaries of many of the more substantive findings of past research related to questions of which, why, and where households move may be found in Simmons (1968), Moore (1972), and Quigley and Weinberg (1977). The major focal points of this investigation lie in the analysis of the modeling approaches that have generated much of those findings and the theoretical and empirical development of a model of residential relocation that builds on the positive features of past modeling efforts and is useful for addressing substantive policy issues.

1.1. HOUSING CONSUMPTION ADJUSTMENT AND RESIDENTIAL RELOCATION

Population mobility is indeed a ubiquitous phenomenon in our contemporary society. United States Bureau of the Census data reveal that since 1947 between 18 and 20% of the U.S. population has changed residence annually. Most of the observed mobility of the American population is of intraregional character. Sixty-five to 70% of annual moves both originate and terminate within the same county jurisdiction. In contrast to the situation of interregional mobility, for which the literature has developed around the cornerstone view of migration as a form of human capital investment at the microlevel and labor market adjustment mechanism at the macrolevel, no such consensus has developed toward intraregional mobility. The very question of "why households move" is muddled due to the interplay of exogenous vital events of life (e.g., marriage, divorce, birth, death), the effects of workplace location, endogenous housing market forces, and the ambiguity of the phrase "housing related." Although most works addressing "reasons for moving" (e.g., Rossi, 1955; U.S. Bureau of the Census, 1966) suggest that the bulk of intraurban moves are "housing related," precise figures are difficult to assemble since any single move may be attributed to multiple reasons. Furthermore, what actually constitutes a "housing-related" move depends on how broadly "housing" is defined.

The findings of the U.S. Bureau of the Census (1966) in table 1.1 are typical of recent mover surveys. When multiple reasons are counted as unweighted inde-

Table 1.1. Percentage Distribution of All Reasons for Moving by Males 18-64 Years Old for Intracounty Moves: March 1962-March 1963

Reason for Moving	*All Reasons (%)*
Related to job	10.8
Voluntary housing related	55.3
Family status related	19.1
Forced moves	5.8
Other reasons	9.0
	100.0

Source: U.S. Bureau of the Census (1966).

pendent responses, voluntary housing-related reasons account for more than 55% of all reasons stated. Although this percentage is substantial, housing is defined rather narrowly in this context. The term "housing related" encompasses such reasons as the need for more space and the simple desire for better housing quality. Yet moves precipitated by a change of workplace and the desire for reduced commuting time and expenses are classified as job related. An actual workplace change may be legitimately treated as exogenous to the housing market, but the desire for easier commuting can also be justifiably treated as being housing related.

The purchase of housing involves more than shelter alone. Housing is more accurately defined as a multidimensional bundle of attributes of the dwelling and its locational environment. It is this entire bundle of attributes, including neighborhood characteristics, quality of public and quasi-public services, and locational accessibility to daily activity nodes such as workplace, that the household must evaluate with the relocation decision process. Accordingly, most job commuting-related reasons (accounting for almost 11% of all reasons) may be treated as instances of households adjusting their consumption of housing to demand shifts precipitated by a workplace change. When viewed in this light, moves precipitated by exogenous changes in household status, such as marriage or divorce, are also housing related in many instances, for they reflect shifts in housing demand. Thus, if one carries this line of reasoning to its fullest extent, nearly all intraurban household moves can be classified as housing consumption adjustment related.

The role of residential relocation as a dynamic mechanism of housing consumption adjustment is further suggested by examining changes in the housing consumption experienced by recent movers. Table 1.2 contains a series of tables illustrating the central city/suburban dwelling location, the number of bedrooms per dwelling, and the rent/value classes for the previous and current dwellings of recent mover households within metropolitan areas over the time period 1974–75. Even a casual inspection of the tables suggests that significant changes in housing consumption are associated with residential relocation. Most households retain their central city/suburban location in the course of relocation. Yet significant fractions of total moves still cross these jurisdictional boundaries. Both renter and owner occupant households exhibit a tendency toward greater consumption of space upon relocation.

With the exception of two instances, the figures in table 1.2B suggest in all groups that less than half of recent mover households consumed the same number of bedrooms before and after relocation. The figures in table 1.2C also suggest that households exhibit a tendency to increase housing consumption expenditures upon relocation. On average, in only about one of every five cases did a household's past and current residence lie in the same value or rent class.

Table 1.2. Changes in the Dwelling Characteristics of Recent Intra-SMSA Mover Households with the Same Head: 1974–1975

A. Locational Change

(All Households)

	Current Location		
Previous Location	*Central City (%)*	*Outside Central City (%)*	*Total (%)*
Central city	75	25	100
Outside central city	17	83	100

B. Change in Number of Bedrooms

(Owner Households)

	Current Number of Bedrooms			
Previous Number of Bedrooms	*None or One (%)*	*Two (%)*	*Three or More (%)*	*Total (%)*
None or one	20	47	33	100
Two	7	38	55	100
Three or more	2	14	84	100

Table 1.2 *(continued)*

(Renter Households)

Previous Number of Bedrooms	*Current Number of Bedrooms*				
	None (%)	*One (%)*	*Two (%)*	*Three or More (%)*	*Total (%)*
None	31	49	17	3	100
One	5	48	40	7	100
Two	3	24	53	20	100
Three or more	2	16	34	48	100

C. Change in Value or Rent

(Owner Households)

Value Class of Previous Unit	*Current Unit*			
	Lower Value Class (%)	*Same Value Class (%)*	*Higher Value Class (%)*	*Total (%)*
Less than $10,000	-	13	87	100
$10,000–14,999	-	22	78	100
$15,000–19,999	3	13	84	100
$20,000–24,999	8	11	81	100
$25,000–34,999	4	16	80	100
$35,000–49,999	11	35	54	100
Greater than $50,000	15	85	-	100

(Renter Households)

Rent Class of Previous Unit	*Current Unit*			
	Lower Value Class (%)	*Same Value Class (%)*	*Higher Value Class (%)*	*Total (%)*
Less than $60/month	-	57	43	100
$60–79	7	24	69	100
$80–99	9	16	75	100
$100–119	19	14	67	100
$120–149	20	23	57	100
$150–174	21	26	54	100
$175–199	29	22	49	100
$200–249	41	32	27	100
$250–299	39	19	42	100
Greater than $300	55	45	-	100

Source: U.S. Department of Commerce (1977).

Overall the data in table 1.2 strongly support the view of residential relocation as a process of housing consumption adjustment and would suggest the importance of its explicit treatment in the study of residential relocation.

1.2. RESIDENTIAL MOBILITY, LOCATION, AND RELOCATION

As a process of housing consumption adjustment, residential relocation necessarily involves not only a decision to *move* from a current residence but also a decision to *locate* at an alternative residence. This distinction may appear to be obvious, but it serves to characterize an important segmentation that has occurred in the course of past research development. The theoretical treatment of these two components of the relocation process is a primary factor differentiating the bulk of past research. The process has been implicitly or explicitly treated as either (1) two discrete and logically separate *movement* and *locational* processes or (2) a single *relocation* process with either simultaneous or sequential decision components. Most studies may be placed in the former class—that is, they have addressed either the *movement* or *location* component as if the other process was unrelated.

Those studies that only model the movement decision component are termed models of residential *mobility* in this book. For the most part these works have focused on household attributes and the social, demographic, and economic correlates of movement propensity differentials (e.g., Rossi, 1955; Butler et al., 1969; Lansing and Mueller, 1964; Deutschman, 1972). In recent years more attention has been devoted to theoretical and empirical models of the movement decision process (e.g., Brown and Moore, 1970; Speare et al., 1974; Hanushek and Quigley, 1978). An implicit assumption underlying most models of residential mobility is that the external housing market situation is irrelevant to the movement decision. Households are viewed as being solely concerned with their "satisfaction" with their current housing and oblivious to external housing market opportunities. While it would appear that "satisfaction" must logically be a relative concept, any comparisons of current housing to potential alternatives are not treated explicitly in most mobility models.

On the other hand, a substantial literature has developed addressing only residential *location* (e.g., Alonso, 1964; Muth, 1969; Wilson, 1970; Herbert and Stevens, 1960; Quigley, 1976). By the discrete separation of location from movement, all households are implicitly treated as if they "float in the air" within an exogenously determined locators pool. At some fixed point in time all households simultaneously and instantaneously locate within the context of a competitive housing/land market. Although these models impart useful insight into market competition and individual household and overall market equilibrium, they provide but a "snapshot" description of a long-run equilibrium situation that may be short-lived at best. Their static nature precludes any explanation of the dynamic disequilibrium process of residential relocation.

With the exception of several works (e.g., Brown and Moore, 1970; Speare et al., 1974) that have developed models of *relocation* by treating the movement and locational decisions as sequential but interrelated processes, the bulk of past models lie in the class of residential mobility *or* location. The segmentation has hindered the development of logically complete models of residential relocation. The *equilibrating* motivations of destination residential choice are implicitly ignored in most models of residential mobility. At the same time the household's prior housing consumption is implicitly regarded as irrelevant to residence choice in location models.

Given the substantial information, social, psychic, and search costs of relocation, neither approach would appear to be satisfactory from a logical viewpoint. Because of these costs, a relocation decision is most aptly described as one with the discrete alternatives of complete housing adjustment or no adjustment at all. Indeed this all or nothing nature is strongly suggested in the comparisons of past and present housing of recent movers in table 1.2. The realization of any decision to move is ultimately contingent on the choice processes involved in finding a suitable alternative residence. In fact, why the "decision to move" must precede the choice of destination residence is not even clear. The very decision to move may be stimulated by the availability of a preferred housing alternative. On the other hand, the choice of a new residence should depend on prior housing. When forced to bear relocation costs, households are unlikely to choose a close substitute to their former residence. The major theoretical premise advanced in this study is that the movement and locational dimensions of residential relocation are logically interdependent. The explanation of relocation logically encompasses the explanation of both movement and location.

1.3. RESIDENTIAL RELOCATION AND PUBLIC POLICY ISSUES

The modeling of residential relocation is of far greater importance than mere theoretical interest. By sheer magnitude alone, residential relocation is the central mechanism shaping the change of urban residential structure over time. The assessment of the impact of current programs and the development of future policy toward many urban housing problems such as racial segregation, neighborhood change and decline, and suburbanization, as well as the current phenomenon of displacement from gentrification, requires an understanding of the determinants of residential relocation patterns.

Grigsby (1963) noted some time ago that residential relocation is the key factor establishing linkages among housing submarkets. Relocation facilitates shifts in rents/market values among submarkets, leading certain areas to improve or decay. Grigsby argues that relocation further regulates the rate of "filtering," through which housing becomes available or unavailable to lower-income groups. It has long been recognized that the impact of government intervention in housing markets extends beyond the immediate target group of households or neighborhoods. Residential relocation is a key factor in this regard. The vacancy chain concept introduced by Kristoff (1965) stems from the fact that households both fill and create vacancies in the course of relocation. Policy-induced vacancy creations produce a chain of voluntary household relocations. Several works have invoked the vacancy chain concept to examine overall turnover impact of programs or policies that alter the stock of housing vacancies (e.g., White, 1971; Sands, 1976; Watson, 1974; Porell, 1981).

The impact of programs, however, may be far more complex than a simple chain of residential turnover. Eastman (1972) has argued that the welfare distributional impact of "place-oriented" neighborhood development programs is obfuscated by mobility turnover and the capitalization of benefits in property values and rents. Programs that alter the structural condition of the stock or the dwelling unit composition of neighborhoods may have substantial impact on the composition of households in those neighborhoods as households adjust to changing relative market conditions. Effective housing programs and policies cannot be formulated in a vacuum. We can only begin to understand the repercussions of policy actions within local housing markets by acquiring a fuller understanding of dynamics of residential change. Since residential relocation is the fundamental market process effecting neighborhood dynamics, its modeling forms the basis of departure for this study.

1.4. OVERVIEW OF THE BOOK

The following chapters will present critical reviews of past research, the theoretical development of the short-run model of residential relocation, an empirical case study implementation of the model, and a synthesis of policy and modeling implications of the research.

Chapter 2 is essentially a critical overview of past research on residential mobility/location/relocation. A typological framework is proposed to characterize past research works along two basic dimensions: (1) the extent of the housing consumption adjustment process under study in terms of mobility, location, or relocation models; and (2) the dichotomy between microlevel and macrolevel analyses. The synthesis and classification of works within this framework expose the interrelationships and differences in past research and provide a foundation for theoretical extensions in modeling residential relocation.

The theoretical development of a short-run model of the residential relocation process is presented in chapter 3. The model is founded on the rational behavior of individual households seeking to maximize utility in their choice of residential submarket. Because of the discrete nature of residential relocation (i.e., households either relocate to an alternative submarket or remain in their current residence), relocation demand for housing is treated through application of probabilistic choice theory at the individual household level. The supply sector is introduced by equilibrium constraints imposed on household occupancy in any submarket arising from the assumption of a fixed housing stock in the short run. The macrolevel residential relocation process is characterized in the multisubmarket equilibrium model as one of competition for the limited supply of housing services produced in the housing market in the short run. The nonlinearity of the simultaneous system of household class demand functions, in concert with the additive aggregate supply constraints, precludes the derivation of a reduced form price equation and full identification of all parameters of the model. Some explicit postulations are invoked to achieve a partially identified model at the household class level of aggregation that is quite similar to systemic gravity models of the spatial interaction modeling literature. The last section entails a structural comparison of the model with several alternative models reviewed in chapter 2.

The issue of parameter identification in systemic spatial interaction models is thoroughly discussed in chapter 4. A multistage estimation procedure that draws on important structural properties of the model is outlined. Although the procedure is presented in the context of the model derived in this study, its general logic is widely applicable to systemic gravity models in other fields of study. The model is applied to Wichita, Kansas, using the Intergovernmental Annual Enumeration Survey of Wichita-Sedgwick County, Kansas. The survey contains detailed data on both household and dwelling characteristics at multiple points in time. In terms of population coverage and detail, it is the richest source of data for the study of residential relocation to date.

Chapters 5-7 summarize the empirical application of the model to the rental market in Wichita. The study area and data are introduced in chapter 5. The effects of generalized relocation costs and their estimated parameters are discussed in chapter 6. Chapter 7 contains the estimation of the revealed preference parameters for residential attributes characterizing submarkets. Chapter 8 concludes the study by synthesizing its general conclusions and the policy implications of the results toward such issues as residential segregation and neighborhood composition.

2 A CRITICAL REVIEW OF PAST RESEARCH

Chapter 2 examines the development of models of residential mobility, location, and relocation in the literature. The study of residential mobility has generally proceeded independently of the study of residential location; rarely does a work in one of these studies refer to works in the other. This dichotomy may be largely due to discipline bias. Until recently the study of residential mobility has been the turf of geographers, demographers, and sociologists. On the other hand, economists have dominated the study of residential location. Regardless of why this dichotomy has occurred, there is reason to believe that both studies are relevant to the investigation of residential relocation.

This chapter advances a typology of research approaches, that expose both the differences and interrelationships among past research efforts. In addition to the distinction between studies of mobility and location, the typology is defined in terms of aggregation level and a behavioral versus nonbehavioral classification. Because of the large volume of literature involved in this review, covering all works relevant to the study of residential relocation is impossible. The review attempts to be comprehensive only in the sense of examining representative works that span the literature within the typology. The following section describes the rationale for the typology. The next two sections contain reviews of individual representative works. The last section synthesizes the critical arguments and culminates in the proposal of some structural criteria for the development of logically consistent models of residential relocation.

2.1. A TYPOLOGY OF MODELING PERSPECTIVES

Despite the wide variance of theoretical perspectives taken in the study of urban residential structure and its change, a general typological framework seems to underlie the bulk of these works. The proposed framework for synthesizing and assessing the theoretical perspectives of past research contains two basic dimensions: (1) the process of housing consumption adjustment addressed; and (2) the level of household aggregation. The cross-classification of past research works along these two dimensions provides a meaningful framework for exposing the inherent interrelationships and differences of their varied theoretical perspectives. The rationale for the basic structural dimensions is discussed below.

2.1.1. Housing Consumption Adjustment Decision Processes

As households in general must relocate to adjust their consumption of housing, the housing consumption adjustment process involves not only a movement decision but also a locational decision. The theoretical treatment of these two components is a primary factor differentiating the bulk of past research and thus serves as a basic dimension of the research typology. The crucial assumption differentiating past theoretical perspectives is their implicit or explicit treatment of the housing consumption adjustment/relocation decision as (1) two discrete and separated processes or (2) a single process with either two interdependent decision components or a single relocation decision. Models of residential *mobility* or *location* have been founded on the implicit separation of the residential relocation process into independent movement and locational processes. In accord with the theoretical treatment of the housing consumption adjustment process, the first basic dimension may be represented diagramatically as in figure 2.1.

2.1.2. Household Aggregation Level

In addition to the separation of the movement and location components of residential relocation, there has been a sharp dichotomy between microlevel and macrolevel analyses in past research. Microlevel models have generally been

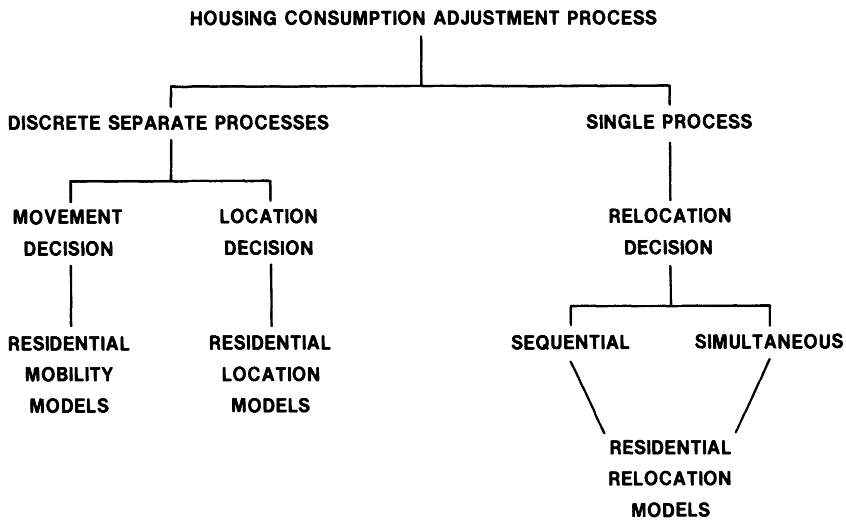

Figure 2.1. Theoretical Treatment of the Housing Consumption Adjustment Process

founded on the independent unilateral behavior of households as decision units. In contrast, most macrolevel models in past research have been of the descriptive statistical variety, with little behavioristic content. This dichotomy is very much attributable to the "aggregation problem" of the social sciences. Any meaningful aggregate process must logically be the cumulative result of individual microlevel actions. As Lancaster (1966a) notes, the aggregation problem is one of establishing internal consistency between microlevels and macrolevels when the number of interrelations among microvariables, microrelations, macrovariables, and macrorelations exceeds the number that can be chosen independently.[1] Although this dichotomy is not peculiar to the study of residential relocation, the demarcation distinguishes the microlevel treatment of *independent unilateral* behavior from the macrolevel emphasis of many residential location models. The latter group of models views aggregate location patterns as a *mutual* process dictated by the *interactive* roles of supply and demand factors. Although the exogenous/endogenous dichotomy of the treatment of price at micro- and macrolevels is a common feature of competitive market models, the distinction is relevant here given the sparsity of mobility models that incorporate the allocative role of price.

The major microlevel and macrolevel classifications of research are each decomposed further in the typology on the basis of their fundamental research

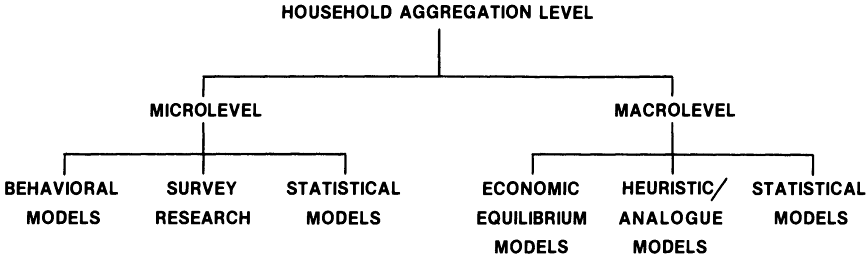

Figure 2.2. Household Aggregation Level and Methodological Approach

methodology. Microlevel research is further stratified into formal behavioral models, general survey research, and statistical models. Whereas microbehavioral models generally have strong theoretical underpinnings, survey research has been more exploratory by nature in its search for regularities in household behavior. For the purpose of this typology macrolevel research may be further classified into economic equilibrium models, heuristic/analogue models, and statistical models. Economic equilibrium models encompass those models with roots in the economic theory of markets. Heuristic/analogue models are defined here to encompass those efforts based on either direct analogy to physical science processes or heuristic theoretical reasoning. Finally, in the context of this typology statistical models are defined as phenomenological models founded on observable empirical regularities of the aggregate process. The second dimension of the typology is represented in figure 2.2.

The two basic dimensions in figures 2.1 and 2.2 together form a multidimensional typology for critically reviewing past research. A two-dimensional cross-classification of representative works to be reviewed is shown in table 2.1. Certainly the basic dimensions and subclassifications advanced here are not beyond reproach. It is difficult to define mutually exclusive and exhaustive categories concisely. Furthermore, many individual works can be assigned multiple classifications. Consider, for example, the "entropy maximization" location model of Wilson (1969, 1970). It is both a statistical and an analogue model. The analogy is to physical molecular systems. Yet the model is also statistical in the sense that it provides a description of empirical regularities rather than a causal explanation of location patterns. The model is classified as an analogue model in table 2.1 since the physical molecular systems analogy provides the basis for its statistical mechanics foundation. Despite these possible ambiguities, the typology provides a meaningful basis for addressing the varied theoretical perspectives of past research.

Table 2.1. A Typology of Past Research with Selected Representative Works

Housing Consumption Adjustment Process	*Aggregation Level*					
	Microlevel			*Macrolevel*		
	Behavioral	*Survey*	*Statistical*	*Economic Equilibrium*	*Heuristic/ Analogue*	*Statistical*
Mobility	Hanushek and Quigley (1978) Cronin (1978)	Butler et al. (1969) Rossi (1955)	Huff and Clark (1978)			Moore (1969, 1971) Johnston (1969)
Location	Alonso (1964) Muth (1969) Quigley (1976) McFadden (1978)			Herbert and Stevens (1960)	Wilson (1970) Anas (1973) Senior and Wilson (1974)	
Sequential relocation	Brown and Moore (1970) Speare et al. (1974)			Ingram et al. (1972)		
Simultaneous relocation	Smith et al. (1979)				Simmons (1974) Stouffer (1940, 1960)	Simmons (1974) Hua (1972) Gale (1969) Gale and Moore (1973)

2.2. MICROLEVEL MODELING PERSPECTIVES

2.2.1. Microsurveys of Residential Mobility

The earliest research in residential mobility consisted of household surveys. The survey approach provided a convenient vehicle for gaining an initial understanding of mobility behavior of households. The focus of surveys is generally to detect empirical regularities in household behavior related to the fundamental questions of who moves, why households move, and where households move. A major thrust toward answering these questions was provided in the work of Rossi (1955) and the subsequent works of Lansing and Barth (1964), Lansing and Mueller (1964), Lansing (1966), Butler et al. (1969), and Deutschman (1972). It is impossible to discuss the major findings of the survey approach in detail here. The excellent reviews of Simmons (1968), Moore (1972), and Quigley and Weinberg (1977) synthesize the major findings in considerable detail. Table 2.2 briefly summarizes many of the findings noted in Quigley and Weinberg (1977) without regard to specific works. The contributions of these works lie in their empirical identification of the demographic, economic, and social correlates of exhibited movement propensities. In fact, the strong empirical associations of household size, age of head of household, and housing tenure status with mobility rates have made the family life cycle explanation of mobility (i.e., as households form, grow, stabilize, and dissolve, housing needs change) a cornerstone in the literature.[2]

Although the emphasis on correlates of mobility has produced some useful insights toward understanding the "typical mover," the emphasis on household characteristics alone has tended to obfuscate the underlying housing consumption process involved in relocation. Quigley and Weinberg note:

> Holding housing prices, transport costs, and incomes constant, there is little reason to expect residential mobility to be associated with particular demographic characteristics of households, except to the extent that such characteristics are good indicators of expected changes in housing demand. On the other hand there is strong reason to expect mobility to be associated with *any* changes in household characteristics that shift the demand curve for housing services. [1977, p. 58, italics added].

An exception in this survey literature is the work of Rossi (1955), whose description of mobility as a process of adjustment to changes stimulated the further development of psychological behavioral models of mobility to be discussed shortly.

Table 2.2. A Summary of Findings Regarding Household Correlates of Mobility

Household Characteristic	*Findings*
Tenure	Persuasive evidence suggests renters are more mobile than home owners.
Marital status	Sparse empirical evidence exists on the following: never married are less likely to move than ever married; current married are less mobile than divorced or separated; mobility rates increase with the number of prior marriages and decrease with duration of marriage. There is substantial agreement that changes in marital status increase mobility.
Age of head	Consistent evidence suggests that mobility rates decline with increasing age.
Sex of head	Evidence is mixed.
Household size	Evidence is mixed on size at any point in time. Changes in family size are highly correlated with mobility.
Household composition	Presence of school-age children reduces mobility.
Prior mobility	Prior mobility is strongly correlated with current mobility.
Race	Evidence is mixed.
Income	Changes in income are associated with higher mobility. While evidence on the static relationship is mixed, highest mobility rates are associated with middle income range.
Education	Higher mobility rates are associated with higher education levels. Evidence is weak.
Occupation	Evidence is mixed.
Workplace location	There is no general concensus on change of workplace accessibility.

2.2.2. Microbehavioral Models of Residential Relocation: Sequential Decision Processes

Rossi's (1955) view of residential relocation as an adjustment process was later formalized in conceptual models of the psychological processes involved in relocation. The pioneering work of this theoretical perspective in the explicit context of residential relocation is that of Brown and Moore (1970). The Brown and Moore model builds on the general work of Wolpert (1965), which drew on Simon's (1957) concept of intendedly rational behavior and psychological awareness concepts to develop a model of migration decision making. The basic concept underlying this theoretical perspective is "place utility," or an abstract measure of a household's level of satisfaction or dissatisfaction with respect to a dwelling unit and its neighborhood environment. Brown and Moore (1970), Brown and Longbrake (1970), Speare et al. (1974), and Clark and Cadwaller (1973) have all incorporated the concept in models of relocation.

A schematic diagram of the Brown and Moore (1970) decision model is shown in figure 2.3. A critical assumption of the model is the sequential treatment of the movement decision and the search for and evaluation of new residences. In the decision to move, the household is assumed to reevaluate continually the place utility of its current residence. Changes in the internal needs of the household and external stimuli from the *immediate* neighborhood environment constitute a continual source of stress affecting the place utility of the household's current residence. When the place utility of the current residence sufficiently diverges from current housing needs (i.e., it reaches a threshold level), the search for a new residence is initiated. The second phase of search and evaluation is defined within a subset of locations termed an "awareness space," or those locations in which the household possesses sufficient information to assign place utilities. Only *after* deciding to seek a new residence is the household assumed to define an "aspiration" region. This region is defined as vector of lower and upper bounds for acceptable dwelling/neighborhood attributes. A "search space" is formed as a subset of locations within the awareness space satisfying the aspiration region. Within a time constraint the place utility of alternatives is evaluated by successive trials. A move is contingent on improvement of place utility. Failure to improve place utility may lead to a revision of aspirations and continued search or a decision to remain at the current residence.

The strongest attribute of the psychological model of relocation is its behavioral base. The assumptions of imperfect information through the concept of awareness space and the incurrence of search and transaction costs add a dimension of realism not found in most economic behavioral models. It is worthy to note that because of these imperfections households are not treated as strict utility maximizers. Rather, households seek only to "satisfice" their housing

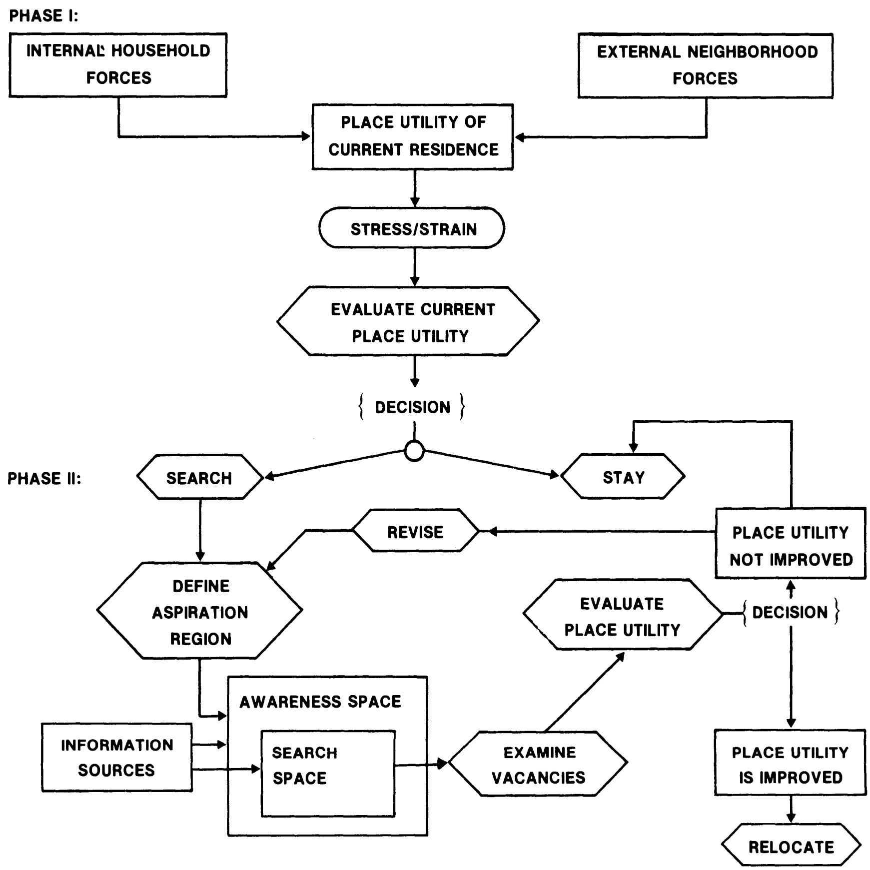

Figure 2.3. A Schematic Representation of the Brown-Moore Relocation Model (adapted from Brown and Moore, 1970)

needs. The formal treatment of relocation decision making in Brown and Moore (1970) was a significant contribution, which has stimulated further research into the complex behavioral aspects of spatial choice (e.g., Golledge and Rushton, 1976). Nevertheless, some apparent weaknesses deserve comment.

The most serious shortcoming of the Brown and Moore model is the restrictive nature of the sequential decision process. The two decision processes of the model in figure 2.3 are mutually interdependent only in the sense that a household may decide not to relocate after search. The decision to move in the first phase is precipitated only by the dissatisfaction or stress resulting from changing needs *internal* to the household or changes in environmental factors of the *immediate* neighborhood. Although satisfaction and dissatisfaction are logically relative concepts, the model does not incorporate the household's perception of market alternatives in their definition. Households are viewed as being oblivious to external housing market opportunities until they reach a threshold level of dissatisfaction with their current housing. *Only* dissatisfied households opt to search, and *only* then do households define aspiration regions from which to evaluate acceptable housing alternatives. The implicit assumptions in this sequential decision process are questionable at best. The selection of an alternative residence may in fact precede the decision to move if the availability of a housing alternative stimulates the decision to move. Also, it is not clear why dissatisfaction must be treated as a necessary condition for search to occur. A highly satisfied household may search if it perceives that the expected benefits from relocation exceed costs.

Cronin (1978) presents some interesting data on the relationship between level of satisfaction with current housing and search propensity. Using survey data of renter households from the Housing Allowance Demand Experiment of the U.S. Department of Housing and Urban Development, which queried households on satisfaction, Cronin does find that expressed level of satisfaction is inversely related to the percentage of households searching within one year of the interview. However, 31% of "very dissatisfied" households did not search, and 33% of "very satisfied" households searched within the year following the survey. This type of behavior cannot be accounted for in the sequential model of figure 2.3.

The work of Speare et al. (1974) rectifies the logical problem of dissatisfied households' not searching. They propose a three-stage model: (1) the development of a desire to consider moving; (2) the selection of an alternative location; and (3) the decision to move or stay. Although the model is similar to that of Brown and Moore (1970), there are two important differences. First, either of the latter two stages may take precedence. Second, the model incorporates a rational cost-benefit decision calculus in the decision to move or stay. Thus dissatisfied households may opt not to search if the expected gains do not exceed costs. While this partially refines the logical problems of the Brown-Moore model, dissatisfaction is still a necessary condition for search to occur. The model precludes the possibility that external housing market opportunities may induce satisfied households to move.

Two other shortcomings of psychological models of relocation should be noted. First, income constraints are not explicitly incorporated in the models. The nebulous concept of "housing needs" is the yardstick for measuring satisfaction. In contrast to the economic concept of demand that is functionally dependent on price and income through constrained utility maximization, the concept of housing needs conceals those constraints operating in the decision process. Second, there is considerable difficulty in translating the conceptual models into empirical ones that may be used for hypothesis testing.

Clark and Cadwaller (1973) have attempted to operationalize crudely the concept of locational stress stimulating the decision to move. Households were surveyed to evaluate their present satisfaction level (from very dissatisfied to very satisfied) on five factors related to size of dwelling, access to work and friends, kind of people in neighborhood, and air pollution. They were also queried on the degree of difficulty involved in finding a desirable alternative location for each of the five factors. Locational stress was measured by an index for which the greatest amount of stress is experienced when a very dissatisfied household thinks that finding better housing elsewhere is easy. Clark and Cadwaller do find their measure to be significantly correlated with a household's expressed desire to move. However, the results are ambiguous since there is no way to relate expressed desire to move to actual search and/or move. Speare et al. (1974) mathematically specify their three-stage model by listing arguments of logistic functions. The logit model for the decision to consider moving is expressed as follows:

$$P_c = (1 + \exp(k(S-t)))^{-1}, \tag{2.1}$$

where

P_c = the probability of considering moving;
S = residential satisfaction of the current residence;
t = threshold for dissatisfaction;
k = estimated parameter.

The decision to relocate to particular submarkets is represented by the following conditional probability model for dissatisfied households considering moving:

$$p_{m/c} = K(S_d - S_o) - C, \tag{2.2}$$

where

$P_{m/c}$ = the probability of moving for those who consider moving;
S_d = expected level of residential satisfaction at destination;
S_o = residential satisfaction at origin;
C = cost of moving;
K = conversion factor between satisfaction and costs of moving.

The unconditional probability of moving under the assumption of independence between (2.1) and (2.2) is simply expressed as $P_m = P_c \times P_{m/c}$. The models (2.1) and (2.2) were not themselves estimated. Rather, Speare et al. (1974) perform a path analysis relating several demographic and housing consumption variables to a residential satisfaction index, the desire to move, and observed mobility behavior. While the path analysis provided no direct empirical support for (2.1) and (2.2), it did provide some explanation for the inconsistent empirical findings from survey models relating household characteristics to observed movement propensities. Their results suggest residential satisfaction to be an intervening variable influenced by both household and dwelling variables. Since household attributes may also influence a household's perception of the costs and benefits from moving, the net association between household attributes and mobility may be quite variable.[3]

2.2.3. Microbehavioral Models of Relocation: Simultaneous Decision Processes

A most questionable assumption in most psychological models of relocation is the discrete separation of the decision to search and the search process itself. Smith et al. (1979) have theoretically developed a search model of relocation that integrates the two processes. Their model is founded on the rational decision-making behavior of households under uncertainty. A schematic representation of the model is shown in figure 2.4. At any time households are assumed to be utility maximizers in their choice of daily consumption activities. Housing consumption is assumed to be fixed in this short-run period. A conditional indirect utility function is derived from constrained utility maximization as $V = V(p, Y\text{-}M, X)$, where p is the price of a single nonhouse commodity, Y is total income, M is an expenditure flow for housing, and X is a composite variable reflecting housing services. Each household is assumed to have a set of beliefs concerning the nature of housing possibilities in neighborhoods ($i = 1, \ldots, N$) represented by a subjective joint probability distribution $F_i(X,M)$ of housing service and cost. The decision to search is initially reached by comparing the expected utility search to be undertaken with that of the current situation. The expected utility of searching is functionally related to the household's perceived probability distribution of housing possibilities $F(X,M)$ and the probability that it may lose a prospective house to other bidders. Under the assumption that households attempt to maximize expected utility, search will occur when the expected utility of search exceeds the utility of the best alternative available for certain. Initially this certain alternative is the current housing. The locational component of the relocation process is integrated with the decision whether to search by treating the rational household as choosing to search the neighborhood giving rise to the *highest* net expected utility. The actual search process is treated in a series of sequential decision periods during which the ex-

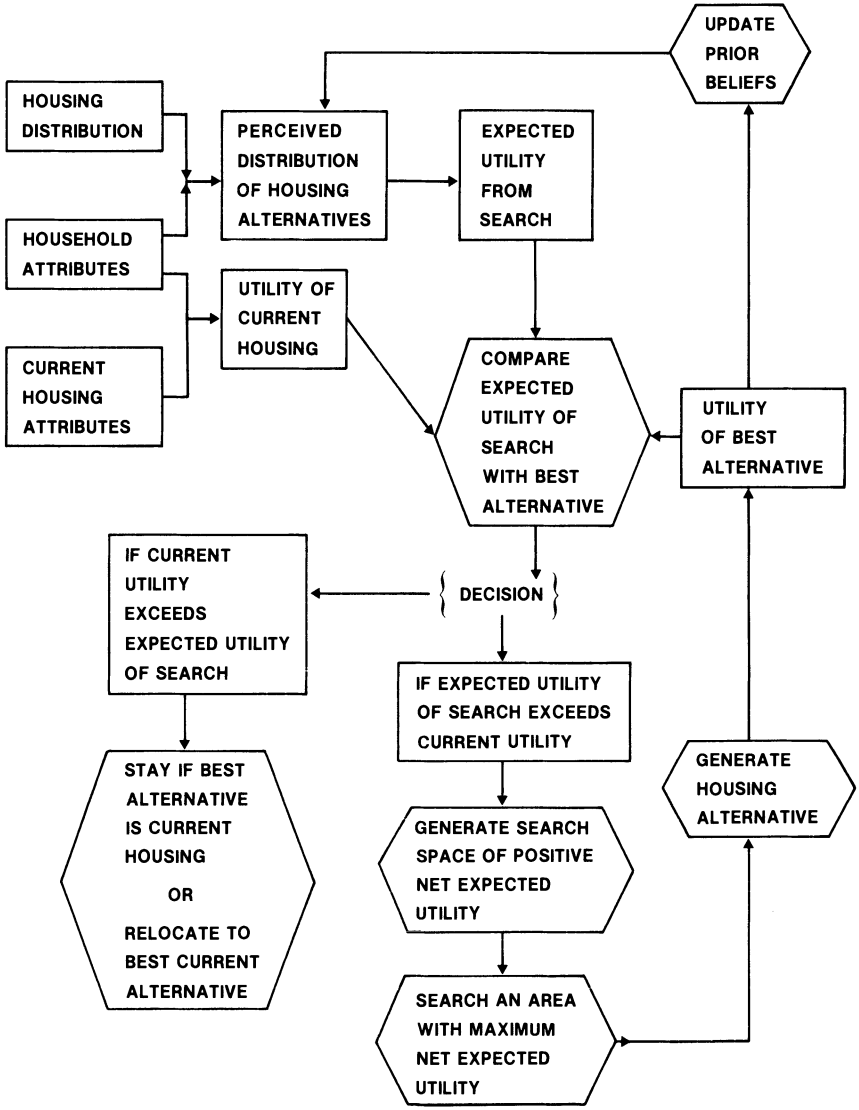

Figure 2.4. A Schematic Representation of the Relocation Model of Smith et al. (adapted from Smith et al., 1979)

pected utility of continued search is compared with the best alternative recallable from previous searches.

The model of Smith et al. (1979) is of interest not only because of its integration of the decision to search and the search process into a single process, but also because its mathematical formulation leads to behavioral implications that might be empirically testable in the future. For example, the structure of the model implies that there is a critical reservation utility level such that when a vacancy is found offering this level, search will cease. Although this result stems from expected utility-maximizing behavior under uncertainty, the ex post result is similar to the result of "satisficing" behavior in the model of Brown and Moore (1970). They also show that the probability of continued search varies positively with levels of net expected utility and inversely with the probability of losing an alternative to other bidders. In simpler terms this would suggest that continued search is more likely the more a household's current housing is in disequilibrium, and less likely when tight market conditions create a seller's market. Finally, they remark that it may be shown that critical reservation levels of utility rise with wealth and initial utility level and that the probability of search will rise accordingly with these factors.

On a theoretical level the model of Smith et al. (1979) is mathematically rigorous with rich implications. Whether the model can be directly implemented with empirical data is not clear. The subjective probability distributions that play a major role in the model may be very difficult to construct empirically. The authors claim to be pursuing the task of empirical implementation at this time. Whether this can be done without a severe compromise of the model's theoretical integrity remains to be seen.

2.2.4. Microbehavioral Models of Residential Mobility

In recent years economists have devoted greater attention to the study of residential mobility as a response to "housing consumption disequilibrium." This discussion will focus primarily on the models of Hanushek and Quigley (1978) and Cronin (1978) as representative works of the recent literature that includes the works of Hanushek and Quigley (1979), Cronin (1979), Goodman (1976), Weinberg et al. (1981), and Mark et al. (1979).[4] The basic premise of these models is that relocation costs of the monetary and nonmonetary variety preclude households from continually adjusting their consumption of housing over time in the course of demand shifts. Whereas "equilibrium" housing consumption is defined as the utility maximizing consumption that would be chosen by households in a frictionless world of costless mobility, housing consumption in the short run may deviate from optimal levels due to relocation costs and thus produce "housing consumption disequilibrium." The basic hypothesis of economic mobility models is that the probability of moving is positively related to the degree and composition of housing consumption disequilibrium.

Hanushek and Quigley (1978) develop several versions of a mobility model in which the probability of moving over some time period t to t+1 (represented as M_t) is a function of the disequilibrium gap between equilibrium and current consumption of housing. The simplest specification is

$$M_t = f(|H^d_{t+1} - H_t|; C), \tag{2.3}$$

where H^d_{t+1} is the equilibrium housing consumption demanded at the end of the period; H_t is the current housing consumption; and C is search and transaction costs. In a more complex formulation, the total disequilibrium measure in (2.3) is decomposed into two parts: (1) initial disequilibrium and (2) the change in equilibrium consumption over the period t to t+1. Initial disequilibrium is defined as $|H^d_t - H_t|$, or the gap between equilibrium and current housing consumption at the beginning of the period. The second component is the disequilibrium due to changed equilibrium demand due to factors such as income shifts and changed family size and is denoted as $|H^d_{t+1} - H^d_t|$. Finally, two additional versions of (2.3) are specified to account for possible "ratchet effects" in housing consumption disequilibrium—that is, households may be more sensitive to underconsuming than overconsuming housing. The absolute value measures of disequilibrium in (2.3) and its expanded version are divided according to algebraic sign for the latter two models.

Housing service is treated in the model as a single-valued homogeneous service commodity in the context of the long-run, perfectly competitive housing market theory of Olsen (1969).[5] Thus housing consumption is measured in all specifications in terms of annual housing expenditures. "Equilibrium" housing consumption demands at any time, or (H^d_t, H^d_{t+1}), cannot be directly observed. They are operationally defined by housing demand models estimated by regressing the housing expenditures of *recent mover* households on their social, economic, and demographic characteristics. This is done under the premise that recent movers exhibit utility-maximizing levels of housing expenditures. The assumption, of course, is that households do not adjust their consumption in anticipation of future equilibrium demand. Data on moving costs were unavailable. The distribution of these costs was assumed to be normally distributed and independent of the level of disequilibrium. Under this assumption all models were estimated under probit model specifications.[6] While the empirical results for the simplest model of (2.3) were only weakly supportive of the disequilibrium hypothesis, the expanded models supported the premise that changes in equilibrium demand, particularly those leading to underconsumption, induce mobility. At mean movement probabilities, a 10% increase in equilibrium demand increases the probability of moving 9-15%.[7]

Cronin (1978) has developed an economic model of intraurban mobility similar to Hanushek and Quigley's in the sense that the probability to move is related to disequilibrium. The measure of disequilibrium, however, is different. The "income equivalent value," or the amount of additional income necessary to make a household as well off with its current consumption of housing as it would be if it were to consume its equilibrium quantity of housing services, is used as a measure of the perceived benefits of moving. The long-run competitive market concept of housing service was also invoked by Cronin (1978), and equilibrium demand was estimated via the housing expenditures of recent mover households. Logit models were estimated for three processes: (1) the probability of searching, (2) the probability of moving, and (3) the probability of moving given search.[8] Defining M_t as the probability that a household will move over a time period, the basic mobility model estimated is

$$M_t = (IEV, DEM, MOVCOSTS, IDSS, SOCBONDS, PMOB). \qquad (2.4)$$

IEV is the income equivalent value of equilibrium consumption. *MOVCOSTS* is used here to represent three separate moving costs variables: (1) the estimated annual tenure discount from long-term occupancy foregone by moving, (2) predicted search days, and (3) predicted monetary costs.[9] DISS is comprised of dummy variable classifications of household responses to their level of dissatisfaction. *SOCBONDS* is an index of the strength of neighborhood social bonds that may impede mobility. *PMOB* is a set of dummy variables indicating the number of previous moves in the last three years. *DEM* is used here to represent demographic variables such as age of head of household and household size.

The empirical results consistently supported the hypothesis that search and movement were significantly related to the income equivalent value of equilibrium consumption. The signs of the moving cost variables were variable and often inconsistent with theoretical expectations. Dissatisfaction was only found to be positively related to search but not movement. Previous mobility had a significant positive impact on search and movement probabilities only when household demographic characteristics were left uncontrolled. Overall, the results did, however, support the hypothesis that households respond to the economic benefits of adjustment and are impeded by moving costs in the mobility decision.

The most significant element of microeconomic mobility models is their treatment of mobility as a dynamic process of housing consumption adjustment. Movement propensities are explicitly related to disequilibrium. However, they are classified as mobility models in this typology because of the lack of explicit attention given to the location component of the relocation process. One may argue that by the use of "equilibrium" consumption in the definitions of disequilibrium they are relocation models. This is only true to the extent that the conceptual device of housing service and hence expenditures is accepted as a meaningful and useful measure of housing consumption in the context of relocation. It has become common practice to invoke the concept of housing service in the demand models used for estimating income and price elasticities of housing consumption. Yet by invoking the concept one must also accept the assumption of long-run equilibrium in a perfectly competitive housing market. Otherwise a single unit price of housing service cannot prevail, and dwellings commanding the same rent may not produce the same flow of housing service. It is questionable why Hanushek and Quigley (1978) reject the long-run equilibrium models of housing consumption in light of movement costs and later implicitly invoke the assumption for recent movers. This would seem to produce a rather curious market situation in which 20% of households (i.e., recent movers) are governed by the same long-run equilibrium prices as the remaining 80% of households in disequilibrium.

A second issue regarding the use of the housing service concept is that all dwellings commanding the same market rent must be treated as perfect substitutes by households. Realistically it is plausible that households may have different demand elasticities for particular housing attributes such as size and quality. This point is relevant given the comment of Mayo et al. (1979) that the benefits of moving low-income households tend to be quite small. Using an estimated price elasticity of -0.22, the income equivalent value of a 40% price rebate ($60/month) to a household initially spending $150/month would be only about $3/month. They also note in contrast that the costs of moving are considerable and that cost variables consistently explained more variation in mobility rates than did benefit measures. Mayo et al. (1979) attribute the latter point to variations in local housing market conditions that are reflected in expected search time and tenure discounts. They do not fully address the former point, which would suggest that many moves may be irrational in the sense that benefits are small relative to costs. A plausible explanation might be that although rent differentials may be small, household demand for *particular* residential attributes may be far from its equilibrium demand. The invocation of housing service and expenditure analysis precludes the investigation of whether housing attributes mix matters in relocation.

2.2.5. Microstatistical Models of Residential Mobility

Huff and Clark (1978) have developed a model of residential mobility that integrates the independent trials process of statistical Markov models (Clark, 1972), the cumulative inertia hypothesis of McGinnis (1968), and the stage of life cycle aspects of the early residential mobility literature. In Markov models waiting times between moves are assumed to be geometrically distributed, so that prior residential history and duration of stay in the current residence have no impact on the probability of moving. Alternatively, the cumulative inertia hypothesis posits that the probability of moving declines with increasing duration of stay in the current residence. The life cycle hypothesis states that the probability of moving is normally quite low, but increases sharply in transitions between life cycle stages. None of these hypotheses is likely to capture the full essence of mobility response over time. Duration of residence studies (Land, 1969; Morrison, 1967) contradict the Markov assumption. Clark and Huff (1977), however, presented evidence that although time dependencies do exist, the monotonically decreasing relationship between mobility and length of residence in the cumulative inertia hypothesis does not consistently hold as well. Finally, the life cycle concept is burdened with ambiguities about the points at which stages or transitions between stages are relevant.

The model of Huff and Clark (1978) is built on the initial assumption that the probability to move during a short time period $P(t)$ is proportional to the differences between the household's stress level $S(t)$ and its resistance to moving $R(t)$. The probability of moving is greater than zero only if $R(t) < S(t)$. The remaining model development lies in assumptions concerning how $S(t)$ and $R(t)$ change over time and between moves. Duration of residence effects are approximated by an exponential decay function over time in $R(t)$. Stress level is also assumed to increase at a constant rate and is also represented by an exponential function. The impact of moves on subsequent mobility is incorporated by allowing stress and resistance levels to change after a move. Life cycle effects are incorporated by stratifying households into subpopulations and allowing households to move between subpopulations over time.

The major contribution of Huff and Clark (1978) obviously lies in their integration of life cycle and duration of residence effects within a probability model of mobility. In contrast to earlier psychological models of mobility that view movement *solely* as a response to increased stress, the model explicitly incorporates the role of relocation costs with the resistance function $R(t)$. The major shortcoming of the model is its treatment of the movement decision as a discrete and separate process from the choice of new residence. Also Huff and Clark (1978) describe the model as behavioral. While it may have behavioral content, it provides no explanation of the mobility process itself. Stress and resistance functions are treated as "black boxes" in the model, with temporal relations that are not founded on behavioral processes. To fully understand residential mobility, we need to understand the determinants of stress and resistance. Nevertheless, the work of Huff and Clark (1978) has clarified some of the confusion over the elements affecting timing of moves.

2.2.6. Microbehavioral Models of Residential Location

In accord with the discrete separation of the residential location process into two independent processes, the residential location decision has been an area of study distinct from residential mobility. Behavioral models of residential location have been founded on the implicit assumption that either all households are immigrants to an urban area without a current residence or that households may freely, costlessly, and instantaneously locate anywhere, so that prior residence does not matter. Although variants exist in the literature, the traditional models of Alonso (1964), Wingo (1961), and Muth (1969) characterize the general theoretical perspective of the bulk of the behavioral residential location models.[10]

The traditional models all rest on an explicit set of common behavioral assumptions regarding the trade-off of housing and work trip expenditures in an urban area with a monocentric workplace. Under the assumption of long-run equilibrium in the residential land/housing market, all households are typically assumed to have a utility function $U(H,X)$ separable into single-valued homogeneous good of "housing" H and a composite good of all other goods and services denoted as X. Under the monocentric workplace and long-run equilibrium assumptions of competitive bidding for locations, the unit price of housing $P_H(d)$ should decline with increasing distance from the employment center.[11] In accord with conventional microeconomic models of utility maximization, households are assumed to maximize utility subject to a budget constraint Y encompassing expenditures for housing $P_H(d)H$, expenditures for other goods and services $P_X X$, and commuting expenditures $c(d,Y)$ that are a function of distance d and income Y due to value of time. Imposing the usual first-order marginal conditions of the constrained maximization problem leads to the major behavioral implications, shown in (2.5),

$$-\frac{\partial P(d)}{\partial d}H = \frac{\partial c(d,Y)}{\partial d}, \tag{2.5}$$

that households will choose that location in which the marginal savings in housing expenditures from locating incrementally farther from the employment center equal the additional increment of transportation costs.

The forte of these models is the insight imparted in their theoretical explanation of the household's consumption/location equilibrium. They also provide the basic impetus for the development of the "new urban economic" modeling approach.[12] However, their static nature, the monocentric workplace assumption, and the long-run equilibrium abstraction in which housing is treated as a single-valued homogeneous good have drawn considerable criticism in recent years. Aside from the obvious unrealism of the monocentric workplace assumption (which provides analytical tractability), Straszheim (1975), Kain and

Quigley (1975), and Whitehead and Odling-Smee (1975) have forcefully argued that the extreme durability of the housing stock, high costs of physical transformation, lags in new construction, and the significance of substantial relocation costs suggest that the powerful assumption of long-run equilibrium, with the invocation of the conceptual device of housing service, is widely at variance with reality.

Recent works have grappled with some of the unrealistic elements of the traditional models. For example, the works of Papageorgiou (1976) and Romanos (1976) have departed from the monocentric workplace assumption by introducing multiple employment centers. The emerging dissatisfaction with the "workplace dominance" assumption, echoed in the work of Ellis (1967), Oates (1969), Ellickson (1971), Barr (1973), Polinsky and Shavell (1973), Little (1974), and Stegman (1969), has led to a greater emphasis on the importance of neighborhood environmental amenities in residential location. Straszheim (1975) and King (1975) have relaxed the assumption that housing be treated as a single-valued homogeneous good. Rather, households are treated as choosing an "optimal" bundle of individual housing attributes $U(H_1 \ldots, H_n, X)$ in a constrained utility maximization framework. Richardson (1977a) offers a more general model that not only accounts for multiple employment centers and neighborhood environmental amenities but also for nonwork trips, constraints imposed on locational choice by search and information costs, and the limited supply of dwellings available for occupancy at any time.

Although the greater realism in these latter works has imparted some new insights (such as the possibility of positively sloped bid rent curves [Richardson, 1977b]), these works also expose the analytical inoperability of the conventional microeconomic approach when many of the unpalatable assumptions of the traditional models are relaxed. In contrast to the simple and elegant implications of the former traditional models, the introduction of greater realism often precludes the attainment of meaningful closed form analytic solutions. From a theoretical perspective, abandonment of the long-run equilibrium conceptual device of housing service requires that the discrete multidimensional heterogeneity of housing be more carefully addressed. In the conventional microeconomic formulations of Straszheim (1975) and King (1975), households are treated as choosing particular housing attributes *individually* in the utility-maximizing framework. The aggregation of these individual attributes form the "optimal" housing bundle. However, because of the localization of housing and the indivisibility of attribute bundles, households may not purchase attributes individually, nor in divisible quantities. Rather, households must choose among *discrete* bundles of housing services. These shortcomings point toward the need for a theoretically grounded model that is both empirically operational and capable of addressing the discrete heterogeneity of housing bundles.

The recent works of Quigley (1976) and Williams (1979) explicitly address the discrete heterogeneity of a highly durable housing stock. The monocentric employment center assumption is abandoned, but the trade-off between transport costs and housing expenditures is retained. Under the assumptions that households (1) have a fixed workplace with inelastic demand for work trips, (2) can compute monetary and time costs of work trips, and (3) have knowledge of the schedule of all market prices for all housing types (differentiated by dwelling attributes), Quigley (1976) analytically separates the location decision into two choices.

With knowledge of market prices, households can compute the total "effective" costs of each house type at each location as the sum of transportation costs from their workplace to that location and the market price of the house type at that location. In the first of the two choice processes, the optimal location for any particular house type is determined as the minimum "effective" cost for that house type:

$$P^*_{ijy} = \min_m [P_{ijym}] = \min_m [R_{im} + T_{jmy}], \tag{2.6}$$

where

R_{im} = (monthly) price/rent of housing type i at site m;
T_{jmy} = (monthly) cost of commuting between workplace j and residence site m for households with income y;
P_{ijym} = total (monthly) cost of housing type i at location m for households with income y;
P^*_{ijy} = the effective minimum price of consuming housing type i for households with income y and work site j.

This cost-minimizing calculus yields a subset of optimal locations with one location for each house type. From this optimal subset, households are assumed to undertake a second utility-maximizing process of choosing among housing types on the basis of attributes of the discrete house types and their "effective" total costs. The formal model is based on stochastic utility theory (McFadden, 1973). Households with income y and demographic characteristics a are assumed to possess a mixed direct-indirect utility function for a vector of residential attributes and prices of house types i (denoted as $\mathbf{X}_i$ and P^*_i) that is comprised of two components: (1) a nonstochastic component reflecting representative preferences of the household class and (2) a stochastic component reflecting unobservable idiosyncracies of households.

$$U_{ya}(\mathbf{X}_i, P^*_i) = W_{ya}(\mathbf{X}_i, P^*_i) + \epsilon_{ya}. \tag{2.7}$$

Households are assumed to be deterministic utility maximizers, so that the probability that a household of a particular class (y,a) will choose house type i (i.e., Prob$[i|ya]$) is expressed as the probability that the utility of house type i exceeds that of all other house types. Conventional assumptions concerning the distribution of stochastic utility components produce the multinomial logit model.[13]

$$\text{Prob}(i|ya) = \frac{\exp W_{ya}(\mathbf{X}_i, P_i^*)}{\Sigma_j \exp W_{ya}(\mathbf{X}_j, P_j^*)}. \tag{2.8}$$

The obvious strengths of Quigley's model lie in its theoretical foundation, abandonment of the monocentric workplace assumption, and its explicit treatment of the discrete heterogeneity of housing. It does provide an explanation of residence choice that is lacking in mobility and past relocation models. However, the analytic separation of the location choice into two sequential choice processes is questionable in light of the localization of housing and the capitalization of housing services in market prices. Because of localization, environmental and public service attributes of the locational neighborhood are encompassed within the heterogeneous bundle of housing and should be capitalized in market prices. Unless all locational neighborhood attributes are homogeneous over an urban area, the cost minimization calculus of the first decision process is meaningless, as "equivalent" bundles are not being compared.

The weakness of the sequential choice process is rectified in the nested logit model of residential relocation of McFadden (1978). Under the assumption that the households have a mixed direct-indirect utility function that is linearly separable into attributes that vary only by location and attributes that vary with both dwelling and community, the simultaneous dwelling-location choice may be analytically separated into sequential decisions in a manner that is logically consistent. Assume the utility function $U_{ya}(\mathbf{X}_{im}, \mathbf{Z}_m, P_{ijym}) = W_{ya}(\mathbf{X}_{im}, \mathbf{Z}_m, P_{ijym}) + \epsilon_{ijyam}$, where $\mathbf{Z}_m$ is a vector of location-specific attributes and $\mathbf{X}_{im}$ is a vector of dwelling attributes by location. All other symbols conform to those in (2.6) and (2.7). The probability of choosing location m is[14]

$$\text{Prob}(m|yaj) = \frac{\exp W'_{ya}(\mathbf{Z}_m)\,(\Sigma_i \exp W'_{ya}(\mathbf{X}_{im}, P_{ijym}))}{\Sigma_m \exp W'_{ya}(\mathbf{Z}_m)\,(\Sigma_i \exp W'_{ya}(\mathbf{X}_{im}, P_{ijym}))}, \tag{2.9}$$

and the probability of choosing house type i conditional on m is then written

$$\text{Prob}(i|m,yaj) = \frac{\exp W'_{ya}(\mathbf{X}_{im}, P_{ijym})}{\Sigma_i \exp W'_{ya}(\mathbf{X}_{im}, P_{ijym})}. \tag{2.10}$$

Multiplying (2.9) by (2.10) yields a simultaneous model of dwelling-location choice of the multinomial logit form.

The discrete choice models of Quigley and McFadden are important contributions to the residential location literature, but they still share the fundamental weakness of providing but a "snapshot" of locational equilibrium. As a result, all residential locators or movers must be treated as *exogenous* to the models since their prior residence, or consumption of housing, is assumed to be irrelevant in the residential location process. However, prior housing consumption/residence location should influence the locational choice in the simple sense that households are unlikely to choose a residence that is a near-perfect substitute for their prior residence since they must bear relocation costs of both the monetary and nonmonetary variety. Unless households are "de novo" to an urban area without prior residence, an explanation of location may not be logically separated from the explanation of the movement decision; these interdependent dimensions of the relocation process should be jointly addressed.

2.3. MACROLEVEL MODELING PERSPECTIVES

2.3.1. Macrostatistical Models of Residential Mobility

The works of Moore (1969, 1971) and Johnston (1969) are representative of macrolevel ecological models of residential mobility. Their development has taken two major directions: (1) the detection of regularities in the spatial variation of aggregate population turnover rates with distance from the center of a mononuclear city; and (2) investigation of associations between aggregate demographic, socioeconomic, and housing stock characteristics of spatial units with population turnover and mobility rates. The basic assumption of the former approach is that population turnover is a function of population density as surrogate of many factors related to movement propensities embodied in spatial development patterns of mononuclear cities. Denoting the turnover rate at some distance d from the city center as $T(d)$ and L as a threshold level of turnover that is independent of d, the following function explained about 58% of the variance in turnover rates in Brisbane, Australia (Moore, 1971):[15]

$$T(d) = \alpha \exp(-\beta d)(1 + \beta d) + L. \tag{2.11}$$

The second approach relates turnover rates to economic, demographic, and housing variables by regression and path analysis techniques. The empirical results suggested reasonably strong associations of turnover rates with the proportion of single adults, proportion of single-family units (negative), and percentage of Australian-born population (negative). However, path analysis in Moore

(1969) and partial correlation analysis in Moore (1971) suggested that much of the associations were due to a common association with accessibility (distance) and did not add much to the explanation of turnover rate variance explained by (2.11).

The empirical performance of ecological/statistical models has been unsatisfactory. Moore (1971) notes, "It is shown that when attempts are made to model patterns of population turnover in a mononuclear city, regression analyses have little impact either in terms of producing reliable short-run predictions or in identifying ecological relations which are of value to the urban theorist or planner" (Moore, 1971, p. 84). As purely descriptive statistical models without behavioristic content, these works provide little insight into the mechanisms underlying the residential relocation process. They provide at best a parsimonious empirical description of the dynamic stability of aggregate residential spatial structure.

2.3.2. Macroheuristic/Analogue Models of Residential Location

Classical ecological models of residential location emerged from the theoretical perspective of "human ecology," in which the economic competition for space creating land use patterns is treated as analogous to ecological processes of invasion and succession in plant and animal communities. While the spatial element of urban form varies in the works of Park et al. (1925) (concentric zonal residential land use), Hoyt (1939) (sectoral land use), and Harris and Ullman (1945) (multiple nuclei), they share a common growth-oriented residential succession description of urban form.[16] Although these classical models of urban growth may have imparted some insight into the historical patterns of urban residential development, the ecological analogies of "invasion" and "succession" in themselves impart little understanding of the behavioristic elements underlying the residential location process. Their verbal description of urban form and its change are too simplistic for understanding the complex systemic process of residential relocation in modern urban areas.

The works of Wilson (1969, 1970) are representative of the macrolevel systemic perspective of residential location modeling. The foundation of the elementary residential location model of Wilson is based both on analogy and the theory of statistical mechanics. The analogy is built on the physical science treatment of analyzing the macroproperties of a gaseous system of a huge number of interacting gas molecules. The entropy maximization model is derived in terms of microlevel *states* and mesolevel *distributions* of a system and also macrolevel *constraints*. In the context of residential location a microlevel state of the system is defined as an assignment of *individual* workers to a two-way table of workplace zones and submarkets defined by house type and location zone. The *total* number of individuals assigned to all workplace-submarket pairs constitutes a mesolevel distribution of the system. Numerous states of individual microlevel assignments can give rise to any single mesolevel distribution.[17] Under the assumption that all microstates are equally probable, the objective of entropy maximization procedures is to find the most probable mesolevel distribution (i.e., that distribution with the greatest number of microstates associated with it), subject to any macrolevel constraints imposed on the system.[18]

Although more complex disaggregated models are described in Wilson (1970, 1974), the basic entropy model incorporates three fundamental types of macrolevel system constraints: (1) the sum of workplace-residence flows from a workplace zone i must equal the total number of jobs in that zone; (2) the sum of workplace-residence flows to a submarket must equal the total number of houses in that submarket; and (3) the total generalized expenditure on work travel must equal the total generalized costs of the system. In simplest terms the objective is thus to find the most probable distribution of workplace-residence flows that satisfies aggregate marginal distributions of employment and housing stock and also the total cost constraint. A general statement of the entropy maximization model of residential location may be formalized after supplying the following definitions:

T_{ijwk} = the number of households of income group w whose head of household works in zone i and resides in residence zone j in house type k;
H_{jk} = the total number of houses of type k in residence zone j;
E_{iw} = the total number of jobs in work zone i offering income w;
C_{ij} = the generalized journey-to-work cost between work zone i and residence zone j;
c'_{ij} = money component of journey-to-work cost between work zone i and residence zone j;
C^w = the total generalized cost of work travel.
q^w = the average percentage of income (after transport costs have been deducted) that a household of income w spends on housing;
p^k = the price of house type k in residence zone j;
σ_w^2 = the variance of the normal distribution of housing expenditures to the mean level for income class w.

With these definitions the formal mathematical programming statement of the entropy location model is[19]

$$\max \ln S = \frac{\sum_i \sum_j \sum_k \sum_w T_{ijwk}!}{\Pi_{i,j,k,w} T_{ijwk}!} \tag{2.12}$$

subject to the constraints

$$\sum_{i}\sum_{w} T_{ijwk} = H_{jk} \quad \forall j,k, \tag{2.13}$$

$$\sum_{j}\sum_{k} T_{ijwk} = E_{iw} \quad \forall i,w, \tag{2.14}$$

$$\sum_{i}\sum_{j}\sum_{k} T_{ijwk} C_{ij} = C^{w} \quad \forall w, \tag{2.15}$$

$$\sum_{i}\sum_{j}\sum_{k} [p_j^k - q^w(w-c'_{ij})]^2 = \sigma_w^2 \quad \forall w. \tag{2.16}$$

The right-hand side of (2.12) is the entropy or the combinatorial formula of possible assignments of states.[20] Equations (2.13) and (2.14) are the marginal distribution constraints of houses and jobs. Equation (2.15) is the total generalized cost constraint. Equation (2.16) is added as a constraint to ensure that households of an income class w are assigned houses compatible with their income. $(w-c'_{ij})$ is the income left after deducting monetary costs of commuting. $q(w-c'_{ij})$ is the expected housing expenditures for household class w. Equation (2.16) ensures that the variance of $[p_j^k - q(w-c'_{ij})]$ is equal to σ_w^2 for each income class. This allows households to deviate within limits from a mean level of housing expenditures. Wilson (1970) has demonstrated that the solution to (2.12)-(2.16) yields the following model:

$$T_{ijwk} = A_{iw} E_{iw} B_{jk} H_{jk} \exp(-\beta C_{ij}) \exp(-\mu^w [p_j^k - q^w(w-c'_{ij})]^2). \tag{2.17}$$

A_{iw} and B_{jk} are "balancing factors" ensuring satisfaction of (2.13) and (2.14) with the following mathematical definitions:

$$A_{iw}^{-1} = \sum_{j,k} B_{jk} H_{jk} \exp(-\beta C_{ij}) \exp(-\mu^w [p_j^k - q^w(w-c'_{ij})]^2), \tag{2.18}$$

$$B_{jk}^{-1} = \sum_{i,w} A_{iw} E_{iw} \exp(-\beta C_{ij}) \exp(-\mu^w [p_j^k - q^w(w-c'_{ij})]^2). \tag{2.19}$$

The entropy model exhibits several important structural features that are critical to the development of a macrolevel model of residential relocation. Although the model is not founded at the microlevel of individual households, it is disaggregated in the sense that households may be segmented into groups or classes that are relatively homogeneous on the basis of household attributes that affect residential location behavior. In light of the variations in household preferences, tastes, and budgets that affect housing consumption, it is essential that these differences be explicitly accounted for in the explanation of residential relocation. It also is not burdened by the monocentric employment assumptions of the microlevel models discussed earlier.

Two other important structural features of the model are its (1) structural consistency and (2) the interdependence among all household group location flows. By way of the exogenously imposed summation constraints in the mathematical programming model, the so-called balancing factors A_{iw} and B_{jk} ensure structural consistency upon aggregation between expected household group location flows and aggregate employment and housing distributions over zones. All households of each income group in every employment zone are allocated to residences, and all available housing stock of every type and residence zone is occupied. The more interesting feature is the explicit structural *interdependence* among all household group flows exhibited in the mutual interlocking simultaneous definitions of A_{iw} and B_{jk} in (2.18) and (2.19), respectively. Through these systemic factors, exogenous changes in the spatial distribution of employment (by income level), housing stock (by type), or generalized transport/housing costs would generate a complex redistribution of all expected household workplace-to-residence location flows.[21]

While the systemic interdependency among household class location flows in (2.17)-(2.19) is strongly suggestive of an underlying market mechanism, the entropy model is burdened with some fundamentally logical problems. In a sense these problems arise because the analogy between gas molecules in a closed system and human spatial interaction is not very good. The fundamental weakness of the entropy approach stems from the questionable *exogenous* imposition of constraints (2.13), (2.15), and (2.16) in the mathematical programming formulation (2.12)-(2.16). None of these constraints is *causally* binding. While E_{iw} may be legitimately treated as exogenous under a "workplace dominance" assumption that is characteristic of behavioral location models, H_{jk} should logically be the result of locational choices and supply response within the static market framework of residential location. The location of dwellings is exogenously supplied, and prices are exogenously determined prior to household assignment. Economic theory would suggest that both are *outcomes* of the market process. Note also that the total generalized costs of travel C^w and the mean percentage of household income spent on housing q^w are exogenously supplied. C^w and q^w again should be the *endogenous result* of locational choice.

The endogeneity of these costs is explicit in the microeconomic behavioral models of residential location of Alonso (1964) and Muth (1969), among others, discussed earlier. The constraints (2.13) and (2.15) in particular are really ex post accounting identities rather than causally binding constraints. The failure of the molecular analogy is most apparent here. In the statistical mechanics model analogy, the total amount of energy *available* to all gas molecules in a closed system (to which C^w is analogous) may indeed by predetermined exogenously—for example, by heating. Yet C^w should not be viewed as resources *available* to households for travel. It is actually the amount that households with volition *choose* to devote to travel. The exogenous treatment has serious implications for forecasting issues as well. The reader is referred to Hua and Porell (1979) for a more complete discussion of these matters.

More complex and comprehensive entropy models of residential location have been developed in recent years. Senior (1973, 1974) has provided a rather comprehensive review of recent developments.[22] Although these efforts have addressed many significant issues of disaggregation, relaxation of some static equilibrium assumptions, and empirical implementation, the entropy model (2.12)-(2.16) still remains the basic core of these efforts. The entropy maximization model provides an interesting approach to the study of residential location, but the exogenous specification of crucial market variables precludes its being much more than a descriptive statistical model.

2.3.3. Macroeconomic Equilibrium Models of Residential Location

The Penn-Jersey model of Herbert and Stevens (1960) is a macrolevel model grounded on the atemporal allocation of households to residential sites. It is classified here as an economic equilibrium model in light of the equivalence between the linear programming allocation of households to sites (via maximization of total bid rents, or aggregate rent-paying ability of households) and an allocation resulting from decentralized utility-maximizing behavior under price system.[23] By its dual formulation, the maximization of bid rents is equivalent to minimizing the actual aggregate rent paid by households, or indirectly the minimization of transport outlays, subject to household preferences for housing consumption. Thus the equilibrium allocation is established under maximization of consumer surplus of households. The linear programming solution establishes a "market-clearing" solution to the residential location of competing household groups. Formally, the primal allocation model of Herbert and Stevens (1960) may be expressed as follows:

$$\max Z = \sum_{k}^{U} \sum_{i}^{N} \sum_{h}^{M} X_{kih}(\mathrm{b}_{ih} - c_{kih}) \tag{2.20}$$

subject to

$$\sum_{i}^{N} \sum_{h}^{M} S_{ij} X_{kih} = L_k \qquad \forall k, \tag{2.21}$$

$$\sum_{k}^{U}\sum_{h}^{M} X_{kih} = N_i \qquad \forall i, \tag{2.22}$$

$$X_{kih} \geqslant 0 \qquad \forall k,i,h,$$

where

k = subscript denoting residence areas k=1, . . . , U;
i = subscript denoting household groups i=1, . . . , N;
h = subscript denoting residential bundle types h=1, . . . , M;
b_{ih} = the residential budget allocated by a household of group i to the residential bundle h;
c_{kih} = the annual cost to a household of group i of a residential bundle h in area k exclusive of site cost;
S_{ih} = the number of acres in site used by a household of group i for bundle type h;
L_k = the number of acres available for residential use in area k;
N_i = the number of households of group i to be allocated;
X_{kih} = the number of households of group i allocated to residential bundle type h in area k.

The problem dual to (2.20)-(2.22) is the minimization of total rents:

$$\min Z' = \sum_{k}^{U} r_k L_k + \sum_{i}^{N} v_i N_i \tag{2.23}$$

subject to

$$S_{ih} r_k - v_i \geqslant b_{ih} - c_{kih} \qquad \forall k,i,h,$$
$$r_k \geqslant 0, \quad v_i \geqslant 0 \quad \forall k,i, \tag{2.24}$$

where

r_k = the annual rent per unit of land in area k;
v_i = the annual subsidy per household for all households of group i.

The Herbert and Stevens (1960) model is quite interesting because of several important structural features. Although it is macrooriented in scale, it is disaggregated in the form of household groups. Also, because of the linear programming formulation in which the aggregate bid rents of *all* households groups are maximized subject to household group and land constraints, the location of household groups is inherently *interdependent.* At the same time the constraints ensure the structural consistency between land supply and location demand that is critical to an equilibrium allocation. Further, the dual variables r_k are endogenously generated in the dual formulation as shadow prices with the economic interpretation of land rents.

Aside from operational problems in the empirical implementation of the Herbert-Stevens model, important questions have been raised about the "equilibrium" solutions of the model that deserve comment. Wheaton (1974) notes that an "equilibrium" allocation of households to sites should satisfy the following basic conditions:

1. All households must be located somewhere.
2. Land supply and demand must balance.
3. Each household selects only one house in a zone that yields the highest net rent/acre.
4. Any located household must have a net land rent greater than or equal to the net land rent accruable to all households not located in that area.
5. Net land rents must be equal for all households located in the same area.

Only if all five conditions hold will no household have an incentive to locate elsewhere. In the Herbert-Stevens formulation (1) and (2) are satisfied through the constraints (2.21) and (2.20), respectively. Wheaton (1974) goes on to show that unless the dual "subsidy" variables in (2.23) and (2.24) are all effectively zero valued, (3)-(5) may not be simultaneously satisfied. Nonzero values of v_i arise because the household bid rents or residential budgets b_{ih} in (2.20) are *exogenously* supplied as inputs to the model (2.20)-(2.22). Unless these bid rents are true "equilibrium" bids, equilibrium conditions (3)-(5) are unlikely to be satisfied. Still, the model forces an allocation maximizing (2.20) and satisfying the constraints (2.21) and (2.22). There will always be as many nonzero allocations X_{kih} in the linear programming primal allocation as there are constraints. Thus with U residence areas and N household groups, $U + N$ of X_{kih} will be nonzero. To ensure satisfaction of (2.22), different household groups may have to be allocated to the same residence area. Since the same unit rent must be charged for all land units in an area, household groups with different levels of rent-paying ability must be provided "subsidies" that may be positive or negative.

The obvious root of the problem is the *exogenous* specification of bid rents in the model. In the original bid rent formulation of Alonso (1964), bid rents are not only a function of zonal characteristics but also utility levels. A family of bid rent curves should exist corresponding to different utility levels. Exogenous specification of bid rents is then equivalent to the exogenous predetermination of utility levels. Yet utility levels (and hence bid rents) should be the *endogenous* result of the competitive locational processes of all household groups. Wheaton (1974) has proposed an iterative procedure whereby the dual variables of the primal linear program are used to adjust residential budgets. A dummy household group whose bid rent is uniformly equal to the opportunity cost of land is added to transform the problem into a pure "transportation problem" of the operations research literature. Although convergence cannot be proved, Wheaton (1974) notes that convergence has readily been obtained in practice.

Although the modification of Wheaton (1974) would suggest that Pareto optimal equilibrium allocations may be obtained through the Herbert-Stevens framework, one is led to ask why we would want to obtain such an allocation. If the bulk of households seem to be in a state of housing consumption disequilibrium at any time, as suggested in the microlevel residential mobility literature (e.g., Hanushek and Quigley, 1978), any simultaneous long-run equilibrium of all households may bear little resemblance to reality. Under the premise that market imperfections make such long-run allocations unreasonable, Senior and Wilson (1974), Wilson and Senior (1974), and Anas (1973) have proposed "suboptimal" versions of the Herbert-Stevens model within the entropy maximization framework discussed earlier. In the versions of Senior and Wilson (1974) the maximand of the original Herbert-Stevens model is treated as a constraint with a prespecified value of Z. The model maximizes the entropy measure

$$S = -\sum_i \sum_k \sum_h \ln X_{kih}! \tag{2.25}$$

subject to (2.20)-(2.22) to yield

$$X_{kih} = A_i N_i \exp(-\beta_k S_{ih}) \exp[\mu(b_{ih} - c_{kih})], \tag{2.26}$$

where

$$A_i^{-1} = \sum_k \sum_h \exp(-\beta_k S_{ih}) \exp[\mu(b_{ih} - c_{kih})]. \tag{2.27}$$

Equation (2.27) ensures that (2.22) is satisfied, and β_k and μ are Lagrangian multipliers associated with (2.20) and (2.21).[24] Although the Senior and Wilson model can generate suboptimal allocations, its obvious theoretical flaw is that aggregate bid rents Z must be *exogenously* supplied as an input to the model. How one chooses a level of aggregate bid rents with legitimacy is questionable at best. Aggregate bid rents should be the *endogenous* result of the market competition of households for dwellings/sites. Thus it is not clear that the suboptimal version of Senior and Wilson improves on the earlier formulation of Herbert and Stevens (1960). Both models require exogenous specification of bid rents. However, in the Herbert-Stevens model aggregate rents are at least an endogenous result of the market.

2.3.4. Macroheuristic/Analogue Models of Residential Relocation

The traditional gravity model of spatial interaction has been utilized by Simmons (1974) in one of the few empirical modeling efforts analyzing spatial patterns of residential relocation.[25] The social gravity model was originally formulated by Zipf (1946) as an analogy to the Newtonian gravity law of physics. By analogy with the physical theory, the underlying hypothesis of the model is that the expected interaction (i.e., flow) between any two places is positively related to the generative and attractive characteristics of the two places and negatively related to the impedance or costs of interaction between them. Suppressing all parameters for notational simplicity, a general statement of the model in the context of residential relocation may be expressed as follows:[26]

$$I_{ij} = kV_iW_jF_{ij}, \tag{2.28}$$

where

I_{ij} = the relocation flow of households from place i to place j over a time period;
V_i = a generation index characterizing the origin place i;
W_j = an attraction index characterizing the destination place j;
F_{ij} = an index characterizing the facility of relocation between places i and j (or the inverse of the generalized relocation costs between place i and place j);
K = constant.

The social gravity model has drawn much criticism because of its lack of theoretical underpinnings and its gross level of aggregation. Although in principle the model may be applied to stratified household groups, empirical works such as Black (1972) suggest that better statistical predictions are generally obtained at higher (rather than lower) aggregation levels. The fundamental logical problem of the traditional gravity model is its independence of flows property. In (2.28) the relocation flow between any two places is *only* a function of variables describing those *two* places and a pair-specific linkage factor. The logic of the independence of flows assumption is incompatible with the concept of flow diversion. By (2.28) the expected flow between a particular pair of places is unchanged by exogenous changes in the characteristics of any third place in the residential system regardless of the location of the third place.[27]

The earliest consideration of the systemic interdependence of spatial interaction flows is found in the intervening opportunities concept of Stouffer (1940), who posited that the attenuating effects of distance (the common surrogate of spatial generalized relocation costs) in the F_{ij} term of the traditional gravity model (2.28) may not be due to distance at all. Rather he argued that distance effects actually reflected the absorbing effect of intervening opportunities that lie between an origin and potential destinations. In addition to Stouffer's original application to the study of residential relocation, the concept has found application to workplace-residence location (e.g., Schneider, 1969; Okabe, 1977). The original formulation may be expressed

$$I_{ij} = kW_j O_{ij}^{-\alpha}, \tag{2.29}$$

where all terms other than O_{ij} are defined in accord with (2.28). O_{ij} represents the intervening opportunities that lie within a circle centered at place *i*, with the distance between *i* and *j* as the radius. In a later formulation Stouffer (1960) extended the intervening opportunities to account for the effects of competition from other origins for the opportunities at a potential destination

$$I_{ij} = kV_i W_j O_{ij}^{-\alpha} C_{ij}^{-\beta}. \tag{2.30}$$

O_{ij} was redefined to be a circle with the distance between *i* and *j* as the diameter. C_{ij}, or competition, was defined as competitors within a circle centered at *j*, with the distance between *i* and *j* as the radius.

The implicit behavioral hypothesis in (2.29) and (2.30) in the context of residential relocation is that households consider potential residences in sequence beginning with the closest. Although the independence of flows assumption is abandoned in the sense that the relocation flow between two places is functionally related to the opportunities of places other than the pair under consideration, the formulation suggests an extreme rigidity in household behavior. Only those opportunities within a certain geographic area intervening between a pair of places are assumed to be relevant. It is more logical that all opportunities within the system are relevant and that all flows are interdependent. Aside from these points, criticisms of circularity have been aimed at the model. Stouffer operationally defined intervening opportunities and competition in terms of the ex post total (inflow) of households into the spatially defined intervening area. Since flow totals are simply the summation of individual pairwise flows, an obvious circularity problem exists in the logical explanation of pairwise flows from exogenous ex post flow totals.

In spite of their logical shortcomings, gravity models of relocation do have some attractive features that are not found in most of the models discussed thus far. First, residential relocation is modeled in an explicit spatial context. Relocation flows between spatial units are the focal point for statistical explanation. Second, common spatial biases—for example, distance-decay regularities that should reflect spatially related generalized costs such as search, information, social, and psychic wear—may be accounted for by distance surrogates. Third, attributes of the housing stock may be entered as explanatory factors of intra-urban relocation. It should also be noted that recent gravity model developments reviewed in Hua and Porell (1979) have rectified some of the logical problems associated with the traditional gravity model and intervening opportunities models. For example, the generalized systemic model of Alonso (1974, 1978) that was developed in the context of intermetropolitan migration is capable of addressing the interdependence among flows and the endogeneity of flow totals at a macrolevel. In accord with the definitions supplied for (2.28), the Alonso model is

$$I_{ij} = kV_iO_i^{\alpha-1} W_jC_j^{\beta-1}F_{ij}, \tag{2.31}$$

where

$$O_i = \sum_j W_jC_j^{\beta-1}F_{ij}, \tag{2.32}$$

$$C_j = \sum_i V_iO_i^{\alpha-1}F_{ij}. \tag{2.33}$$

The Alonso model exhibits several attractive structural properties. Aggregate flows are explicitly interdependent. The systemic factors O_i and C_j serve similar roles to the balancing factors of entropy maximization models of Wilson (1970) in this respect. An exogenous change in the characteristics of any place will produce a complex expected redistribution of flows throughout a residential system. In contrast to the entropy model, however, total flows are endogenous to the model and functionally determined by the same factors that determine pair flows. Summing (2.31) over all origins or destinations produces total flow equations that are structurally consistent with (2.31):

$$\sum_j I_{ij} = V_iO_i^{\alpha}, \tag{2.34}$$

$$\sum_i I_{ij} = W_jC_j^{\beta}. \tag{2.35}$$

Despite the recent gravity model developments, heuristic models lack the theoretical underpinnings necessary for a truly explanatory/predictive model of residential relocation. While the systemic factors O_i and C_j in (2.31) can interlink and redistribute aggregate household relocation flows in a manner suggestive of an underlying market mechanism, the equilibrating role of price has not been explicitly specified. Since residential relocation is a key functional mechanism of the housing market, its explicit treatment within the economic theory of markets is necessary for a fuller understanding of the process.

2.3.5. Macrostatistical Models of Residential Relocation

The Markov chain model of stochastic processes has been utilized in several different contexts related to the intraurban residential relocation process in recent years. On the one hand, Simmons (1974) and Gale (1969) have analyzed residential relocation patterns between spatially defined areas. On the other hand, White (1971), Hua (1972), Sands (1976), Porell (1981), and others have exploited the duality of the household-housing relation in residential relocation and have analyzed vacancy transfers between housing submarkets. With the exception of household formations, dissolution, outmigration, and inmigration, relocating households both create and fill vacancies. Thus local residential relocation may simultaneously be viewed as a vacancy transfer in the reverse direction.

The critical assumption of the Markov model is its "no-memory" property.[28] Defining states as housing submarkets, the no-memory property requires that the probability of relocation from an origin submarket i to a destination submarket j over a time period be independent of all past relocation history. In other words, the residence history of households can be of no value toward prediction of where a household will relocate in the future. Only the current submarket residency is relevant. While the no memory assumption is obviously questionable in the case of household relocation, it appears very reasonable in the case of vacancy transfers.[29]

The parameters of the Markov Chain model are the household or vacancy transition probabilities estimated from an observed matrix $\bar{\bar{\mathbf{I}}} = \{I_{ij}\}$ of household relocation flows between submarkets over a time period. The household transition probabilities p_{ij} are estimated from the cell count of relocations between a submarket pair I_{ij} divided by the total outflow of movers from an origin submarket i (or $p_{ij} = I_{ij}/\Sigma_j I_{ij}$). The vacancy transition probabilities q_{ij} accordingly are estimated by the cell count I_{ij} divided by the total inflow of movers to submarket j (or $q_{ij} = I_{ij}/\Sigma_i I_{ij}$). Under assumptions of parameter stability over time, the forte of the Markov model lies in the predictions that result from the mathematical properties of the model. White (1971), Hua (1972), and Porell (1981) demonstrate in the context of vacancy transfers the utility of the Markov model for projecting vacancy multiplier impacts as a crude guide for local housing policy.

In spite of its potential policy value and the insight it produces into quantification of submarket interdependences, the Markov model is but a descriptive statistical model. It provides no causal explanation of the residential relocation process. In fact, to invoke its powerful statistical properties requires assumptions of parameter stability that have not yet withstood serious empirical testing. More fruitful directions toward increasing our understanding of housing dynamics would seem to lie in works such as Spilerman (1972) and Ginsberg (1972) that seek to explain Markov transition probabilities causally by exogenous factors.

A more recent modeling perspective related to the study of residential relocation is the joint statistical analysis of occupancy and neighborhood change proposed in the works of Gale and Moore (1973) and Moore and Gale (1973). Stripping away the philosophical arguments of Gale (1973) concerning models of data, the K^n model of Moore and Gale can be best described as a finite multidimensional contingency table model. In its most general form households would be stratified into classes and cross-classified at two points in time into submarkets, jointly defined by dwelling type and geographic location. The generality of the approach lies in the multitude of substantive issues that may be addressed through recent developments in the analysis of categorical data (e.g., Bishop et al., 1975). Most models of residential relocation, mobility, and location rest on implicit assumptions concerning homogeneity and statistical independence among various classificatory dimensions in household class and submarket definitions that have not been subject to empirical testing. In general, stratification is pursued on an ad hoc basis. On the one hand, the Gale and Moore approach may be described as a "return to basics" for examining fundamental modeling issues. On the other hand, it provides a descriptive social accounting mechanism for the study of neighborhood change. While the statistical orientation of the contingency analysis approach does not constitute a theoretically grounded model of relocation, future efforts should provide useful insight into the complex multidimensional interrelationships involved and stimulate further model development.

2.3.6. Macroeconomic Equilibrium Models of Residential Relocation

The National Bureau of Economic Research (NBER) Urban Simulation Model of Ingram et al. (1972) is representative of models that incorporate both mobility and locational components of the residential relocation process at the macrolevel. The model is unmatched by any of the models discussed thus far in terms of comprehensiveness. As a simulation model of an urban housing market it addresses employment change, residential mobility, dwelling and locational choice, supply response, and filtering, as well as market clearing and endogenous price formation within a journey-to-work context. Figure 2.5 provides a brief description of each of the seven interrelated submodels. Since the focus of this book is on residential relocation, only the movers demand allocation, and market clearing submodels will be discussed here.

The purpose of the mover submodel is to generate the number of households by type and workplace location entering a mover pool in any time period of the model. This mover pool of housing demanders is comprised of intrametropolitan movers, new households, and migrants from other regions. Intrametropolitan movers are generated as a result of workplace changes other than life cycle determinants. A pool of "provisional movers" by workplace and household class is initially generated by applying exogenous household class mobility rates. These mobility rates are estimated from observed historical proportions of households of a class that moves annually. Next this provisional mover pool is modified to account for movers associated with employment increases at work sites. In accord with the workplace dominance assumption, all households whose jobs are affected by employment shifts are assigned to the mover pool. Also, the demographic characteristics (i.e., age and family size) of households in the mover pool are modified to reflect housing demand shifts associated with moving.

The demand allocation submodel is a model of residential choice that is logically similar to the two-step choice process of Quigley (1976) discussed earlier. Gross prices for housing types by location are computed as the sum of market clearing prices from the previous time period and travel costs from workplace to residence zone. However, computational problems preclude the use of the cost-minimizing calculus of Quigley (1976). A weighted average of gross prices for each house type is computed. Weights are constructed from the proportions of available units of each house type in residence zones and proportion of work trips by income class to those zones. Mover households are then assigned to *house types* from a demand model in which the dependent variable is the proportion of a household income class by workplace choosing a house type and the independent variables are the relative weighted gross prices of housing types.

After a series of filtering and supply submodels have revised the available housing supply, moving households, already assigned to housing types, are assigned to available housing by residence zone within a market-clearing submodel. The market-clearing model is a linear programming formulation with the objective function of minimizing total work trip travel costs subject to the constraints that all households be located and all units be filled. Since households choosing a particular dwelling type cannot be allocated to different housing types when available units are filled, and also since the transportation linear

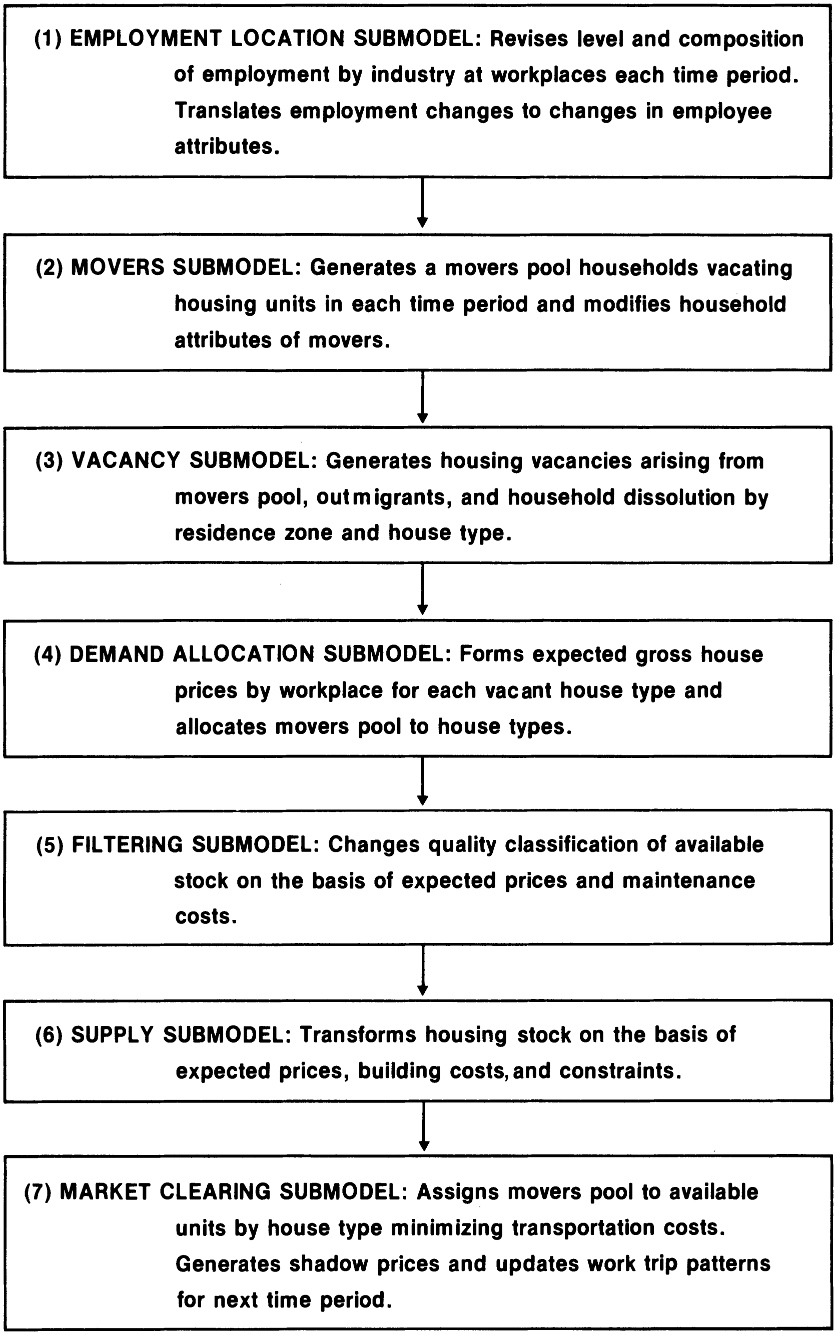

Figure 2.5. Submodels of the NBER Urban Simulation Model (adapted from Ingram et al., 1972)

program requires equal numbers of households and dwellings for solution, dummy households and units are added. Housing occupied by dummy households is treated as vacant. Households assigned to dummy dwellings are in "limbo" until the next time period. The dual of the minimization problem produces shadow prices for updating market prices for the next time period.

Certainly the NBER model is impressive in the sense that it attempts to address a multitude of complex aspects of the housing market with a fair amount of detail. However, in the context of residential relocation at least, it would appear that comprehensiveness has been purchased at a substantial cost. Operational constraints apparently have led to a sacrifice of theoretical integrity. Consider the simplicity of the mover model. Movers are generated probabilistically only on the basis of historical mobility rates by household class. Also, only *after* movers have been identified are household characteristics modified to reflect demand shifts. Certainly, one of the few areas of empirical consensus in the residential mobility literature is that changes in household characteristics are strongly associated with mobility. The demand allocation model also suffers from shortcomings due to the discrete separation of dwelling choice from location. Households can substitute different dwelling types only on the basis of *past* period market clearing prices in the demand allocation submodel. In the market-clearing model all dwellings of a particular type are perfectly substitutable except for location.

In spite of its comprehensive scope, the NBER model exhibits serious shortcomings from the perspective of development of a model of relocation. It is truly a merger of independent mobility and location models rather than a relocation model. Movers are determined independently of locational considerations of housing adjustment. Movers are exogenous to the location model. Nevertheless, the model has an economic foundation that explicitly treats relocation as an explicit component of housing market dynamics that is crucial to furthering our understanding of the residential relocation process.

2.4. AN OVERALL ASSESSMENT OF PAST RESEARCH

The overview of past research has not only provided a brief synthesis of the varied modeling approaches in past works but also has subjected many implicit or explicit assumptions regarding the nature of the housing consumption adjustment process and the housing market to critical assessment. The purpose of this section is to synthesize the major issues raised in the overview and to advance formally a set of criteria to underlie a complete and consistent model of the intraurban residential relocation process.

The bulk of past research has implicitly treated the housing consumption adjustment process as two discrete and separate processes. The logic behind the separation of the movement decision from the location decision is questionable. The notion of separation used here is not addressed to whether households sequentially or simultaneously undertake the residential movement/location decisions. Rather, what is at issue is the degree to which these decisions are *interdependent.* Models of residential mobility have been founded largely on the implicit assumption that the external housing market situation is irrelevant in the household's movement decision. Households are portrayed as being solely concerned with their "satisfaction" with their current housing. Whereas dissatisfied households may move, "satisfied" households never consider moving, even if the apparent benefits to do so would exceed expected costs of relocation. Although the concept of "satisfaction" bears connotations of relativity, the only possible comparison a household can make is between its current level of satisfaction and past levels.

The role of alternative housing opportunities in such a comparison is left unspecified in most residential mobility and sequential relocation models. The recent microeconomic mobility models (e.g., Hanushek and Quigley, 1979; Cronin, 1979) are exceptions to this general rule. These models are explicitly founded on the premise that mobility is an adjustment process motivated by housing consumption disequilibrium. Since disequilibrium can only be defined in reference to an equilibrium level of housing consumption, alternative housing opportunities at least are implicitly treated in these models. The distinction of "implicit treatment" is made here because of their invocation of the long-run concept of housing service. Under this assumption, housing consumption is measured solely in terms of housing expenditures. All housing units commanding the same market rent are treated as perfect substitutes regardless of their size, location, and so forth. Because of the extreme heterogeneity of the housing stock and the importance of locational attributes in the housing bundle, it would seem more reasonable to assert that the movement decision is contingent on some type of rational comparison between a household's current housing and the *attributes* and *prices* of prospective housing alternatives. Still, the concept of disequilibrium advanced in these latter models is crucial to a logically complete model of relocation.

In a similar manner residential location models have been founded on the discrete separation of the locational decision from the mobility decision. All locating households are exogenously determined and are figuratively treated as "floating in the air" in a mover pool differentiated only by workplace. Clearly in some instances, such as inmigration, household formation and dissolution, and forced moves, the movement decision may be justifiably treated as exogenous to the location decision. However, as shown in the first chapter, even under very conservative definitions of housing the majority of local household relocations are housing consumption adjustment related. To defend the exogenous treatment of the movement decision in the explanation of the locational decision for housing adjustment relocations, one must also defend the implicit assumption that prior housing consumption does not matter in locational choice. Yet if one accepts the premise that the movement decision is itself contingent on some type of comparison of housing alternatives with current housing, prior housing should ultimately affect locational choice as well. Since households must incur substantial relocation costs of both the monetary and nonmonetary variety, it is unlikely that a household will choose a residence that is highly substitutable with its prior residence. Indeed, the data presented earlier in table 1.2 suggest that households alter their housing consumption significantly in the course of relocation.

In spite of these logical problems, residential location models do provide some guidance toward the development of relocation models. Quigley's (1976) model is an important contribution for several reasons. It is founded on the rational utility-maximizing behavior of households. It also explicitly incorporates the discrete heterogeneity of housing. Earlier long-run equilibrium location choice models of Muth (1969), and even the multidimensional models of King (1975) and Straszheim (1975), have treated the location choice as a continuous marginal process whereby the household chooses an optimal housing bundle along all attribute dimensions. In contrast, the choice model of Quigley (1976) treats the location choice as choosing a *particular discrete bundle* among a choice set of alternative bundles. Since households do not actually purchase attributes individually, and since many continuously generated "optimal" attribute bundles may not even exist in the short run due to the inelasticity of housing supply, the choice model approach would appear to have theoretical merits in building a microlevel model of relocation.

The logical problems of the discrete separation of movement and locational components of the relocation process should be apparent if one accepts the premise that the *complete relocation event* is indeed the endogenous phenomenon to be explained. This can be seen more clearly by examining the implicit structures of mobility and location models arising from the aggregation of relocation flows. Denote by I_{ij} the expected number of households (possibly stratified by household class and workplace) relocating between submarket i and submarket j over a time period. Since rational households would not incur relocation costs to relocate within a submarket comprised of units identical to its current dwelling, I_{ii} denotes stayers. Total movers from any origin submarket i are found by summing I_{ij} over all submarkets other than i, or $\Sigma_{j \neq i} I_{ij}$. Conceptually, this is the endogenous quantity that is the focal point of mobility models. At the individual microlevel its probabilistic equivalent is used. The general structure of most mobility models may be represented by

$$\sum_{j \neq i} I_{ij} = f(\mathbf{H}_i, \mathbf{D}_i), \tag{2.36}$$

where $\mathbf{H}_i$ is a vector of household attributes and $\mathbf{D}_i$ is a vector of residential attributes characterizing the *origin* submarket. The explanation of individual intersubmarket relocations I_{ij} should ultimately be contingent on factors associated with destination submarkets. The explanations of total movers (or the probability of moving) should also be dependent on external housing market characteristics since they are simply the *sum* of intersubmarket flows.

The logical problems of most residential location models that exogenously specify total movers can be similarly exposed. The summation of total movers by origin submarket over all origin submarkets yields a total mover pool (differentiated by household class and workplace), or $\Sigma_i \Sigma_{j \neq i} I_{ij}$. The endogenous quantity to be explained in residential location models is the number of households choosing a particular submarket j (or its probabilistic equivalent). In terms of I_{ij} this is simply its summation over all origin submarkets *other* than j, or $\Sigma_{i \neq j} I_{ij}$, if a mover pool is specified. If all households are located, including nonmovers, this summation would simply include j. The general structure of most locating models may be represented by

$$\sum_{i \neq j} I_{ij} = f\Big(\sum_{i}\sum_{j \neq i} I_{ij}, \mathbf{H}, \mathbf{D}, \mathbf{T}\Big), \tag{2.37}$$

where $\mathbf{H}$ is a vector of household attributes, $\mathbf{D}$ is a vector of submarket attributes (which may include submarkets other than j), and $\mathbf{T}$ is a vector of work travel costs. An obvious question of circular logic can be raised about (2.37) by the explanation of location flows from exogenously imposed mover totals. Total movers and locators are both the logical result of partial summation over the *same* intersubmarket flows.

The basic premise advanced here is that the explanation of residential relocation logically encompasses both the explanation of movement and locational components of the housing consumption adjustment process. This also should include the decision to stay at a current residence. Although nearly 80% of all households do not relocate annually, almost no attention has been given in past research to the explanation of not moving. Yet this side of the decision process may prove to be quite useful in explaining relocation. It has already been noted that Mayo et al. (1979) found that moving cost variables consistently explained more variation in mobility rates than did measures of the benefits of housing adjustment. The role of relocation costs themselves needs more explicit attention in models of relocation. While spatial patterns of search have been an issue of independent investigation in the literature (e.g., Barrett, 1973; Brown and Holmes, 1971; Adams, 1969), only spatial gravity models of relocation (e.g., Simmons, 1974) have incorporated the frictional effects of generalized costs reflected in distance. Location models have ignored spatially related costs other than those of the journey to work. Yet the powerful distance-decay relationships commonly found in the works just noted would suggest that spatial bias is an important factor influencing locational choice as well.

The second basic dimension of the research typology exposed the sharp dichotomy between microlevel and macrolevel models in past works. This dichotomy is not peculiar to models of residential relocation. However, the level of household aggregation and the linkages between micro- and macrolevels bear a special importance in models of residential relocation in light of their functional role in the urban housing market. Microlevel models have been founded on the *independent,* unilateral rational behavior of households in response to exogenous market conditions. Yet in the aggregation of many *independent* household actions, ex post macrolevel residential relocation flows of households should be *interdependently* determined with prices, through the overall market resolution of demand preferences and supply in the urban housing market. Macrolevel relocation flows of household class aggregates are inherently *interdependent* on each other, as it is these flows that should interactively define linkages among a complex system of housing submarkets through the aggregate housing market process.

Several of the macrolevel models of residential location reviewed here do exhibit the important structural interdependencies among households that are characteristic of market competition. Dwelling and household accounting constraints in the models of Herbert and Stevens (1960), Wilson (1970, 1974), Senior and Wilson (1974), and Anas (1973) not only create this interdependence but also serve to ensure that household locations are consistent on aggregation over household classes with the aggregate occupied housing stock. The Herbert-Stevens model further exhibitis the desirable property of endogenously determined prices. Unfortunately, these desirable macroproperties are attained at the expense of unacceptable microproperties. Residential budgets, bid rents, or utility levels of houshold classes are treated as exogenous inputs to the macrolevel system. Yet there is no theoretical justification for treating the *endogenous* outcomes of microlevel processes as *exogenous* in a macrolevel process. Macrolevel processes are simply the logical cumulative result of microlevel behavior.

The interdependence among household relocation flows has implications for the structural relationships between individual household relocation flows and macroproperties of the urban housing market. On the one hand, it is essential that a model be disaggregate in the sense that behavioral differences in housing consumption demand, due to variations in tastes and/or budgets (income), are accounted for. Households should at least be segmented into classes so as to reflect variations in residential preferences. On the other hand, the long lags in the supply sector deem that the housing stock and supply of housing services may be virtually fixed in any short-run period of time. Accordingly, the residential relocation process may be characterized as an interdependent process of competition for the scarce and limited housing services produced in the market. Since the individual household's relocation decision should encompass the option of remaining at the current residence, the aggregate household occupancy of current stock is the logical result of many interdependent household relocation decisions. It is therefore essential that a model purported to explain individual household relocation, or flows by household class, be consistent on aggregation with the explanation of the aggregate occupied stock.

Although this assessment of past research has not addressed all potential modeling issues pertinent to the study of residential relocation, an attempt was made to focus on the most critical issues impinging on the theoretical development of a complete and consistent model of the intraurban residential relocation process. In a formal sense, the major arguments of this review and assessment may be synthesized via a proposal of a formal set of minimum structural requirements for models of residential relocation. Since it has been argued that the explanation of residential relocation logically encompasses the explanation of mobility and location, the first criterion addresses this concern:

1. All household moves, as sums of all intersubmarket relocations, should be endogenously determined as a function of housing market factors in *all* submarkets of the residential system. Total movers should be endogenously determined simultaneously with residential location flows.

The second and third criteria are proposed to ensure interdependence and structural consistency:

2. Each residential relocation flow of households of any class is affected by all submarkets and the relocation flows of all household classes. All household class relocation flows are interdependent.
3. All expected household class relocation flows should add up over all submarkets to the expected total flow of that household class from that submarket. The summation of all relocation flows of any household class to a submarket over all submarkets should equal the expected total flow of that household class to that submarket. The summation of expected flow totals to any submarket over all household classes should equal the expected total flow of all households to that submarket. Thus the model should exhibit structural consistency.

Although these proposed structural criteria are rather straightforward and obvious, none of the models reviewed in this chapter has fulfilled all of these proposed criteria. Whereas microlevel models have been firmly rooted in the behavior of households, (e.g., Hanushek and Quigley, 1978; Alonso, 1964;

Brown and Moore, 1970), these works have not addressed consistency with the macrolevel phenomena of the urban housing market in the last two criteria. The few disaggregate but macrolevel works that address the last two criteria (e.g., Herbert and Stevens, 1960; Wilson, 1970) have focused only on the residential location process and thereby violate the first criterion by the exogenous treatment of movers. The bulk of residential relocation models that satisfy the first criterion do not fulfill the latter two (e.g., Simmons, 1974; Alonso, 1974). Satisfaction of all three criteria is essential for the development of a structurally complete and consistent model of residential relocation.

Obviously, the proposed criteria should not be viewed as sufficient conditions for judging residential relocation models. A foremost concern is the strength of theoretical underpinnings. An explanative/predictive model of relocation should be founded on a behavioral base at the microlevel of the household. Aggregation assumptions should be made explicit. Housing submarkets should be defined jointly by dwelling and locational considerations. All of these concerns and others are relevant. The proposed criteria may be better viewed as necessary logical criteria on which a model should be constructed. The overview of past research in this chapter has provided a proper point of departure for development of a logically consistent model of relocation. In the next chapter a theoretical model that is founded on the proposed criteria and integrates recent developments in the mobility and location modeling literature will be developed.

NOTES

1. In addition to Lancaster (1966a), thorough discussions of the many facets of aggregation issues may be found in the works of Theil (1954), Allen (1957), Green (1964), and Ijiri (1971).

2. Although there is fairly widespread agreement that changes in age, family composition, earnings, and so forth, over time effect mobility in something like a family life cycle, there is lesser agreement on the precise definitions of stages and on whether individual stages or transitions between stages are associated with higher movement propensities. See Glick (1947), Lansing and Kish (1957), and Abu-Lughod and Foley (1960).

3. One may draw similar conclusions from the economic mobility model of Hanushek and Quigley (1978). Equilibrium consumption is a function of current household attributes. Current expenditures are related to past characteristics since presumably households are in equilibrium as recent movers in their model.

4. The interest of economists in the study of residential mobility seems to be the result of the Housing Allowance Demand Experiment of the U.S. Department of Housing and Urban Development. One of the important research questions of this research effort is the mobility response of households to rent subsidies.

5. Muth (1960) first introduced the concept of housing service as a single-valued measure of the flow of services per unit of time yielded by the structure, land, and environment. In a perfectly competitive market in long-run equilibrium, a single-unit price of housing

service should prevail. Although unit price and quantity of housing service are not observable independently, their product of housing expenditures is observable. Under a single-unit price, ratios of expenditures should equal ratios of housing service. See Olson (1969).

6. The probit model is useful in situations in which the dependent variable is discrete (e.g., binary) and probabilities must lie in an interval between 0 and 1. It is based on maximum likelihood estimation with a cumulative normal probability function. See Finney (1964).

7. Hanushek and Quigley (1978) also estimate a trichotomous model with the actions of (1) moving, (2) searching but not moving, and (3) not moving. The results suggest that the net effect of disequilibrium increase on search but not moving to be small, or that search is generally more intensive (and successful) with larger disequilibrium.

8. Logit estimation is an alternative to probit estimation of discrete choice models. Rather than the cumulative normal distribution, it is based on the cumulative logistic function. (See Pindyk and Rubinfield, 1976, chapter 8.)

9. Tenure discounts were estimated from hedonic price functions and occupancy duration. The latter two cost variables were estimated by regressing search days and moving costs of recent movers on household socioeconomic and demographic characteristics. If mover households systematically incur lower than average costs, these estimates will be biased downward.

10. See Romanos (1976), Senior (1973, 1974), and Quigley (1974) for other general reviews of various residential location models.

11. Under the assumption of a perfectly competitive housing market with elastic supply, unit prices should vary over the fixed factor of location. With transportation costs a function of distance from the employment center, competition for central locations bids up land rents.

12. The "new urban economics" approach to modeling has received both acclaim and criticism. See Richardson (1977b) for a review.

13. Although founded on the work of Luce (1959) and the powerful "independence of irrelevant alternatives" axiom of individual choice behavior, the formalization of discrete choice models in the context of utility theory is attributable to McFadden (1973). For a general survey of models of discrete choice, see McFadden (1976).

14. Equations (2.9) and (2.10) are restricted versions of the extreme value model of McFadden (1978), in which the coefficient of the inclusive value is constrained to zero.

15. Population turnover rates were defined as a sum of intraunit movers and the maximum of total inmovers or outmovers divided by population.

16. See Johnston (1971), Senior (1973), and Romanos (1976) for detailed reviews of classical ecological models of residential structure. Senior (1973) also reviews factorial ecological models of Murdie (1969), etc., which integrated classical models with the social area analysis concepts of Shevky and Bell (1955).

17. For example, consider four workers at a site (A, B, C, D) who reside in submarkets 1 and 2. A mesolevel distribution might be that three workers reside in submarket 1, and one worker resides in submarket 2. Since any of the four workers could be the one residing in submarket 2, there are four microlevel assignments that could produce the mesolevel distribution.

18. See Gould (1972) and Cesario (1975) for lucid explanations of the entropy maximization concepts underlying the models of Wilson.

19. The workplace zone and residence zone subscripts are reversed in the formulation here. Wilson (1970) defines T_{ijkw} as the number of workers living in zone i in a house type k who work in zone j with wage w. Since we are actually dealing with residential assignment, the i and j subscripts are reversed here.

20. The logarithm of S is maximized rather than S to allow use of Stirling's approximation $\log N! = N\log N - N$ in the solution of the maximization problem.

21. For example, if journey-work generalized transport costs decrease between a particular employment and residence zone (i.e., c_{ij} decreases between a particular i-j pair), a greater location flow is expected between that employment zone i and residence zone j by (2.17). Lesser location flows are expected from employment zone i to all other residence zones as a decrease in c_{ij} results in an increase in A_{iw}^{-1} in (2.18), so that A_{iw} decreases in (2.19) for all other location flows from employment zone i. Note that B_{jk}^{-1} also increases when c_{ij} is decreased in (2.19). This has the effect of decreasing location flows from all employment zones other than i to residence zone j. Note that since no changes occur in the distribution of housing stock across residence zones, those employees who were previously assigned to residence zone j must be located elsewhere. Since A_{iw}^{-1} and B_{jk}^{-1} both increase due to the decrease in c_{ij}, all other A_{mw}^{-1} and B_{nk}^{-1} for $m \neq i$ and $n \neq j$ decrease. This subsequently increases expected flows between all other employment-residence zonal pairs via (2.17).

22. Discussion of the works of Anas (1973), Senior and Wilson (1974), and Wilson and Senior (1974), which have entropy model foundations, are deferred until the next section because of their relation to the Herbert and Stevens (1960) model.

23. For discussions on this point see Koopmans and Beckmann (1957) and Koopmans and Reiter (1951).

24. The disequilibrium model of Anas (1973) differs from Senior and Wilson's in the way suboptimality is introduced. Expected utility levels for household groups are estimated by the econometric procedure proposed by Wheaton (1977). Disequilibrium is defined as the difference between expected and actual utility levels. An entropy measure similar to (2.25) is maximized subject to total employment constraints (2.14) and an aggregate utility disequilibrium constraint for each household group. Expected and actual utility levels and the aggregate disequilibrium must be exogenously supplied to the entropy maximization problem.

25. The gravity model of spatial interaction has also been used for the analysis of workplace-residence location flows in the works of Voorhees (1955) and Carroll and Bevis (1957).

26. Simmons (1974) does not actually estimate the model (2.28) directly. Rather he estimates two total flow models and a distributive interplace gravity model. Denote by I_{i*} the total outflow of households from place i and by I_{*j} the total inflow of households to place j. In accord with the notation in (2.28), he estimates the following models $I_{i*} = f(V_i)$; $I_{*j} = f(W_j)$; and $I_{ij} = kI_{i*}I_{*j}F_{ij}$.

27. More comprehensive discussions of the logical flows of the traditional gravity model may be found in Ewing (1974) and Hua and Porell (1979).

28. See Kemeny and Snell (1960) for a rigorous discussion of the Markov Chain model and its properties.

29. It is obviously questionable to assume that a household's relocation probabilities are independent of its past residence location. Since a relocation from submarket i to submarket j defines a vacancy transfer from submarket j to submarket i, the no-memory assumption for vacancy transfers only requires that the household relocation probability be independent of where the previous household in submarket j (whose vacancy is filled by the household in submarket i) relocates.

3 A SHORT-RUN MODEL OF INTRAURBAN RESIDENTIAL RELOCATION

The objective of this chapter is to develop a short-run theoretical model of residential relocation that satisfies all of the logical and structural criteria advanced at the end of chapter 2. The following section introduces the model with a brief discussion of some general assumptions underlying its development. The second section examines the formal theoretical development of the model. The third section discusses aggregation problems and the additional postulates necessary for operationalizing the model. The fourth section discusses the logical structure of the model with respect to the entropy maximization model discussed in chapter 2. The last section briefly examines the satisfaction of the structural criteria proposed in chapter 2. The appendix to this chapter summarizes the major symbol definitions for easy reference.

3.1. AN OVERVIEW OF THE MODEL

The model to be developed in this chapter may be best described as a systemic spatial interaction model of household relocation that is founded on a short-run static equilibrium model of a housing market. The market model is founded on the rational behavior of households seeking to maximize utility in their choice of housing consumption. In contrast to most models of housing consumption (e.g., Muth, 1969), the model is not founded on the assumption of long-run equilibrium in the housing market. The assumption of long-run equilibrium greatly facilitates the analysis of housing consumption behavior since one may bypass complexities associated with the heterogeneity, durability, and localization of housing through the conceptual device of housing service. Yet many researchers, such as Ingram et al. (1972), Kain and Quigley (1975), Straszheim (1975), Whitehead and Odling-Smee (1975), Kirwan and Ball (1973), and Apgar and Kain (1972), have presented convincing arguments that long-run equilibrium is most likely to be at wide variance with reality.[1]

From the perspective of developing a model of household relocation, the most serious questions raised about the long-run equilibrium approach would seem to be the continuous treatment of consumption via housing service, the effective dismissal of relocation costs of both the monetary and nonmonetary variety, and the assumption of complete adjustment of the housing stock. Clearly these three factors are not independent. The implausibility of the latter two assumptions cast doubt on the former assumption. Thus discussion will focus primarily on the latter two assumptions.

The implausibility of complete housing stock adjustment is suggested by the minimal annual contribution of new construction to the total stock and the recent empirical evidence suggesting the long-run supply elasticity of the existing stock to be quite low. Wheaton (1977) has remarked that a model in which the existing stock is completely rigid (even over a period of ten to twenty years) should be a better approximation of reality than one in which capital is assumed completely mobile. He defends this argument on two grounds. First, even in the U.S. postwar period of excessive housing demand, new construction added only 1-2% to the stock annually. Second, as long as housing units are at least minimally maintained, existing market rents provide a high opportunity cost against which replacement or extensive alteration is compared. The plausibility of the latter argument is supported by the empirical evidence of de Leeuw and Ekanem (1971) and Ozanne and Struyk (1976), which suggests that the *long-run* supply elasticity of the standing stock is in the range 0.3-0.7.[2] Thus it would appear quite plausible to treat the housing stock as being virtually fixed in a short-run model of relocation.

The rigidity of the housing stock in the short run raises important questions about the realism of conventional constrained utility maximization models of housing consumption as a foundation for a model of relocation. In these models (e.g., Muth, 1969; Straszheim, 1975; King, 1975) households face exogenous fixed prices for individual residential attributes (that are submarket invariant) and choose an "optimal" housing bundle via marginal analysis. Because of the rigidity of the stock, it would seem implausible to treat households as choosing attributes *individually* and in *divisible* quantities. Many "optimal" bundles may not even be produced in the local market, as much of the composition of the current stock result from the demand preferences of past generations. Further, there are likely to be rigid substitutabilities among various dwelling and environmental attributes that may lead to price inelastic demand for particular bundle types in which strong residential preferences exist. In conjunction with a relatively inelastic supply, this should produce location rents for various attributes and hence market segmentation.[3] Thus in the absence of long-run equilibrium, implicit prices for individual attributes may vary across submarkets.

A more realistic view of relocation choice is that households face a choice of discrete submarket alternatives existing at some time. Demand may be more aptly characterized as a choice among submarkets *constrained* by the composition of the stock, and hence translated into probabilistic behavior at the individual household level. Probabilistic choice theory, along the lines of McFadden (1973), provides a theoretical base from which to model microlevel relocation behavior.

Quigley's (1976) model of residential location (reviewed in chapter 2) is founded on similar considerations of short-run demand. However, the model to be developed here differs in several important ways. Of foremost importance is the incorporation of "generalized" relocation costs into the *relocation* choice of households. "Generalized" relocation costs are broadly defined here to encompass all monetary and nonmonetary costs of relocation. As such, the term encompasses not only search, information, and transactions costs, but also the social and psychic costs of leaving familiar surroundings. The effect of generalized relocation costs on relocation choice is that a household's relocation choice may be biased away from the likely to be chosen in a frictionless world of costless mobility.[4] From one perspective these costs create locational inertia that may bias the household's submarket choice in favor of its current dwelling. In this sense a household's choice of not moving may be quite rational even though its current consumption may deviate from its "optimal" level in a frictionless world. In addition, the strong distance-decay regularities exhibited in spatial household relocation patterns (e.g., Moore, 1972; Simmons, 1974) suggest that generalized costs may also bias the household's choice of destination submarket.

Questions have been raised about possible confounding effects of the spatial distribution of housing opportunities (e.g., Curry, 1972; Moore, 1970).[5] Most, however, would attribute this "distance bias" to the limited spatial awareness of households and the high costs of information and search. The costs presumably bias destination choice toward areas where greater familiarity exists. These spatially related costs are ignored in mobility and location models since neither approach considers *both* origin and destination submarkets and the entirety of the relocation process. Yet their specification is essential to a model of relocation.

The choice model of Quigley (1976) is further extended in this chapter by the explicit incorporation of supply constraints of fixed housing stock. "Demand" in the context of Quigley's choice model is ultimately measured in terms of the relative frequencies by which certain submarkets are chosen over others. "Preferred" submarkets are those chosen with greater frequency at existing prices/rents. Wheaton (1977) correctly observes that the meaning of preference may be muddled by constraints imposed by the composition of the current stock. There simply may be more units of a particular submarket than others in the existing stock. It would appear that additional assumptions regarding price/rent dynamics should be made explicit to maintain consistency between the aggregation of microlevel relocation choices and macrolevel constraints of a fixed housing stock in the short run.

Several of the macrolevel models discussed in the last chapter (e.g., Wilson, 1970; Herbert and Stevens, 1960; Ingram et al., 1972) have explicitly accounted for supply constraints directly within mathematical programming frameworks. Supply constraints are *exogenously* imposed and shadow prices are endogenously generated as dual variables. Prices/rents are viewed as responsive to demand fluctuations and serve as the allocative mechanism by which ex ante demand is adjusted to satisfy supply constraints. Although this approach is quite useful in *static* models of residential location, the crucial role of housing vacancies in the dynamic process of residential relocations is ignored. Vacancies do not serve any real purpose in these models other than a residual quantity to ensure that exogenously imposed household and supply constraints are met. "Dummy" household groups are generally allocated to submarkets in which supply exceeds demand. Occupancy by a dummy household class is equated with a vacancy. Since households both fill and create vacancies in the course of relocation, vacancies deserve attention in a model of relocation if only for their role in facilitating household turnover.

Housing analysts have traditionally used vacancy rates as indicators of the tightness or softness of housing markets. It is generally assumed that some "normal" vacancy rate exists for the frictional need of household turnover. Deviations from this rate are viewed as leading to price changes that eventually lead to supply response. Vacancy rates have been uncritically accepted by practitioners as useful market indicators; curiously, however, one cannot find any theoretical or empirical works that define what is (or what should be) a "normal" equilibrium vacancy rate other than rules of thumb. This is not surprising given the observed positive correlations between vacancy rates and mobility rates noted by Schmitt (1957), U.S. Department of Housing and Urban Development (1969), Carmen (1969), and Duncan and Hauser (1960). For purposes of frictional turnover, vacancy rates should be related to mobility rates. Practitioner rules of thumb for "normal" vacancy rates in the rental market exceeding those in the ownership market are reflective of this relationship. For this reason the vacancy rate concept does not provide a meaningful way of imposing short-run equilibrium constraints in a model of relocation. Exogenous imposition of "normal," or equilibrium vacancy rates by submarket, is virtually equivalent to exogenous specification of mobility rates. An obvious logical problem arises since mobility is the phenomenon to be ultimately explained by the relocation model.

In the development of a continuous time Markov model of a local housing market, Hua (1972) offers a short-run equilibrium definition in which equilibrium vacancy rates vary with turnover rates but are not exogenously specified. Hua (1972,1977) argues that short-run supply price adjustments are the result of the opportunity costs of the expected duration of a vacancy on the market rather than vacancy rates per se. Since housing sellers must bear operating costs (e.g., maintenance, property tax, insurance) and forego rent during the vacancy period, higher (lower) expected vacancy duration should exert downward (upward) pressure on asking prices/rents. For example, even ignoring the time value of money, the rent foregone by an additional two months of vacancy duration alone would be roughly equivalent to one-twelfth of monthly rent over two years of occupancy in the rental market.

Hua (1972,1977) has shown that in a submarket of units that are close substitutes, the expected waiting time before sale/rent may be expressed stochastically as the number of vacancies divided by the inflow rate of households over a defined period of time.[6] Since a short-run market equilibrium should be characterized by stable prices/rents, this should occur when the expected vacancy duration is constant for submarkets over the period. With a fixed stock in the short run, a sufficient condition for equilibrium is a constant vacancy level. Alternatively, this is equivalent to imposing the equilibrium condition that the expected total outflow *equal* the expected total inflow of households in all submarkets over a time period. Although this condition may appear restrictive, it does not require direct exogenous specification of "normal" vacancy rates. Vacancy rates may vary across submarkets due to turnover differentials. The imposition of the conditions does carry, however, the assumption that supply prices shift to equate demand with the occupied stock on aggregation of micro-level relocation choices.

In summary, the model to be developed extends the choice model approach of Quigley (1976) in several important ways. First, it addresses the entirety of the relocation process. Second, it incorporates a spatial dimension and the inertia of generalized relocation costs into the relocation decision framework. Finally, it explicitly considers the interdependence of relocation choices in aggregation and the constraints imposed by a fixed stock in the short run. The following section examines the formal theoretical development of the model.

3.2. DEVELOPMENT OF THE THEORY

Consider a residential system of M submarkets exhaustively encompassing all housing units and geographic places within a relatively closed system of residential movement. ***Submarkets*** are defined as groups of dwelling units that are close substitutes for each other. That is, submarkets are comprised of internally homogeneous dwellings with respect to housing type and geographic location. Thus submarkets are defined *jointly* by N spatial units and L housing unit types on the basis of dwelling attributes such as tenure, structure type, quality, size, and so forth. Households are defined as all persons occupying a housing unit. By definition the number of households in the residential system at any time equals the number of occupied housing units. On the basis of appropriate demographic, socioeconomic, race, and tenure characteristics of the head of household and members of the household, K internally homogeneous household classes are defined. The following basic assumptions underlie the theoretical development of a static equilibrium model of the intraurban residential relocation process in the short run:

1. During any time period, all households as decision units and utility maximizers choose a residence submarket from the system of all submarkets, including the submarket of their current residence. Since a relocation incurs the disutility of generalized relocation costs, households choosing their residence submarket actively choose to remain in their current housing unit. No households change residence within the same submarket. All household relocations are voluntary in the sense that all households may exercise the option of staying.
2. The short run is defined as a period of time that is sufficiently long for price shifts to act as an equilibrating mechanism, yet sufficiently short so that housing suppliers may not adjust housing services to long-run equilibrium levels. The housing stock is assumed fixed throughout the time period under consideration.
3. In the short run, the system of residential submarkets may be treated as an approximation of a stable and closed system. All housing-related relocations occur within the boundaries of the system. Exogenous disturbances to the system in the form of household formations, dissolutions, inmigration, and outmigration, as additions or subtractions to the stock of households, approximately cancel each other out, leaving the stock of households constant in the short run.

3.2.1. A Behavioral Model of Household Relocation

During any time period, all households are assumed to face a relocation decision in the form of a choice among discrete submarket alternatives $j = 1, \ldots, M$

inclusive of their current residence.[7] Under classical assumptions of rational utility-maximizing behavior, the relocation decision is cast as one of households' choosing to relocate to that submarket that maximizes utility subject to resource constraints. In choosing a submarket, households should consider their tastes or preferences for the dwelling and location environmental attributes that characterize submarkets. Formally, each household is assumed to have a utility for the consumption of housing services of each submarket in the Lancastrian sense (Lancaster, 1966b). That is, the utility for housing is a "derived" utility from consumption activities over time rather than a utility for housing per se. The intrinsic attributes of the dwelling and its locational environment are inputs into a housing production function for consumption activities. Hence submarket choice should be a function of household preferences for the attributes that characterize submarkets.

In addition to attribute preferences, submarket choice should ultimately depend on the costs associated with consumption and relocation. One component of these costs obviously is housing outlays, as reflected in submarket prices/rents. Since housing units are locationally fixed and both demand and supply for a particular dwelling type should vary across locations due to the importance of environmental attributes, submarket prices should vary across both dwelling type and location dimensions in the short run. Aside from submarket price, it can also be argued that submarket choice will be influenced by two other types of costs: (1) the expected commuting costs of both the monetary and nonmonetary variety between workplace and residence and (2) the "generalized" costs of relocation, or the social, psychic, information/search, and transaction costs incurred in relocation.[8] These latter costs in a sense modify market prices to form "effective" submarket prices that spatially bias submarket choice.[9] Since workplace location and current residence submarket will be treated as given, households at different workplaces and/or origin submarkets should face different "effective" prices for the same submarket when all costs are considered.

In accordance with the conventional approach to stochastic choice theory pioneered by McFadden (1973), it is formally postulated that all households possess a mixed direct-indirect utility function for the housing services of all submarkets. The arguments of this function include (1) a vector of intrinsic attributes characterizing a submarket, including its market price/rent, denoted $\mathbf{W}$; (2) a vector of household attributes that includes workplace location in addition to conventional demographic and socioeconomic characteristics, denoted $\mathbf{X}$; and (3) an inverse vector of attributes characterizing the disutility of both commuting costs between workplace and residence and the generalized costs of relocation between the current residence and potential destination submarket, denoted $\mathbf{C}^{-1}$.[10] Given the spatial nature of generalized relocation and commuting costs, the postulated utility function should be formally expressed as being conditional upon current residence and workplace location. Thus the utility for housing services of any submarket j for a household of a class k (inclusive of workplace) currently residing in submarket i may be stated as follows:

$$U_{kij} = U(\mathbf{X}_k, \mathbf{W}_j, \mathbf{C}_{kij}^{-1}), \tag{3.1}$$

where $\mathbf{X}_k$ is a vector of household attributes describing the kth household class, $\mathbf{W}_j$ is a vector of attributes (including price) of the jth submarket; and $\mathbf{C}_{kij}^{-1}$ is a vector of cost attributes characterizing the commuting and relocation costs incurred by choosing submarket j.[11]

Since the mixed direct-indirect form of (3.1) implicitly embodies resource constraints and costs, households as deterministic utility maximizers should choose to relocate to that submarket in which (3.1) is maximized.[12] However, all relevant submarket, household, and cost attributes are unlikely to ever be observed. Thus it is assumed that the utility function (3.1) may be decomposed into two components as follows:

$$U_{kij} = V(\mathbf{X}_k, \mathbf{W}_j, \mathbf{C}_{kij}^{-1}) + \epsilon(\mathbf{X}_k, \mathbf{W}_j, \mathbf{C}_{kij}^{-1}). \tag{3.2}$$

$V_{kij} = V(\mathbf{X}_k, \mathbf{W}_j, \mathbf{C}_{kij}^{-1})$ is a nonstochastic strict utility for submarket j that reflects the "representative tastes" of the general observed population. $\epsilon_{kij} = \epsilon(\mathbf{X}_k, \mathbf{W}_j, \mathbf{C}_{kij}^{-1})$ is treated as a stochastic component conditioned on the values of observed components. ϵ_{kij} is specified to account for all unobservable "idiosyncracies" peculiar to any individual household that may influence its choice of submarket.

Under the "independence of irrelevant alternatives" axiom of Luce (1959), the *relative* likelihood of a household choosing one particular submarket over a second one depends only on its relative utilities for the housing of those two submarkets and is independent of the utility for all other submarkets. By invoking this axiom, the utility-maximizing choice of submarket may be completely determined by a series of paired comparisons. Although the individual household is assumed to be a deterministic utility maximizer, only probabilistic statements can be made regarding any individual decision because of the unobservable stochastic utility component in (3.2). Accordingly, the probability that a household of class k currently residing in submarket i will choose to relocate to a particular submarket j is simply the probability that U_{kij} exceeds U_{kim} for all submarkets $m \neq j$. Denoting this probability as $P[j|i,k]$, this is stated using (3.2) as follows:

$$P[j|i,k] = \text{Prob}\,[(V_{kij} + \epsilon_{kij}) > (V_{kim} + \epsilon_{kim})] \quad \forall\, j \neq m, \;\; j \in M. \tag{3.3}$$

Rearranging (3.3) yields the following probabilistic statement:

$$P[j|i,k] = \text{Prob}\,[(\epsilon_{kim} - \epsilon_{kij}) < (V_{kij} - V_{kim})] \qquad \forall j \neq m, \qquad j \in M. \quad (3.4)$$

The form of (3.4) allows for derivation of the functional form of choice probabilities by postulation of a parametric joint distribution for its stochastic components. Under the assumption that the stochastic components ϵ_{kij} are independently and identically distributed with a reciprocal exponential distribution, McFadden (1973) has shown that the choice probabilities may be expressed in the familiar multinomial logit form.[13]

$$P[j|i,k] = \frac{\exp V(\mathbf{X}_k, \mathbf{W}_j, \mathbf{C}_{kij}^{-1})}{\Sigma_m \exp V(\mathbf{X}_k, \mathbf{W}_m, \mathbf{C}_{kim}^{-1})}. \qquad (3.5)$$

A necessary assumption in deriving (3.5) from (3.4) is that the stochastic utility components ϵ_{kij} are *independent* across alternative submarkets. The plausibility of this assumption depends on the degree to which households perceive different dwelling types within the same geographic location to be similar. On one hand the familiar "green bus-blue bus" problem associated with "the independence of irrelevant alternatives" property of (3.5) stems from defining alternatives that are not truly distinct.[14] These problems may be minimized by defining submarkets in such a way that each submarket possesses some specific characteristics distinctly different from all others and that these characteristics are of importance in choice. On the other hand, since submarkets are jointly defined by dwelling unit type *and* location, submarkets of different dwelling type (however defined) can share the same geographic location and hence exhibit identical location attributes. Because of this, any unobserved location attributes relevant to the choices of dwelling types at a location would comprise part of the stochastic components ϵ_{kij}. As a result, the ϵ_{kij} may not be independently distributed. This would raise questions about the validity of the multinomial logit structure in (3.5).

McFadden (1978) has shown that (3.5) is a special case of a more general nested logit structure that circumvents these problems to some degree. Replacing the single destination submarket index j with a double index nl, where n refers to locations $n = 1, \ldots, N$ and l to dwelling types $l = 1, \ldots, L$, a nested logit version analogous to (3.5) is

$$P[nl|i,k] = \frac{\left\{\exp\left(\frac{V_{kinl}}{1-\sigma}\right)\left[\sum_l \exp \frac{V_{kinl}}{1-\sigma}\right]^{-\sigma}\right\}}{\left\{\sum_n \left[\sum_l \exp\left(\frac{V_{kinl}}{1-\sigma}\right)\right]^{1-\sigma}\right\}}. \qquad (3.6)$$

In (3.6) the parameter σ ($0 \leqslant \sigma \leqslant 1$) has been termed the "similarity coefficient" (McFadden, 1978). The "more similar" households perceive different dwelling types in the same geographic location to be, the closer should σ be to unity. In the extreme case, in which different dwelling types are perceived identical, $\sigma = 1$. At the other extreme is the multinomial logit model of (3.5), in which $\sigma = 0$. While the value of σ is ultimately an empirical matter, it is restricted to zero in the model development. This of course carries the implicit assumption that households perceive all submarkets as distinct dissimilar alternatives.[15]

3.2.2. A Static Equilibrium Model of Household Relocation

The multinomial logit model (3.5) forms a microlevel theoretical base from which spatial demand functions may be derived as part of a short-run static equilibrium model of household relocation. This will require some explicit postulates regarding aggregation procedures and the functional form of the strict utility component V_{kij} in (3.5). First we assume that all households may be stratified into a set of internally homogeneous classes ($k = 1, \ldots, K$) on the basis of pertinent demographic, socioeconomic, tenure, and job location characteristics included in the attribute vector **X** of (3.5). Thus for each household of a class k, the strict utility component V_{kij} may be stated as being conditional on household class, or $V_{ij|k} = V_k(\mathbf{W}_j, \mathbf{C}_{ij}^{-1})$.

Given a stratification of households into classes, a functional form must be postulated for $V_{ij|k}$. Standard logit formulations generally assume an additively separable linear-in-parameters form (i.e., $X+Y$). Stopher and Meyburg (1976) note that this formulation implies that differences in the characteristics of alternatives are the assumed comparative mechanism for human decision making. On the other hand, if a logarithmic product form [i.e., $\log(XY)$] is postulated, ratios of characteristics form the implied comparative mechanism. Even though there is little theory to guide one's choice, the joint *nature* of discrete housing bundles would suggest that the *interactive* multiplicative form is more appropriate. Also, given the spatial dimension involved in residential relocation, the log-multiplicative form leads to a model suggestive of gravity-type spatial interaction behavior. Thus it is formally postulated that for each household class k,

$$V_k(\mathbf{W}_j, \mathbf{C}_{ij}^{-1}) = \log(W_{kj} C_{kij}^{-1}). \tag{3.7}$$

W_{kj} is defined as a composite multiplicative variable of the attributes characterizing the jth submarket with respect to the kth household class. C_{kij}^{-1} is a composite multiplicative variable comprised of attributes characterizing commuting and generalized relocation costs. For purposes of clarification, W_{kj} and C_{kij}^{-1} may be further explicated as Cobb-Douglas-type multiplicative functions:

$$W_{kj}C_{kij}^{-1} = a_{kj}Y_j^{\alpha k}P_j^{-\beta k}T_{kj}^{-\gamma k}F_{ij}^{-\delta k}. \tag{3.8}$$

$Y_j^{\alpha k} = \Pi_r y_{jr}^{\alpha kr}$ is a multiplicative function of individual dwelling attributes characterizing the jth submarket. $T_{kj}^{-\gamma k} = \Pi_r t_{kjr}^{-\gamma kr}$ is a multiplicative function of variables characterizing the commuting costs between the workplace of the kth household class and the jth submarket. It is useful to note here that because household classes are stratified by workplace, commuting access in effect is treated as a residential attribute particular to a class. $F_{ij}^{-\delta k} = \Pi_r f_{ijr}^{-\delta kr}$ is a multiplicative function of variables characterizing the generalized relocation costs between submarkets i and j. Finally, a_{kj} is a constant reflecting some basic attractiveness of the jth submarket to the kth household class, and P_j is the unit price of housing services in the jth submarket. Since the housing services characterized by attributes in Y_j should be capitalized in total price/rents, price should be specified theoretically in the form of the concept of unit price to avoid "double counting" the flow of housing services reflected in submarket attributes. In fact, if long-run equilibrium was assumed, any specification of price/rent would be redundant if all relevant submarket attributes were specified. In long-run equilibrium a single marketwide unit price should prevail (Olsen, 1969). P_j is treated as submarket specific in the short run due to possible quasi-rents arising from inelastic supply.

Although households have been stratified into internally homogeneous classes and any submarket is comprised of perfectly substitutable units with common environmental attributes by definition, aggregation of (3.5) by direct enumeration of households still requires an explicit postulate regarding commuting and generalized relocation costs. These costs may vary at the microlevel since the *specific* spatial locations of individual units will vary unless individual units are treated as submarkets. Whereas linear models may often be consistently aggregated into population groupings by use of mean attribute levels, for nonlinear models such as (3.5) mean attribute levels can lead to biased probability estimates unless the attribute levels faced are uniformly distributed across households (Stopher and Meyburg, 1976, chapter 1). Research efforts have begun to probe aggregation issues related to choice models such as (3.5) (e.g., McFadden and Reid, 1975; Koppelman, 1975); however, much remains to be accomplished in this area. For our purposes here, it is formally postulated that all households of a class face identical generalized and commuting costs, or that any differentials are not systematic and thus contained in the stochastic elements in (3.2). Thus aggregate demand functions D_{kij} for any submarket j may be derived for each household class k by inserting (3.7) and (3.8) into (3.5) and enumerating the number of households of class k residing in submarket i as H_{ki}:

$$D_{kij} = H_{ki} \frac{a_{kj} Y_j^{\alpha_k} P_j^{-\beta_k} T_{kj}^{-\gamma_k} F_{ij}^{-\delta_k}}{\Sigma_m^M a_{km} Y_m^{\alpha_k} P_m^{-\beta_k} T_{km}^{-\gamma_k} F_{im}^{-\delta_k}}$$

$$\forall, i,j = 1, \ldots, M, \quad \forall, k = 1, \ldots, K. \tag{3.9}$$

In the system of aggregate demand equations (3.9), all submarkets are explicitly modeled as interdependent. A change in the housing services produced in any submarket, or its price, should result in the reallocation of demand among all submarkets for any household class. The demand equations for any particular household class and residence submarket are also structurally consistent along the choice dimension of submarkets in the sense that $\Sigma_{j=1}^M D_{kij}$ must structurally be equal to H_{ki}. The demand functions (3.9), being derived from the *independent, unilateral* choice process of individual households, do not alone reflect the interdependency among household classes that is characteristic of the competitive housing market process. As an aggregate or macrophenomenon, the residential relocation process may be aptly characterized as an *interdependent* market process in which observed household relocation flows are the interactive result of *both* supply and demand factors of the urban housing market.

The previous section discussed the rationale for using constant vacancy levels in all submarkets as a meaningful condition for short-run equilibrium in a relocation model. Given the prior assumptions of a fixed housing stock and a relatively closed housing market (in the sense that any exogenous disturbances due to regional migration, household formation and dissolution, etc., approximately offset each other), these conditions translate into the imposition of short-run supply constraints as a constant level of occupied stock in all submarkets over a time period. Since all dwelling units of a submarket are homogeneous by definition, S_j, $j = 1, \ldots, M$, is used to denote the submarket supply as the occupied stock at the beginning of the time period. The short-run equilibrium conditions may be formally expressed by equating the total demand for housing of submarket j, or D_j, with S_j in all $j = 1, \ldots, M$ submarkets. Summing the demand equations (3.9) over all household classes and origin submarkets yields the following formal statement of equilibria conditions:

$$\sum_k^K \sum_i^M D_{kij} = \sum_k^K a_{kj} Y_j^{\alpha_k} P_j^{-\beta_k} T_{kj}^{-\gamma_k} \left[\sum_i^M H_{ki} F_{ij}^{-\delta_k} \left[\sum_m^M a_{km} Y_m^{\alpha_k} P_m^{-\beta_k} T_{km}^{-\gamma_k} F_{im}^{-\delta_k} \right]^{-1} \right]$$

$$= S_j \quad \forall j = 1, \ldots, M. \tag{3.10}$$

The simultaneous system of equations in (3.9) and (3.10) constitutes a theoretically grounded static equilibrium model of the residential relocation process in the short run. There are $M^2 \cdot K+M$ simultaneous equations and $M^2 \cdot K+M$ endogenous unknowns: $M^2 \cdot K$ of the equilibrium household class specific flows, denoted D_{kij}, and the M submarket prices P_j. By the nature of the general equilibrium conditions, all household classes and submarkets are explicitly modeled as interdependent through the endogenous market variable of price. Structural consistency in the model is maintained across submarkets and household classes in the sense that at short-run equilibrium not only must $\Sigma_j^M D_{kij}$ equal H_{ki} for all household classes $k \in K$ in all submarkets $i \in M$, but also $\Sigma_k^K \Sigma_i^M D_{kij}$ must equal S_j in all submarkets $j \in M$.

It should be obvious that an analytic "reduced form" expression for the "market clearing" submarket prices cannot be obtained via (3.10). Not only are there additive constraints imposed on the aggregation of nonlinear demand functions by the general equilibrium conditions, but also all submarket prices are simultaneously embedded in the aggregation over all origin submarkets for any household class.[16]

The analytic difficulties that are encountered here are not surprising in light of the aggregation imposed on the system of demand equations by the market equilibrium conditions. While the demand equations for housing were theoretically derived at the "microlevel" of household class, the short-run equilibrium conditions imposed on the system are aggregate or "macrorelations." Thus a variant of the obiquitous classical "aggregation problem" exists in maintaining internal consistency in the interrelationships between the household class demand "microrelations" with the submarket equilibrium "macrorelations."[17]

3.3. THE AGGREGATION PROBLEM AND OPERATIONALIZATION OF THE MODEL

Clearly, if the simultaneous system of equations (3.9) and (3.10) is to be the basis for an operational model of the residential relocation process, further attention must be given to aggregation issues. The problem of identification is particularly thorny here because of the "aggregation problem" of establishing internal structural consistency between the system of nonlinear household class demand functions and the additive constraints logically imposed by the general equilibrium conditions. The purpose of this section is to address this aggregation problem in further depth and to propose an explicit "aggregation postulate" to allow incorporation of short-run supply constraints in the model.

Problems of the relationship between the behavior of individuals and properties of collective aggregates are by no means peculiar to this model of intraurban residential relocation, as variants of the classical "aggregation problem" are ubiquitous in the social and behavioral sciences. Lancaster (1966a) notes that the aggregation problem arises because of the multiplicity of interrelationships among microvariables, microrelations, macrovariables, and macrorelations. Microvariables affecting the individual decision unit are functionally related through microrelations. Similarly, macrovariables characterizing the collective aggregate process are functionally related through macrorelations. The root of the aggregation problem is that the collective aggregate process must be the logical accumulative result of individual microlevel actions. A result of this tautological relationship is that macrovariables must be functionally related to the generative microvariables. Inevitably there are more interrelationships among these four elements than can be chosen independently, and the problem of obtaining internal consistency among all interrelationships is paramount.

In general, structural consistency upon aggregation is analyzed in terms of the microsystem, macrosystem, and the aggregation function. By holding any two of these three components constant, conditions are imposed on the third so that internal consistency is maintained.[18] Because of the multiplicity of interrelationships, maintenance of internal consistency in general requires the invocation of an explicit "aggregating postulate" of the deterministic or statistical variety.[19] In light of the nonlinearity of the household class demand functions of (3.9) and the additive constraints of the equilibria conditions of (3.10), the range of analytically tractable aggregating postulates is severely limited, as linearity is crucial to consistent aggregation. However, in accord with the "macro" equilibrium conditions, the following explicit aggregating postulate yields an internally consistent "equilibrium" model of the residential relocation process that does not severely compromise the theoretical integrity of the simultaneous system of (3.9) and (3.10):

P1: In any short-run time period, the price elasticities of demand are invariant across all household classes $k \in K$. More formally, $\beta_1 = \beta_2 = \cdots \beta_k = \cdots = \beta_K$.

Although the postulation of homogeneous short-run price elasticities may appear behaviorally restrictive, the residential attributes that produce the flow of housing services of a submarket Y_j retain household class-specific parameters in which household classes are differentiated by income. The substantive implications of this postulate are that while unit prices of housing services and residential attribute composition are both of importance in determining the relative submarket preferences of households, all household classes are in a sense relatively equally vulnerable to being "squeezed out" of any submarket by short-run price fluctuations. In other words, this postulate suggests that the aggregate residential composition of submarkets by household class should remain relatively invariant over price fluctuations in the short run.[20]

The general equilibrium conditions (3.10) may be restated in terms of P1. However, in order to simplify notation, define L_{ki} as the "choice set" or the denominator of the household class demand functions of (3.9):

$$L_{ki} = \sum_{m}^{M} a_{km} Y_m^{\alpha_k} P_m^{-\beta} T_{km}^{-\gamma_k} F_{im}^{-\delta_k}. \tag{3.11}$$

By inserting (3.11) into (3.9), the resultant expression may be summed across all origin submarkets, producing the total demand for submarket j by households of class k:

$$\sum_{i}^{M} D_{kij} = D_{kj} = a_{kj} Y_j^{\alpha_k} P_j^{-\beta} T_{kj}^{-\gamma_k} \left[\sum_{i}^{M} H_{ki} L_{ki}^{-1} F_{ij}^{-\delta_k} \right]. \tag{3.12}$$

Define

$$M_{kj} = \sum_{i}^{M} H_{ki} L_{ki}^{-1} F_{ij}^{-\delta_k}; \tag{3.13}$$

(3.13) may be inserted into (3.12) and the resultant expression summed over all household classes k to yield the total demand for housing of submarket j:

$$\sum_{k}^{K} \sum_{i}^{M} D_{kij} = \sum_{k}^{K} D_{kj} = P_j^{-\beta} \sum_{k}^{K} a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} M_{kj}. \tag{3.14}$$

Define R_j for notational simplicity as

$$R_j = \sum_{k}^{K} a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} M_{kj}; \tag{3.15}$$

the general equilibria conditions (3.10) may be restated as follows:

$$\sum_{k}^{K} \sum_{i}^{M} D_{kij} = D_j = P_j^{-\beta} R_j = S_j \quad \forall j = 1, \ldots, M. \tag{3.16}$$

Rearrange (3.16); the following expression is given for equilibrium prices $(P_j^*)^{-\beta}$:

$$(P_j^*)^{-\beta} = S_j R_j^{-1}. \tag{3.17}$$

Note that (3.17) is not an analytic "reduced form" expression for equilibrium prices in the conventional sense of the term. All submarket prices remain embedded within the right-hand side of (3.17) through R_j. R_j is defined in terms of M_{kj}. M_{kj} is defined in terms of L_{ki}^{-1} in (3.13). L_{ki} is defined in terms of all submarket prices in (3.11). However, (3.17) does provide a means of operationalizing the theoretically grounded static equilibrium model by translating it into a systemic spatial interaction model of household relocation. Inserting (3.17) into the household class demand functions (3.9) (and invoking P1) yields a short-run spatial "equilibrium" model of household relocation that structurally reflects the interdependency among household classes and submarkets and the structural consistency characteristic of the formal static equilibrium model (3.9)-(3.10):

$$\begin{aligned} D_{kij} &= H_{ki} L_{ki}^{-1} a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} (P_j^*)^{-\beta} F_{ij}^{-\delta_k} \\ &= H_{ki} L_{ki}^{-1} a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} S_j R_j^{-1} F_{ij}^{-\delta_k}. \end{aligned} \tag{3.18}$$

Equation (3.18), along with the accounting constraints $\Sigma_j^M D_{kij} = H_{ki}$ (i=1, . . . , M; k=1, . . . , K), and $\Sigma_k^K \Sigma_i^M D_{kij} = S_j$ (j=1, . . . , M) constitute the systemic spatial interaction model equivalent of (3.9) and (3.10). The system is still underidentified in the sense that there are $M^2 \cdot K+M$ endogenous unknowns (i.e., $M^2 \cdot K$ of D_{kij} and M of R_j) but only $M \cdot (M-1) \cdot (K-1)+(M-1)^2+(M-1)$ independent equations due to the redundancy in the accounting constraints.[21] The implications of this underidentification and the endogeneity of R_j for the econometric estimation of (3.18) will be discussed in chapter 4. The next section explores the relationship between (3.18) and several models discussed in chapter 2.

3.4. STRUCTURAL ASPECTS OF THE MODEL

For those familiar with the current spatial interaction modeling literature, model (3.18), along with the definitions of L_{ki} in (3.11) and R_j in (3.15), should bear a strong resemblance to the "doubly constrained" entropy maximization models of Wilson (1970, 1974). In fact, with relatively minor manipulation one may derive a model quite similar to (3.18) from the entropy maximization approach. Broadly define G_{kij} as a "generalized" cost measure inclusive of relocation costs, commuting costs, and the inverse of residential attractiveness attributes. In terms of (3.18), G_{kij} would be formally specified as follows:[22]

$$G_{kij} = \log[a_{kj}^{-1} Y_j^{-\alpha_k} T_{kj}^{\gamma_k} F_{ij}^{\delta_k}]. \tag{3.19}$$

Given (3.19), consider the following "etropy maximization" problem:

$$\max \log \frac{\left(\sum_k^K \sum_i^M \sum_j^M D_{kij}\right)!}{\Pi_{k,i,j}^{KM} D_{kij}!} \tag{3.20}$$

subject to

$$\sum_j^M D_{kij} = H_{ki} \qquad \forall\, k=1, \ldots, K;\ \ i=1, \ldots, M,$$

$$\sum_k^K \sum_i^M D_{kij} = S_j \qquad \forall\, j=1, \ldots, M,$$

$$\sum_i^M \sum_j^M D_{kij} G_{kij} = G_k \qquad \forall\, k=1, \ldots, K.$$

The solution to the mathematical programming model (3.20) yields the following model:

$$D_{kij} = H_{ki} L_{ki}^{-1} S_j R_j^{-1} \exp^{-\mu G_{kij}}, \tag{3.21}$$

where

$$L_{ki} = \sum_j^M S_j R_j^{-1} \exp^{-\mu G_{kij}},$$

$$R_j = \sum_k^K \sum_i^M H_{ki} L_{ki}^{-1} \exp^{-\mu G_{kij}}.$$

The closeness of (3.21) to (3.18) is evident when one notes that

$$\exp(-\mu G_{kij}) = (a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} T_{ij}^{-\delta_k})^{\mu}.$$

In fact, by setting $\mu = 1$, they are structurally analogous.

The relationship between (3.18) and (3.21) suggests that the concept of economic equilibrium bears some analogy to the physical "statistical mechanics" concept of equilibrium, but it also exposes some of the fundamental logical weaknesses in directly resorting to the entropy maximization approach rather than a careful economic derivation of a residential relocation model. Since several of the general logical problems of the entropy maximization approach have already been discussed in chapter 2, the comments here will be brief and focused on particular points. The most serious problem in (3.20)-(3.21) is the necessary exogenous specification of G_k as the total resource or cost restraint. The obvious general logical flaw arising from the fact that these costs should be the *endogenous* result of the relocation process is of particular concern here due to the inclusion of residential attribute preferences/aversions in G_{kij}. The household class-specific preference parameters of Y_j, estimates of which are generally sought as the empirical objectives in themselves, must be exogenously supplied as *inputs* into the entropy model (3.21). Exogenous specification of G_{kij} in (3.20)-(3.21) reduces the entropy model to but a parsimonious statistical description of expected intersubmarket relocation flows when marginal totals are known.

In addition, the entropy model (3.20)-(3.22) embodies many hidden implicit assumptions that were made explicit in the theoretical development of (3.1)-(3.18). The most obvious case is that of the postulate P1 of the household class invariant price elasticities of demand. This postulate was invoked to transform the theoretically grounded simultaneous equation system (3.9)-(3.10) into the spatial relocation model (3.18) and is open to theoretical and empirical scrutiny. The same postulate is embedded in (3.21)-(3.22) but is difficult to detect. Similar concerns may be directed toward the imposition of the short-run supply constraints S_j in (3.21). Whereas stock constraints are generally imposed in entropy models as simple accounting constraints to ensure structural consistency, in the economic derivation short-run supply constraints were imposed under explicit postulates regarding short-run market equilibrium. Invoking the concept of expected vacancy duration as the market force inducing supply price shifts, short-run equilibrium was defined in terms of stable vacancy duration/prices. In a closed system with a fixed stock this was shown to be equivalent to imposing the constraint of a constant level of occupied stock in all submarkets. Clearly, the value of the derivation (3.1)-(3.18) is that all assumptions are explicitly related to economic behavior and not lost within the human-molecular analogy of entropy maximization.

Before closing this section, we should reexamine the interpretation of equilibrium prices P_j^* in (3.17). Rearranging (3.17) and solving for P_j^* yields

$$P_j^* = (R_j/S_j)^{\beta}. \tag{3.22}$$

Equation (3.22) is quite consistent with intuition. Since R_j may be loosely interpreted as total ex ante demand for the attributes characterizing submarket j discounted by expected commuting and relocation costs, (3.22) suggests that higher (or lower) unit prices should prevail in submarkets, depending on the relative magnitude of ex ante demand to the fixed short-run supply. Also, a long-run equilibrium situation characterized by submarket invariant unit prices (i.e., $P_j = P_k$ for all $k,k=1, \ldots, M$) will occur only when R_j/S_j is invariant across submarkets. When this occurs, the original demand equations (3.9) are reduced to a model of submarket choice, based entirely on preferences for residential attributes characterizing the flow of housing services discounted only by commuting and generalized relocation costs. Since relative submarket prices should only reflect differentials in housing services in the long run, the model exhibits theoretical consistency.

The reasonableness of the expression for equilibrium prices is further supported by the works of Champernowne et al. (1976) and Neuberger (1971). Drawing on Neuberger's formulation of generalized consumer surplus measures of benefit, Champernowne et al. (1976) have shown that the entropy model (3.20)-(3.21) is structurally equivalent to the following maximization of "generalized" surplus formulation:[23]

$$\max -\frac{1}{\mu}\sum_k^K \sum_i^M \sum_j^M D_{kij}\left[\log\left(\frac{\Sigma_k^K D_{kij}}{H_{ki}S_j}\right) - 1\right] - \sum_k^K \sum_i^M \sum_j^M D_{kij}G_{kij} \tag{3.23}$$

subject to

$$\sum_j^M D_{kij} = H_{ki} \qquad \forall\, k=1, \ldots, K;\; i=1, \ldots, M,$$

$$\sum_k^K \sum_i^M D_{kij} = S_j \qquad \forall\, j=1, \ldots, M.$$

The dual variables of the supply constraint of (3.23) are equal to $\log R_j$ in (3.21) and hence to $\log R_j$ in (3.15). Thus, given our specification of G_{kij} in (3.19), R_j embodies a shadow price opportunity cost interpretation that is consistent with the direct short-run equilibrium interpretation of equilibrium prices in (3.22).

3.5. CLOSING REMARKS

The previous section has served to illustrate some of the structural similarities and differences of the model derived in this chapter with other modeling approaches. The chapter will conclude with a review of how the model satisfies the proposed structural criteria advanced at the end of chapter 2. Satisfaction of the second and third criteria has already been discussed in the course of the derivation. All household class relocation flows are explicitly modeled as *interdependent,* and structural consistency is ensured by the satisfaction of short-run equilibrium supply constraints. The first criterion was that all household moves should be *endogenously* determined as a function of housing market factors of all submarkets. Since the microlevel choice model was developed by including the household's current residence as a viable alternative intrasubmarket, household relocation flows in (3.18) are actually stayers. Summation of (3.18) over all submarkets *other* than the origin submarket *i* yields expected total movers:

$$\sum_{j \neq i}^{M} D_{kij} = H_{ki} \cdot \frac{\Sigma_{j \neq i}^{M} a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} S_j R_j^{-1} F_{ij}^{-\delta_k}}{\Sigma_{j \neq i}^{M} a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} S_j R_j^{-1} F_{ij}^{-\delta_k} + a_{ki} Y_{ki}^{\alpha_k} T_{ki}^{-\gamma_k} S_i R_i^{-1} F_{ii}^{-\delta_k}} . \tag{3.24}$$

L_{ki} has been separated into two parts in (3.24) to show the interdependence of external housing market factors and demand for housing of the current residence in the endogenous determination of movers households. Thus (3.24) establishes satisfaction of the first criterion, which maintains that the explanation of relocation logically encompasses *both* the explanation of mobility and location. The next chapter initiates the empirical estimation of the model developed in this chapter.

APPENDIX: NOTATIONS AND DEFINITIONS

i,j: Submarket indices encompassing *M* submarkets of an intraurban residential system. The *M* submarkets are jointly defined by *L* housing unit types and *N* geographic places.

k: Household class indices k=1, . . . , *K* encompassing all households residing in the residential system.

n,l: Indices characterizing the N geographic places and L housing unit types characterizing submarkets.

D_{kij}: The expected relocation demand for housing in submarket j by households of class k residing in submarket i at the beginning of the time period.

D_{kj}: The expected demand for housing in submarket j by all households of class k during a time period.

D_j: The expected total demand for housing in submarket j during a time period.

H_{ki}: The number of households of class k residing in submarket i at the beginning of the time period.

S_j: The occupied housing stock in submarket j at the beginning of the time period.

U_{kij}: The utility of housing services of submarket j of a household with characteristics X_k residing in submarket i.

V_{kij}: The nonstochastic strict utility for the housing services of submarket j of a household of class k residing in submarket i.

ϵ_{kij}: The stochastic utility component for the housing of submarket j of a household of class k residing in submarket i.

$\mathbf{X}_k$: A vector of demographic, socioeconomic, race, job location, and tenure characteristics of the kth household class.

$\mathbf{W}_j$: A vector of attributes that characterize the jth submarket.

$\mathbf{C}_{ij}$: A vector of attributes that characterize both the generalized relocation costs between submarket i and j and the commuting costs between the workplace of the kth household class and the jth submarket.

$P[j|i,k]$: The probability that a household with characteristics $\mathbf{X}_k$ residing in submarket i will choose to relocate in submarket j over a time period.

Prob[. . .]: The probability that. . . .

Y_j: A composite multiplicative variable of attributes of the housing stock and environmental attributes that produce the flow of housing services in the jth submarket.

P_j: The unit price of housing in the jth submarket.

P_j^*: The short-run "equilibrium" unit price of housing services in submarket j.

F_{ij}: A composite multiplicative variable of factors representative of the generalized costs of relocation between submarkets i and j.

T_{kj}: A composite multiplicative variable of factors characterizing the commuting costs between the workplace of the kth household class and the jth submarket.

a_{km}: A constant characterizing the basic attractiveness of the jth submarket to the kth household class.

NOTES

1. Kirwan and Ball (1973) have cited a formidable list of factors: (1) the durability of the stock, (2) the slow rate of supply adjustment, (3) lags and inertia in demand response, (4) high costs of information, (5) the significance of household and supplier expectations, (6) significant movement and transaction costs, and (7) the dual role of homeowners as consumers and producers. While these factors do not preclude the possibility of long-run equilibrium, their potential effects taken together cannot be a priori easily dismissed.

2. The distinction of the supply elasticity from the existing stock stems from the fact that existing structures may be upgraded/downgraded in response to price shifts. Ozanne and Struyk's (1976) estimated elasticity of 0.3 is a ten-year elasticity. The estimates of de Leeuw and Ekanem (1971) are probably over longer periods since the estimates were obtained by a cross-sectional analysis over metropolitan areas in which differentials may persist across several decades. Muth (1969) has produced contrasting evidence suggesting that stock may reach 90% of full adjustment within a period of six years.

3. The question of whether housing markets are segmented due to location rents is not fully resolved empirically. Whereas Apgar and Kain (1972) and Straszheim (1975) have found some empirical support for market segmentation, Schnare and Struyk (1976) did not.

4. Quigley's (1976) distinction between market prices and gross prices (as the sum of market price and commuting costs) is conceptually similar to the effects generalized costs should impart to relocation choice. By including commuting costs into the decision-making calculus, otherwise identical households at different workplaces may choose quite different submarkets.

5. In essence Curry (1972) and Moore (1970) argue that since housing opportunities are not uniformly distributed across space, observed relocation patterns will reflect the irregularities in this distribution. Curry (1972) further argues that housing submarket attributes should be spatially autocorrelated in a manner reflecting distance-decay properties. This issue will be discussed further in forthcoming chapters.

6. Consider a submarket of identical units in which V units are vacant. Suppose each day M units are filled by inmover households and M units are vacated by outmover households. If each vacant unit is filled on the basis of a queue, exactly V/M days are needed before a newly vacated unit is filled again. The stochastic formulation is similar except that waiting times are "expected" ones.

7. Note that submarkets are *jointly* defined by dwelling types and location. A single subscript is used to denote these joint dwelling-location combinations for notational simplicity.

8. It is implicitly assumed here that household travel other than commuting is spatially ubiquitous. But it should be noted that these types of accessibility may be treated as a residential attribute.

9. The term "effective" price as used here is *conceptually* similar to the concept of "gross" price in the location models of Quigley (1976), Ingram et al. (1972), and Williams

(1979). It differs not only because of the inclusion of generalized relocation costs, but also because no attempt will be made to translate nonmonetary components into dollars to calculate additively an estimated "effective" price.

10. Note that the postulated utility function is mixed because it contains both direct utility arguments in the form of submarket attributes and indirect arguments of income as a household attribute and prices due to resource constraints. C is specified as an inverse of costs since costs should be treated as providing disutility.

11. In terms of psychological models of choice behavior (Luce, 1959), C_{kij}^{-1} may be viewed as analogous to the concept of "response bias" when submarket attributes are treated as stimuli. Alternatively, C_{kij}^{-1} may be viewed as implicit "spatial discount" factors in the sense of Smith (1976). That is, households may implicitly discount their utility for submarkets by their disutility for costs incurred to realize consumption.

12. It should be noted here that this is only justified when choice set alternatives are feasible ones defined in accordance with budget constraints (see Talvitie, 1976). Also note that by the direct postulation of (3.1) as a mixed direct-indirect utility function, the choice of a particular submarket should fully determine the income available for the purchase of nonhousing goods and services.

13. See Stopher and Meyburg (1976) for a lucid demonstration of the mathematical steps necessary to arrive at the multinomial logit structure from (3.4) and the reciprocal exponential assumption.

14. Suppose that an individual is observed to be indifferent between choosing a train and a bus to work. Thus $P(\text{train}) = P(\text{bus}) = 1/2$. Suppose we introduce a third alternative, identical in all respects to the former except in the matter of color, where the choices are green and blue. Under the "independence of irrelevant alternatives" axiom, the relative probability of choosing a train over a blue bus must remain constant when the third alternative is added. Since one should be indifferent between the blue bus and the green bus, the axiom requires that $P(\text{train}) = P(\text{green bus}) = P(\text{blue bus}) = 1/3$. Intuitively, one would expect that the train would still be chosen half of the time since color is unlikely to be a meaningful distinguishing characteristic.

15. Although it is possible to utilize (3.6) in the model development, it adds complexities to the empirical estimation that will be shown to be already cumbersome with the simpler form of (3.5). Equation (3.6) is introduced to make all assumptions explicit in the model development.

16. Even if (3.10) were analytically tractable, only relative submarket prices could be identified because of the "accounting" constraints imposed in the general equilibrium analysis of a closed system of submarkets. Although the economic equilibrium conditions form a system of $M^2 \cdot K+M$ equations and endogenous unknowns, by the nature of the accounting constraints inherently imposed in such a closed system there are actually only $M \cdot (M-1) \cdot (K-1)+(M-1)^2+(M-1)$ independent equations. Since all H_{ki} are treated as given, the total occupied stock is known. Since all submarket equilibrium conditions imply an overall market equilibrium $D = S$, only $M-1$ of (3.10) are independent. For $K-1$ household classes $M \cdot (M-1)$ relocation flows determine the entire flow matrix, given only the marginal totals H_{ki}. For the last household class only $(M-1) \cdot (M-1)$ relocation flows need to be known to determine the rest since not only are the H_{ki} known, but also the marginal totals to any submarket can be determined from the total supply constraints S_j and the complete flow matrices of the other $K-1$ classes.

17. The familiar "aggregation problem" arising from the interrelations between microrelations and macrorelations is by no means unique to this model development, as it is common in the social sciences. For a formal discussion of aggregation issues see Theil (1954)

and Allen (1957). Meyburg (1977) and Cesario and Smith (1975) discuss aggregation issues in the context of spatial interaction-type modeling.

18. Lancaster (1966a) outlines three basic approaches to aggregation consistency. In the MICMAV approach, microtheory, macrotheory, and microvariables are taken as given, and consistent macrovariables are derived. The MIVMAC approach posits the microtheory, micro-, and macrovariables as given and derives a consistent macrotheory. Finally, the MAVMIC approach posits a macrotheory, macro-, and microvariables, and derives implicit restrictions on the microtheory.

19. The most common deterministic postulate is that of identical individuals (i.e., the "identity" postulate). Statistical postulates assume that the variation between individuals in the coefficient of some microvariables is independent of the variation between individuals of the microvariable itself. Linearity in functional form is generally crucial to the invocation of statistical postulates.

20. This is not at variance with empirical reality. Despite the significant turnover of households due to residential relocation, neighborhood change in terms of household class composition is a slowly evolving process as residential composition bears remarkable stability in the short run. See Gale and Moore (1973).

21. Note 16 explains this redundancy. It should also be stated here that the L_{ki} are not truly endogenous even though they contain R_j. Once all R_j are determined, L_{ki} may be calculated.

22. It is assumed here that submarket attributes are specified as attractions in (3.18) so that a higher value is more attractive. In (3.19) more attractive attributes are viewed as being less costly, for example, in terms of opportunity cost. By choosing more attractive submarkets, the opportunity cost of forgone submarket alternatives is less.

23. Note that the equivalence between (3.23) and (3.21) requires that μ be invariant across household classes. Champernowne et al. (1976) interpret μ as the "marginal utility of generalized expenditure." Given the specification of G_{kij} in (3.19), this restriction would appear identical with P1 of constant price elasticity.

4 PARAMETER IDENTIFICATION IN SYSTEMIC MODELS

The purpose of this chapter is to address some general issues underlying the empirical estimation of the model developed in the previous chapter. The systemic structure of the model is founded on an "accounting-type" structural consistency that requires delineation of all household classes and submarkets. Several general empirical problems associated with disaggregated systemic models are discussed in the first section of this chapter. A general multistage estimation procedure is outlined in the second section. By invoking certain structural properties of the model, the estimation procedure allows one to retain the systemic structure of the model from an econometric perspective even though the system may be incompletely specified from an accounting perspective. The third section summarizes the chapter.

4.1. EMPIRICAL PROBLEMS ASSOCIATED WITH SYSTEMIC MODELS

From a theoretical perspective the short-run model of residential relocation developed in chapter 3 exhibits several attractive attributes. On the one hand, the model is disaggregate in the sense that households are stratified into homogeneous classes and submarkets are defined in terms of homogeneous groups of dwellings by location. This disaggregation allows for specification of class-specific parameters. Upon estimation these parameters would provide important insight into household residential preferences and relocation behavior. On the other hand, the systemic nature of the model ensures the interdependency and structural consistency characteristic of short-run market equilibrium. While these features are theoretically desirable, there are serious practical empirical problems associated with the econometric estimation of complete systemic models such as (3.18) (including accounting constraints). These problems arise from two basic related sources. First, there is the "disaggregation problem" of sparse matrices and the geometric expansion of parameters in the course of household and submarket disaggregation. Second, there is the problem of incomplete data. The interdependency and structural consistency of (3.18) results from accounting-type constraints that require a *complete* delineation of *all* household classes and submarkets. For practical purposes of estimation such comprehensive data are unlikely to be available. Even if such data are available, the complete estimation of the model is likely to be too unwieldy to be feasible. The nature of these problems is discussed below.

4.1.1. Disaggregation Problems

The most fundamental decision faced in the empirical development of spatial models of relocation is the choice of appropriate aggregation levels for households and submarkets. Past residential mobility research (summarized in table 2.2) has suggested that a variety of demographic and socioeconomic factors are associated with differential movement propensities of the population. Likewise, past housing research (de Leeuw, 1971; Mayo, 1981) has shown that housing consumption expenditures vary with these same factors. It is essential to try to account for these differentials not only for the purpose of obtaining a better explanation and prediction of residential relocation, but also for assessing the impacts of policy actions on the relocation behavior of population subgroups.

Population/household heterogeneity is commonly dealt with in spatial models of residential mobility/location by disaggregation. Parameters of the model are estimated separately for each disaggregate household class. Unfortunately, as the number of household class dimensions increases (so that households are stratified into detailed classes), the number of different household classes expands in a geometric fashion. For example, consider the hypothetical stratification of household classes along the dimensions of tenure, race, and income. If tenure and race have dichotomous categories, and income is categorized into four classes, sixteen (i.e., $2 \times 2 \times 4$) household classes exist. If four household size and four duration-of-residence classes are added, the number of potential classes increases by a factor of sixteen to yield 256 household classes. Certainly this gross classification of households cannot account for all variations in household behavior. However, by an addition of just one more household class dimension of four or more categories, the number of potential household classes would exceed 1,000!

The basic problem in disaggregation is not simply the geometric expansion of classes. There is also the inevitable vast reduction in the expected observations or counts within any particular class as the number of potential classes expands. For every additional class specified, there is a proportionate increase in the amount of data required for parameter estimation. In spatial models, for which the number of households is limited by the spatial extent of geographic units of observation, the problem of sparse data is more pronounced. Whereas smaller spatial units are more amenable to the maintenance of some degree of internal homogeneity in terms of locational environmental attributes, their populations are not in general sufficiently large to sustain a detailed stratification of households into classes.

The problem of sparse data is particularly severe in the residential relocation model of this study. Submarkets are jointly defined by dwelling unit type and spatial location. The heterogeneity of the housing stock requires that dwelling units be stratified along the dimensions of structure type, size, tenure, and so forth. As in the case of household classes, the number of potential dwelling types expands geometrically as the various dwelling attributes accounted for expand. If M is the number of potential dwelling types and N is the number of spatial units, then $M \times N$ potential submarkets exist. Also, since the basic unit of observation of the model is the flow of households between any pair of submarkets during a time period, there are $(M \times N)^2$ potential intersubmarket flows for any household class. In a residential system of ten dwelling types, ten spatial units, and ten household classes, a comprehensive analysis of all possible intraurban relocation flows would require a matrix of 100,000 cells (i.e., 10 household classes $\times$ $[10 \times 10]^2$ submarket pairs). Since the occupied housing stock in the study area of Wichita in 1975 was only 98,757, it should be evident that even with this extremely limited disaggregation, only a small proportion of these cells would be sufficiently large to be of interest. The great majority of cells would be zeros, with many of the nonzero intersubmarket cells being trivial in size.

Although the problem of unwieldy class expansion in spatial models with heterogeneous populations has been widely recognized in the literature, little progress has been made toward its resolution. On a theoretical level Hyman (1970) has explored the possibility of translating certain discrete household class dimensions such as income class into continuous distributions. The potential benefits of such a translation would clearly be in the reduction of parameters to be estimated since only the parameters of the distribution function would have to be known to make aggregate predictions of spatial flows. Hyman's (1970) method presumes prior knowledge (or assumption) of the distribution of microlevel household parameters. However, the fact is that the estimation of these parameters is itself generally an objective, and mathematical intractability has precluded the operationalization of Hyman's approach thus far. An interesting contribution toward this end may be contained in the work of Choukroun (1975). Choukroun has invoked the theory of Laplace transformations to show that in certain spatial interaction models the functional form of the macrolevel generalized costs function implies a particular distribution of microlevel household generalized cost parameters.[1] Although it is uncertain whether the approach of Choukroun may be integrated with that of Hyman (1970), it is clear that future research on the "disaggregation problem" is warranted.

4.1.2. An Estimation Strategy

Given the severity of the disaggregation problem, it should be quite evident that all parameters of the relocation model (3.18) cannot be feasibly estimated from intersubmarket flow matrices. At any reasonable degree of disaggregation these matrices should be quite sparse. Clearly some trade-offs between theoretical specificity and empirical viability will have to be made. In the next section a multistage approach to parameter estimation is outlined in which an attempt is made to minimize these trade-offs. The basic strategy behind the multistage procedure is to invoke structural properties of the model as a means of *controlling* for the variation in certain model variables so that particular parameters may be estimated independently of the rest. Prior estimation of these parameters allows one to estimate residential attribute parameters from the total flow equations derived from the basic intersubmarket flow equation (3.18). The potential value of such a procedure is the vast reduction in potential cell classifications obtained by reducing the dimensionality of the intersubmarket flow matrix. Consider the previously cited example of a residential system classified by ten dwelling types and spatial units (i.e., 100 submarkets) and ten household classes, which produced a multidimensional intersubmarket matrix of 100,000 cells. When the household class intersubmarket model (3.18) is summed over all origin submarkets, that is,

$$\sum_{i}^{M} D_{kij} = D_{kj} = a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} S_j R_j^{-1} \sum_{i}^{M} H_{ki} L_{ki}^{-1} F_{ij}^{-\delta_k}$$

$$= a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} S_j R_j^{-1} M_{kj}, \tag{4.1}$$

the potential cell classification is reduced to 1,000 cells. Although still large, this number of cells clearly is more manageable than 100,000.

Obviously there are potential problems in estimating the model parameters by (4.1) and these deserve comment. First note that (4.1) is the result of summing the basic intersubmarket market over *all* origin submarkets of the residential system. In practice, obtaining such comprehensive data probably will not be feasible because of cost factors. Even if such data are available, more fundamental problems exist in delineating a complete and closed residential system. No residential system will ever be unambiguously defined and closed. Although researchers have commonly resorted to the use of dummy submarkets (or zones) to provide system closure (e.g., Wilson, 1970, chapter 5), these methods are ad hoc in nature. Since the most common situation is that an analyst will have access to a sample of intersubmarket relocations, any estimation procedure must be formulated in such a way to retain the systemic nature of the model from an econometric viewpoint.

A second point worthy of comment is that the systemic variables denoted M_{kj} and R_j^{-1} in (4.1) are for practical purposes "unobservable" variables. To compute values of M_{kj}, not only must one have data on the complete system, but also one must know, or have previously estimated, the parameters of F_{ij} and the household "choice sets" L_{ki}. To compute values of R_j, M_{kj} must be known. Note also that the household choice set L_{ki} in (3.11) and R_j in (3.15) are defined in terms of the same submarket attributes whose parameters are the object of estimation. We are faced with two interrelated problems. A fundamental theoretical problem is the a priori specification of choice set alternatives for L_{ki}. In the development of the theoretical model from economic choice theory in chapter 3, choice sets were theoretically defined as "feasible" submarket alternatives actually considered by households. In aspatial applications of choice theory for which choice alternatives are limited and well defined, specification of choice sets does not pose conceptual problems. In the context of spatial residential choice, however, there is no a priori way to delineate what submarkets are truly relevant for inclusion. Do all households face the same choice set of *all* submarket alternatives? Or do the choice sets vary by household class, or even origin residence submarket? The gravity of this choice set specification problem is suggested by the recent work of Stetzer (1976), who has compared six alternative methods of estimating models with the general distributive structure of the household class demand models (3.9) by simulation methods. All methods were found to be sensitive to misspecification of choice sets, particularly when the cell counts of flow matrices are small. As the accuracy of choice set specifications diminished on reduction of sample counts in flow matrices, all estimation methods produced increasingly downward-biased parameter estimates.

The related empirical problem is that even on specifications of choice sets, one is faced with the problem of "unobservable" variables in (4.1), defined in terms of parameters whose values are unknown. If use of (4.1) is to be a viable means of reducing the problem of sparse intersubmarket flow matrices, one must at least obtain estimates of the aggregate systemic variables M_{kj} independently of the individual residential attribute parameters that define it. Although the problems of identifying R_j have not been resolved, under the multistage procedure relative values of the unobservable variables M_{kj} may be obtained if the parameters of F_{ij} are estimated separately from the remaining parameters of the model. Since the parameters of F_{ij} cannot be estimated without direct use of intersubmarket household relocation data, one again is faced with the problem of sparse data at any reasonably detailed level of household disaggregation. However, a most attractive feature of the multistage estimation procedure is that all parameters of the model do not necessarily have to be estimated at the same household aggregation level.

The same structural properties of the model that allow for the separate independent estimation of the generalized cost parameters of F_{ij} allow for the postulation of parameter homogeneity across certain household class dimensions in this estimation in a manner that retains the internal structural consistency of the model. In other words, by explicit postulations of parameter homogeneity across particular household class dimensions, the parameters of F_{ij} may be estimated at a higher level of household aggregation than other model parameters, reducing the problem of sparse intersubmarket flow matrices. Once F_{ij} and M_{kj} are identified, the remaining parameters of the model other than R_j may be estimated from total flow equations (4.1) at finer levels of household aggregation. Since aggregation generally requires postulation of parameter homogeneity over *all* model parameters, a major advantage of the multistage procedure is that the degree of theoretical compromise is reduced since homogeneity is not postulated across all parameters.[2] Given these general comments about the empirical problems involving the estimation of the model, the following section provides an overview of the multistage estimation procedure.

4.2. A MULTISTAGE PROCEDURE FOR ESTIMATING DISAGGREGATED SYSTEMIC SPATIAL INTERACTION MODELS FOR INCOMPLETE OR ILL-DEFINED SYSTEMS

The purpose of this section is to present an overview of the process involved in estimating the parameters of the systemic model of residential relocation (3.18). It invokes certain structural properties of the model (shared by most gravity-type spatial interaction models) to *control* for variation in certain variables in the model, so that particular parameters may be estimated independently. Although the general procedure consists of three major interdependent stages, each stage incorporating the empirical results of earlier stages, certain problems peculiar to the study of residential relocation have made it necessary to estimate the model (3.18) in five stages. The procedure is presented here in the context of the model of this particular study. Yet the fundamental parameter identification logic is widely applicable to systemic gravity models in numerous fields of study. For example, the general approach discussed here has been applied with minor modification by Porell and Hua (1981) to estimate the generalized systemic gravity model of Alonso (1974) discussed in chapter 2 in the context of intermetropolitan migration. Since it is easy to lose sight of the logic behind the overall estimation procedure when immersed within the details of any particular stage of estimation, the outline here serves only to introduce the procedure in a unified manner. Detailed discussion of each stage is deferred to chapters 6 and 7.

4.2.1. The Cross-Product Ratio and Identification of the Parameters of F_{ij}

A useful structural property of the systemic model of residential relocation (3.18) and most gravity model formulations is that the parameters of the "generalized" relocation cost attributes of F_{ij} may be estimated *independently* from the remaining model parameters by invoking the cross-product ratio relationship.[3] For the purpose of simplifying notation, the relocation model of (3.18) may be restated by defining $U_{ki} = H_{ki}L_{ki}^{-1}$ and $V_{kj} = a_{kj}Y_j^{\alpha_k}T_{kj}^{-\gamma_k}S_jR_j^{-1}$ as follows:

$$D_{kij} = U_{ki}V_{kj}F_{ij}^{-\delta_k}. \tag{4.2}$$

By (4.2) the relative equilibrium flow of households of class k from any origin submarket i to any two submarkets j and n is independent of U_{ki} as shown in this ratio:

$$\frac{D_{kij}}{D_{kin}} = \frac{U_{ki}V_{kj}F_{ij}^{-\delta_k}}{U_{ki}V_{kn}F_{in}^{-\delta_k}} = \frac{V_{kj}F_{ij}^{-\delta_k}}{V_{kn}F_{in}^{-\delta_k}}. \tag{4.3}$$

The cross-product ratio is formed by dividing (4.3) by the relative flows to the *same* two destination submarkets j and n from a *different* origin submarket m:

$$\frac{D_{kij}/D_{kin}}{D_{kmj}/D_{kmn}} = \frac{(V_{kj}/V_{kn})(F_{ij}/F_{in})^{-\delta_k}}{(V_{kj}/V_{kn})(F_{mj}/F_{mn})^{-\delta_k}} = \left(\frac{F_{ij}/F_{in}}{F_{mj}/F_{mn}}\right)^{-\delta_k} = \left(\frac{F_{ij}F_{mn}}{F_{mj}F_{in}}\right)^{-\delta_k}. \tag{4.4}$$

For any $M \times M$ matrix of household class relocation flows, $(M-1) \times (M-1)$ independent cross-product ratios exist. So long as F_{ij} may be a priori specified as an exponential and/or power function of observable "generalized" relocation cost variables (or observable surrogates such as distance), and the parameters [i.e., δ_k in (4.4)] can be assumed to be invariant across submarket pairs, (4.4) may be readily translated into log-linear form and the parameters of F_{ij} estimated by linear regression methods.[4]

If (4.4) is to be a viable means for obtaining estimates in the face of sparse intersubmarket data matrices, some aggregation of household classes and submarkets is necessary. At this point it is useful to examine the postulates necessary for maintaining aggregation consistency if F_{ij} is to be estimated at higher aggregation levels than other parameters in the model. It must first be postulated that generalized cost attributes can be decomposed into two components: (1) intersubmarket generalized costs borne in relocation to specific submarkets; and (2) intrasubmarket generalized costs reflected in the strong locational inertia impeding household relocation anywhere. Let m and n denote the origin and destination spatial units of submarkets i and j in (3.18) or (4.2). Likewise, let r and s denote the origin and destination dwelling unit types of submarkets i and j. By this expanded notation the following general structure is postulated for F_{ij} for each household class k:

$$F_{ij} = \begin{cases} F_{mn} & \text{if } i \neq j \\ F & \text{if } i = j. \end{cases} \tag{4.5}$$

The postulated structure of F_{ij} in (4.5) entails the following assumptions: (1) Intersubmarket generalized costs are only a function of spatial factors and thus are independent of the dwelling unit types that partially define submarkets. (2) The locational inertia that impedes changes of residence is independent of both dwelling type and location. This amounts to postulating that demand for residential attributes should be reflected in the parameters of the residential attributes themselves. Any "taste biases" derived from residing in a particular dwelling type are assumed to be idiosyncratic, and thus are included in disturbance terms of the model.[5]

Given the postulated structure of F_{ij} in (4.5) and using the expanded notation differentiating dwelling type and location, it is possible to examine under what conditions household classes and dwelling types may be aggregated over and still maintain structural consistency. Restating (4.2) in expanded notation and dropping with kth household class subscript for notational simplicity yields

$$D_{mrns} = \begin{cases} U_{mr} V_{ns} F_{mn}^{-\delta} & \text{if } mr \neq ns \\ U_{mr} V_{ns} F^{-\delta} & \text{if } mr = ns. \end{cases} \tag{4.6}$$

Summation of (4.6) over all origin and destination dwelling types r and s is equivalent to aggregating over all dwelling types:

$$\sum_r \sum_s D_{mrns} = D_{mn} = \begin{cases} \left(\sum_r U_{mr}\right) \left(\sum_s V_{ns}\right) F_{mn}^{-\delta} & \text{if } mr \neq ns \\ \left(\sum_r U_{mr}\right) \left(\sum_s V_{ns}\right) F^{-\delta} & \text{if } mr = ns. \end{cases} \tag{4.7}$$

It should be obvious that given the postulation of (4.5) aggregation over all dwelling types does not violate the structural integrity of the cross-product ratio of (4.4). Taking the cross-product ratio of (4.7) for any two origin spatial units m and a and destination spatial units n and b yields

$$\frac{D_{mn}/D_{mb}}{D_{an}/D_{ab}} = \frac{(\Sigma_s V_{ns}/\Sigma_s V_{bs})(F_{mn}/F_{mb})^{-\delta}}{(\Sigma_s V_{ns}/\Sigma_s V_{bs})(F_{an}/F_{ab})^{-\delta}} = \left(\frac{F_{mn}/F_{mb}}{F_{an}/F_{ab}}\right)^{-\delta}. \tag{4.8}$$

Thus under the postulated structure of F_{ij} its parameters can be consistently estimated by the cross-product ratio when dwelling types are aggregated over.

In contrast, aggregation over certain household classes does not retain internal consistency without invoking an aggregation postulate. To illustrate, consider the aggregation of (4.2) over household classes k under the postulation of homogeneity for the parameters of F_{ij} (i.e., $\delta_k = \delta$). Summing (4.2) over all k classes yields

$$\sum_k D_{kij} = D_{ij} = \left(\sum_k U_{ki} V_{kj}\right) F_{ij}^{-\delta}. \tag{4.9}$$

Taking the cross-product ratio of (4.9) for submarkets i,j,m,n yields the following inequality:

$$\left(\frac{D_{ij}/D_{in}}{D_{mj}/D_{mn}}\right) = \frac{(\Sigma_k U_{ki} V_{kj})(\Sigma_k U_{km} V_{kn})}{(\Sigma_k U_{km} V_{kj})(\Sigma_k U_{ki} V_{kn})} \left(\frac{F_{ij}/F_{in}}{F_{mj}/F_{mn}}\right)^{-\delta} \neq \left(\frac{F_{ij}/F_{in}}{F_{mj}/F_{mn}}\right)^{-\delta} \tag{4.10}$$

It should be obvious from (4.10) that unless certain conditions exist (i.e., parameter homogeneity across household classes for the residential attributes comprising the V_{kj} terms) consistent aggregation cannot be guaranteed. In order to aggregate across household classes, a statistical aggregating postulate must be invoked. Glejser and Dramais (1969) have shown that if the variation in the products $(U_{ki}V_{kj})$ over household classes is relatively small, the following approximation may be invoked:

$$\sum_{k}^{K} U_{ki}V_{kj} \approx (K\text{-}2)\exp\left(\sum_{k}^{K} \log U_{ki}/K\text{-}2\right)\exp\left(\sum_{k}^{K} \log V_{kj}/K\text{-}2\right). \qquad (4.11)$$

It can easily be verified that by substituting the right-hand side of (4.11) into (4.10) the cross-product ratio equality will hold.

Even though it is difficult to evaluate the reasonableness of the approximation in (4.11) directly, inspection of the individual terms comprising U_{ki} and V_{kj} suggest that variations in their products largely result from variations in two factors: (1) variations in H_{ki}, or the number of households by class at origin; and (2) large variations in the residential attribute parameters of $Y_j^{\alpha k}$ across classes. Since no variation in H_{ki} will exist in the limiting case in which each household constitutes a separate class, the first factor should pose no problems when classes are finely stratified. Since the second factor actually pertains only to the household classes to be aggregated over, as long as key household attributes such as race and income are retained, class variations in residential attribute parameters should not be large. Thus (4.11) would appear intuitively reasonable. In any case, the key factor behind invocation of (4.11) is that any deviations from equality are not systematic. As long as deviations are uncorrelated with $(\Sigma_k U_{ki} V_{kj})$, invocation of (4.11) constitutes a meaningful statistical aggregation postulate (Lancaster, 1966a) that is far less restrictive than complete aggregation over all parameters.

The value of the cross-product ratio estimation is threefold. First, it allows for the independent estimation of generalized cost parameters by controlling for possible confounding effects of the spatial distribution of submarket attributes.[6] Second, with little additional postulation the parameters of F_{ij} may be estimated at a higher aggregation level than other model parameters to reduce problems of sparse intersubmarket data matrices. Third, parameter identification of F_{ij} is crucial to further parameter identification through other structural properties of the basic model (3.18). If the attributes characterizing generalized relocation costs are well defined, data are available, and a sufficient number of cells of the intersubmarket flow matrices are nonzero, all parameters of F_{ij} may be estimated by the loglinear version of (4.4), and one may proceed directly to the second major stage of the multistage procedure in section 4.2.3. Unfortunately this situation does not exist in the present study. Surrogates of intersubmarket generalized costs in (4.5) are available, but no data are available to specify the intrasubmarket generalized costs that impede relocations anywhere. Thus the next section describes an indirect method of estimating the parameters of $F^{-\delta}$ in (4.5).

4.2.2. Identification of the Parameters of F

Because of the problem of sparse data, the intrasubmarket generalized cost parameters could not be practically estimated in the first stage cross-product ratio estimation. Further, data were unavailable to characterize the relocation costs such as transactions costs, long-term occupancy discounts to renters, and the social and psychic costs of breaking the locational inertia associated with longer duration of residence. The purpose of this section is to outline the structural properties of the model (3.18) that allow for the indirect estimation of the aggregate effects of these costs.

The basic strategy underlying this stage of the estimation procedure is to isolate the intrasubmarket generalized cost component of the model so that relative estimates of $F^{-\delta_k}$ may be obtained across household classes. The point of departure is the basic intersubmarket equation (3.18). Summation of (3.18) over all destination submarkets *other* than the origin i yields total outmover households:

$$\sum_{j \neq i} D_{kij} = D_{ki*} = H_{ki} L_{ki}^{-1} \sum_{j \neq i} a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} S_j R_j^{-1} F_{ij}^{-\delta_k}. \tag{4.12}$$

Define

$$A_{ki} = \sum_{j \neq i} a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} S_j R_j^{-1} F_{ij}^{-\delta_k}; \tag{4.13}$$

then (4.12) may be restated as follows:

$$D_{ki*} = H_{ki} L_{ki}^{-1} A_{ki}. \tag{4.14}$$

Now summation of (3.18) over all origin submarkets *other* than j yields total inmover households:

$$\sum_{i \neq j} D_{kij} = D_{k*j} = a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} S_j R_j^{-1} \sum_{i \neq j} H_{ki} L_{ki}^{-1} F_{ij}^{-\delta_k}. \tag{4.15}$$

Define

$$B_{kj} = \sum_{i \neq j} H_{ki} L_{ki}^{-1} F_{ij}^{-\delta_k}; \tag{4.16}$$

then (4.15) may be restated as follows:

$$D_{k*j} = a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} S_j R_j^{-1} B_{kj}. \tag{4.17}$$

The estimation equation of this stage is the result of dividing the basic equation (3.18) for *intrasubmarket* flows (i.e., nonmovers) for any submarket i by (4.14) and (4.17). All other terms other than $F_{ii}^{-\delta_k}$, A_{ki}^{-1}, and B_{ki}^{-1} are canceled out, yielding the following equation:

$$\left(\frac{D_{kii}}{D_{ki*} D_{k*i}}\right) = A_{ki}^{-1} B_{ki}^{-1} F_{ii}^{-\delta_k}. \tag{4.18}$$

Given the postulated structure of F_{ij} in (4.5) in which intrasubmarket costs of stayer households are assumed to be independent of dwelling type and location (i.e., $F_{ii}^{-\delta_k} = F^{-\delta_k}$), (4.18) can be used to estimate the relative household class parameters of F as long as A_{ki}^{-1} and B_{ki}^{-1} are estimable up to a scale factor. Equation (4.18) serves to identify these systemic factors as well when it is applied *only* to *intersubmarket* flows. Since the intersubmarket generalized cost estimates of F_{ij} $(i \neq j)$ are obtainable by the cross-product ratio, calibrated values of $F_{ij}^{-\delta_k}$ $(i \neq j)$ are known. Rearranging (4.18) by placing all observed or calibrated factors on the left-hand side yields[7]

$$\left(\frac{D_{kij} F_{ij}^{\hat{\delta}_k}}{D_{ki*} D_{k*j}}\right) = A_{ki}^{-1} B_{kj}^{-1}. \tag{4.19}$$

Equation (4.19) may be translated into log-linear form and estimates of the relative values $(\hat{A}_{ki}/\bar{A})^{-1}$ and $(\hat{B}_{kj}/\bar{B})^{-1}$ obtained by the use of dummy variables in a statistical fixed effects model. $\bar{A}$ and $\bar{B}$ are geometric mean values of the individual origin and destination estimates of A_{ki} and B_{kj}. Estimation of (4.19) constitutes the second stage of the five-stage procedure.

Once estimates of the relative values of A_{ki}^{-1} and B_{kj}^{-1} are obtained using *intersubmarket* relocation flows in (4.19), their calibrated values can be used to identify relative household class estimates of $F^{-\delta_k}$ through (4.18). Rearranging

(4.18) by placing the calibrated estimates of $(\hat{A_{ki}}/\bar{A})^{-1}$ and $(\hat{B_{kj}}/\bar{B})^{-1}$ on the left-hand side yields

$$\frac{D_{kii}(\hat{A_{ki}}/\bar{A})(\hat{B_{ki}}/\bar{B})}{D_{ki*}D_{k*i}} = (\bar{A}\bar{B})^{-1}F^{-\delta_k}, \tag{4.20}$$

where $(\bar{A}\bar{B})^{-1}$ is a cross-sectional constant. Since the right-hand side of (4.20) only varies across household classes, relative estimates of $F^{-\delta_k}$ may be obtained by a log-linear dummy variable statistical fixed effects model applied to non-mover households. Since direct surrogates of the generalized costs creating locational inertia could not be obtained, estimation of (4.20) with stayer households provides an indirect approach for identifying the relative locational inertia associated with different household classes. Note also that the problem of sparse cells should not be as severe in (4.20) as in the cross-product ratio equation (4.4) since about 80% of all households do not move annually. Thus households may be disaggregated into finer classes in the estimation of (4.18) than (4.4). For the particular model of this study, (4.20) constitutes the third estimation stage.

4.2.3. Identification of Systemic Factors L_{ki} and M_{kj}

As noted earlier in the first section of this chapter, the formal structural consistency of systemic models such as (3.18) rests on a complete delineation of the system. In addition to the fact that generally only a sample of relocation data is available, the difficulty of a priori specifying household class choice sets L_{ki} suggests the importance of developing means of identifying systemic factors of ill-defined or incompletely specified systems. This section outlines structural properties (similar to those discussed in the last section) that may be invoked to identify absolute values of the systemic factors when the system is completely specified and relative values for incomplete specifications of the system.

A statistical two-way distribution model for each household class k that is structurally equivalent to (3.18) may be found by first multiplying both sides of the household class total inflow equation (4.1) by M_{kj}:

$$D_{kj}M_{kj}^{-1} = a_{kj}Y_j^{-\alpha_k}T_{kj}^{-\gamma_k}S_jR_j^{-1}. \tag{4.21}$$

Substituting the left-hand side of (4.21) for its right-hand side counterpart in the basic intersubmarket model (3.18) yields the following two-way distribution model:

$$D_{kij} = H_{ki}L_{ki}^{-1}D_{kj}M_{kj}^{-1}F_{ij}^{-\delta_k}. \tag{4.22}$$

The derived relationship of (4.22) is tautological in the sense that the ex post flow total D_{kj} is the logical summation of individual pair-specific flows D_{kij}. Although this tautological relationship provides no theoretical explanation of household relocation flows, the structural equivalence between (3.18) and (4.22) serves to provide a means of identifying L_{ki} and M_{kj}. By drawing on the works of Kirby (1970), Hua and Porell (1979), and Hua (1980), it can be demonstrated that L_{ki} and M_{kj} are cross-sectionally inversely proportional to the expected mean "generalized" costs borne by household flows of class k from or to any submarkets i and j, respectively. Since the individual attributes comprising F_{ij} are defined as measures of generalized costs, calibrated values of $F_{ij}^{-\delta k}$ are actually measures of the "facility" of relocation due to the inverse relationship between costs and demand. Thus $F_{ij}^{\delta k}$ is a measure of the "effective costs" of relocation. Under this reasoning, the expected mean generalized relocation costs borne by households of class k (inclusive of nonmovers) in any submarket i, or θ_{ki}, may be expressed via (3.18) as follows:

$$\theta_{ki} = \sum_{j}^{M} D_{kij} F_{ij}^{\delta k} / H_{ki} = H_{ki} L_{ki}^{-1} \left(\sum_{j}^{M} a_{kj} Y_j^{\alpha k} S_j R_j^{-1} T_{kj}^{-\gamma k} \right) / H_{ki}$$

$$= L_{ki}^{-1} \left(\sum_{j}^{M} a_{kj} Y_j^{\alpha k} S_j R_j^{-1} T_{kj}^{-\gamma k} \right). \tag{4.23}$$

Likewise, the expected mean generalized costs borne by the relocation flow of households of class k (inclusive of nonmovers) to any submarket j, or Δ_{kj}, is

$$\Delta_{kj} = \sum_{i}^{M} D_{kij} F_{ij}^{\alpha k} / D_{kj} = D_{kj} M_{kj}^{-1} \left(\sum_{i}^{M} H_{ki} L_{ki}^{-1} \right) / D_{kj} = M_{kj}^{-1} \left(\sum_{i}^{M} H_{ki} L_{ki}^{-1} \right). \tag{4.24}$$

It should be clear that the proportionality factors $(\Sigma_j^M a_{kj} Y_j^{\alpha k} R_j S_j^{-1} T_{kj}^{-\gamma k})$ in (3.17) and $(\Sigma_i^M H_{ki} L_{ki}^{-1})$ in (3.18) are *constant* for any cross section for a household class k. Further, the work of Hua (1980) demonstrates that they are equal to each other and equal to the square root of the total "generalized" costs borne by households of class k in *all* submarkets. Hua (1980) defines $Z_{kij} = D_{kij} F_{ij}^{\alpha k}$ as the total generalized costs borne by the relocation flow between submarkets i and j. He then postulates origin-destination independence in the distribution of Z_{kij} in a contingency table model:

$$Z_{kij} = \frac{(\Sigma_j^M Z_{kij})(\Sigma_i^M Z_{kij})}{(\Sigma_i^M \Sigma_j^M Z_{kij})}. \tag{4.25}$$

Suitable rearrangement of (4.23) yields the following distributive model:

$$D_{kij} = \left(\sum_i \sum_j Z_{kij}\right)^{-1} H_{ki} \theta_{kij} D_{kj} \Delta_{kj} F_{ij}^{-\delta_k}. \tag{4.26}$$

Comparison of (4.26) to (4.22) demonstrates the inverse cross-sectional proportionality of L_{ki} with θ_{ki} and M_{kj} with Δ_{kj} and the equality of the product of the proportionality factors in (4.23) and (4.24) with the total generalized costs in (4.26).

The significance of this result is that estimates of L_{ki} and M_{kj} may be directly obtained from the observed household class relocation flows and the calibrated measures of $F_{ij}^{\hat{\alpha}_k}$, obtainable via the cross-product ratio relationship. When a cross section is complete in the sense that all choice sets are clearly defined and all intersubmarket flows among all M submarkets of the residential system are obtainable, L_{ki} and M_{kj} may be directly estimated via equations (4.23) and (4.24). Alternatively, since choice sets are generally not known a priori and when only a sample of intersubmarket flows are available, the relative magnitudes of L_{ki}^{-1} and M_{kj}^{-1} across submarkets may be estimated by dummy variables in a log-linear statistical fixed effects model similar to (4.19). It is important to note here that once estimates of M_{kj} are obtained (even if only up to a scale factor), one may focus attention on the total flow equation (4.1) for further parameter identification. The obvious value is the vast reduction in potential cell classifications. The next section discusses problems of further identification in (3.18) and the last stage of the estimation procedure.

4.2.4. Identification of the Residential Attribute Parameters of Y_j

At this point we should take stock of the remaining problems of identification due to the systemic factor R_j in (3.18) arising due to the imposition of the short-run equilibrium conditions in the development of the theoretical model. Examine the structural definition

$$R_j = \sum_k a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k} M_{kj} \tag{4.27}$$

and note that unless estimates of the parameters of Y_j and T_{kj} are known, values of R_j cannot be computed. However, to avoid possible misspecification bias in the estimates of these parameters in the estimation equation, values of R_j must be specified. The root of this identification problem is the unobservability of unit prices of housing services in the absence of long-run equilibrium in the housing market. In long-run equilibrium the supply constraints imposed in (3.10) leading to (3.18) are not necessary since full supply adjustment would ensure that a single unit price of housing services will prevail. Hence submarket choice could be specified entirely on the basis of residential attributes.

The problems of identifying residential preferences in the absence of long-run equilibrium are not limited to this study. The residential location models of Herbert and Stevens (1960), Harris (1966), Wheaton (1974), and Anas (1973) all require the residential preference parameters of households as exogenous inputs to their models. Harris (1966) and Wheaton (1974) have devised approaches to isolate these preference parameters for independent estimation purposes, but their approaches rest on the *crucial* assumption of long-run equilibrium.[8] Since there are obvious logical problems in invoking a long-run equilibrium assumption to identify parameters to compute values of R_j arising due to long-run disequilibrium, their approaches cannot be pursued here.

Because the independent measurement of residential preferences and/or unit prices in long-run disequilibrium has proved to be an elusive goal thus far, there is no obvious way to identify all parameters of the model of this study without further postulates. Although R_j is not identifiable, rent/market price may be used as a residential attribute in the specification of Y_j as an "instrumental variable" that is likely to be correlated with R_j, but independent of disturbances in the model. As market prices/rents should reflect market valuations of attributes of Y_j and T_{kj} that partially define R_j in (3.15), and since supply constraints remain specified in S_j, consistent parameter estimates may be obtained from the following modified version of (4.1) in which rent as an instrumental variable is included as a component of Y_j:[9]

$$\left(\frac{D_{kj}(\hat{M}_{kj}/\bar{M})^{-1}}{S_j}\right) = a_{kj} Y_j^{\alpha_k} T_{kj}^{-\gamma_k}. \tag{4.28}$$

Since S_j is the observed occupied stock of submarket j at the beginning of the time period, it may be moved to the left-hand side of the equation. The $(\hat{M}_{kj}/\bar{M})$ are estimates of the relative values of $\hat{M}_{kj}$ produced by the fixed effects model of the fourth estimation stage. Since nonmovers are included in the total flow equation (4.28), households may be reasonably stratified into classes to identify differentials in residential preferences for policy purposes.

4.3. CONCLUDING REMARKS

This chapter has outlined a rather general multistage procedure for estimating systemic spatial interaction models when information about the system is incomplete or the system is ill defined. The general procedure consists of three

I. Estimation of $F_{ij}^{-\delta k}$ $(i \neq j)$

Estimation equation: log-linear regression of cross-product ratio equation (4.4)

Output: Parameters of intersubmarket generalized cost attributes and calibrated generalized cost scores

↓

II. Estimation of A_{ki}^{-1} and B_{kj}^{-1}

Estimation equation: log-linear fixed effects model (4.19) for intersubmarket relocation flows

Input: Calibrated intersubmarket generalized cost scores from stage 1

Output: Relative estimates of systemic factors: $(\hat{A}_{ki}/\bar{A})^{-1}$, $(\hat{B}_{kj}/\bar{B})^{-1}$

↓

III. Estimation of $F^{-\delta k}$

Estimation equation: log-linear fixed effects model (4.20) for nonmover households

Input: Estimates of $(\hat{A}_{ki}/\bar{A})^{-1}$, $(\hat{B}_{kj}/\bar{B})^{-1}$ from stage 2

Output: Parameters of intrasubmarket generalized costs

↓

IV. Estimation of L_{ki}^{-1} and M_{kj}^{-1}

Estimation equation: log-linear fixed effects model (4.22) for mover and nonmover households

Input: Calibrated generalized cost scores from stages 1 and 3

Output: Relative estimates of systemic factors: $(\hat{L}_{ki}/\bar{L})^{-1}$, $(\hat{M}_{kj}/\bar{M})^{-1}$

↓

V. Estimation of $Y_j^{\alpha k}$ and $T_{kj}^{-\gamma k}$

Estimation equation: log-linear regression of total flow equation (4.28)

Input: Estimates of $(\hat{M}_{kj}/\bar{M})^{-1}$ from stage 4

Output: Residential attribute preference parameters

Figure 4.1. Summary of Multistage Estimation Procedure

major stages: (1) the estimation of generalized cost parameters by the cross-product ratio regression; (2) the identification of systemic variables by statistical fixed effects models; and (3) the estimation of attribute parameters controlling for systemic variables.[10] The peculiar nature of this study has made it necessary to use five stages. The linkages between the five stages are summarized in figure 4.1. The next three chapters describe a case study application of the model to household relocation in Wichita, Kansas. Chapter 5 describes the study area, data, and household class and submarket specification. Chapter 6 presents the first three estimation stages and chapter 7 the last two stages.

NOTES

1. For example, under a specific model Choukroun (1975) shows that homogeneous microlevel generalized cost parameters are consistent with an exponential macrolevel cost function. A macrolevel power function is shown to be consistent when microlevel cost parameters are distributed according to a gamma distribution.

2. It should be noted that homogeneity across subsets of parameters may be invoked in any stratified model by parameter restrictions. The difference between this common approach and what is discussed here is that the dependent variable is aggregated over in the multistage procedure. In the conventional approach of parameter restriction the dependent variable cannot be aggregated over unless parameter homogeneity is postulated across *all* parameters by class.

3. The heritage of the cross-product ratio concept is in the statistical analysis of contingency tables as a measure of statistical independence between row and column classifications. See Mosteller (1968) and Bishop et al. (1975). Hua and Porell (1979) have shown that most gravity-type models share this structural property whereby all place-specific variables are canceled out by the cross-product ratio.

4. Even under the simplest specification of disturbance terms in the basic model (3.18) or (4.2), the cross-product ratio produces a composite ratio of disturbances that do not satisfy conventional independence assumptions. Although unbiased parameter estimates can still be obtained, the variances of these estimates may be biased. The trade-offs will be discussed in chapter 6 in further detail.

5. Note that factors such as transaction costs differentials in owner versus rental housing tenure and duration of residence effects may be specified as household class attributes. Also, "taste bias" is meant to imply any systematic deviation in demand for residential attributes acquired from current or past housing consumption. For example, since demand for space is a function of family size and income, past overconsumption of space is assumed not to systematically bias current residential choice toward overconsumption of space.

6. The issue will be discussed further in chapter 6.

7. Note that (4.19) is stated in terms of expected demand. However, observed relocation flows can be used for D_{kij}, D_{ki*}, and D_{k*j}.

8. In essence, the approach of Harris (1966) and Wheaton (1974) is one in which the nonhousing and commuting expenditures of households are regressed upon residential attributes characterizing housing consumption. Under the assumption that all households of a class experience the same overall utility level in long-run equilibrium, the intercept term of the regression serves as an estimate of this utility level.

9. Instrumental variables are commonly specified in situations such as "errors-in variables" situations in which disturbance terms of the model are correlated with independent variables. In a strict technical sense the use of price may be inappropriate since it itself is an endogenous outcome of the market and hence may be correlated with disturbance terms. It is used here for two reasons. First, no other viable alternative existed. Second, since price is the result of the overall demand by *all* household classes, price may reasonably be treated as exogenous to any *particular* household class if classes are sufficiently disaggregated.

10. Porell and Hua (1981) have used the same basic steps as outlined in this chapter to estimate the systemic model of Alonso (1974) described in chapter 2. In the case of the Alonso model, parameters of the systemic variables themselves are empirically estimated in the third stage.

5 EMPIRICAL ESTIMATION: Study Area, Data, and Model Specification

This chapter introduces the empirical estimation of the model. Some general characteristics of the study area, Wichita, Kansas, are discussed in the first section. The primary data source, the Intergovernmental Annual Enumeration Survey of Wichita-Sedgwick County, Kansas, is briefly discussed in the second section. General issues pertaining to mover household definitions and household class and submarket definitions are presented in the third and fourth sections. The general specification of disturbance terms for the estimation procedure is discussed in the fifth section and is followed by closing remarks.

5.1. CHARACTERISTICS OF THE STUDY AREA

The model of this study has been empirically estimated from a sample of inter-submarket household relocation flows within the central city of Wichita, Kansas, Standard Metropolitan Statistical Area (SMSA). In 1970, the SMSA population of 389,352 ranked it 79th among the 243 SMSAs in the United States. The central city of Wichita had a population of 276,554 in 1970. The percentage of SMSA population residing in the central city of 71% exceeds that of most SMSAs of all sizes. Data from the 1970 census showed that an average central city population comprised about 46% of the SMSA population among all size classes of SMSAs. In terms of the U.S. Bureau of the Census definition of urbanized population (see U.S. Bureau of the Census, 1970), the central city of Wichita encompassed nearly 83% of the 335,709 urbanized population of Wichita in 1970. In terms of population density, the central city population density of 3,197 persons per square mile is more than 68 times the noncentral city population density of 48 persons per square mile. For the combined population of all 243 U.S. metropolitan areas in 1970, the central city population density was nearly 22 times greater than that of noncentral city population. These figures suggest that the city of Wichita comprises the bulk of the "urban housing market" of Wichita, Kansas, and that it is most reasonable to assume that the central city of Wichita dominates the operations of the Wichita housing market.

Historically, population trends in the city of Wichita have oscillated as illustrated in table 5.1. After reaching peaks in 1969, the city population experienced declines in the early seventies. The population declines from 1969 to 1974, however, do not reflect a declining housing market in Wichita. Whereas the central city population declined by 11,885 (or 4.3%) from 1970 to 1975, the number of central city households rose by 6,046 (a 6.5% increase) over the same time period, totaling 98,797 in 1975. This disparity is largely attributable

Table 5.1. Historical Population Trends in Wichita, Kansas

Year	*Wichita City*	*Change (%)*
1950[a]	192,520	
1960[a]	244,500	+39.0
1965	267,949	+9.5
1966	269,996	+0.8
1967	281,110	+4.1
1968	282,381	+0.5
1969	282,989	+0.2
1970[a]	276,554	-2.3
1971	263,297	-4.8
1972	263,801	+0.2
1973	262,766	-0.4
1974	261,846	-0.4
1975	264,669	+1.1

Source: Wichita-Sedgwick County Metropolitan Area Planning Department (1977).

[a]The 1950, 1960, and 1970 estimates are those of the U.S. Bureau of the Census. The other years are those estimated by the Wichita-Sedgwick County Metropolitan Area Planning Department.

to current demographic trends toward smaller households. Overall, the population of persons and households in Wichita has been remarkably stabe over the last decade, and this is reflected in the comparability between 1965 and 1975 populations in table 5.1.

Although quite moderate, recent shifts in the spatial distribution of Wichita's city population have conformed to the "typical" decentralization patterns of the U.S. metropolitan areas. From 1970 to 1975, the bulk of growth has occurred in perimeter areas of the city. Concurrently, the older established residential areas in the core have experienced moderate population declines. The spatial pattern of residential segregation by race in the city of Wichita has been remarkably stable from 1950 to 1970, despite a twofold increase in the percentage of nonwhite population over the period.[1] The bulk of nonwhite population remains spatially concentrated in northeastern sections of the city.

The general population characteristics of Wichita are representative of a large number of U.S. metropolitan areas. In light of its population size and its stable and moderate growth in recent years, the city of Wichita is well suited to the empirical application of the short-run equilibrium model of intraurban residential relocation.

5.2. THE INTERGOVERNMENTAL ANNUAL ENUMERATION SURVEY OF SEDGWICK COUNTY, KANSAS

The major source of data for this study originated from the Annual Intergovernmental Enumeration Survey of Wichita-Sedgwick County, Kansas. A short description of the annual survey is given here. For a more comprehensive discussion of the survey, see Gschwind (1973). Kansas state law requires that the assessor in each county in the state conduct an annual census of the population for the purpose of aiding the state government allocate funds to local governments. While the population of some counties is estimated indirectly through surrogate measures, Sedgwick County (the central county of the Wichita SMSA) performs annual 100% survey enumerations of the population.

Through an intergovernmental effort with funding from various local government agencies, the census enumeration was expanded in 1971 to collect household and dwelling unit information in addition to the name, age, and sex information required by state law. Most of the additional household information was socioeconomic (e.g., race, income); some information, however (e.g., the number of dogs or cats per residence), was directed at serving the particular needs of local government agencies. The dwelling unit information was more limited in scope and encompassed only general housing characteristics such as structural type, exterior building condition, number of bedrooms, and value or rent classes for ownership and rental housing, respectively. Despite minor modifications in the range of particular items covered in the survey, and the subclassifications within items, the general content of the survey has remained relatively unchanged since its inception.

Stephen Gale of the University of Pennsylvania and Eric Moore of Queens University have directed a research project creating two longitudinal data files organized by household and dwelling unit from the massive individual survey data accumulated from 1971 to 1976.[2] Each of the two files contains one- to six-year residence histories of households residing in Sedgwick County from 1971 through 1976 and enumerated in the 100% survey. The dwelling unit file is organized by dwelling unit and contains occupancy histories of all dwelling units existing in Sedgwick County during the six years. Since the focus of this study is the residential relocation of households, the household file, containing residence histories of individual households, provided an easy means of acquiring household relocation data by comparison of time sequential household records.

The household and dwelling unit files used in this study are by far the richest data set to date for the study of intraurban residential relocation. Data relating to intraurban household relocation have always been difficult and costly to acquire. The three major sources of data for intraurban mobility studies have been national census data, indirect information sources, and special surveys. Each data source differs in its degree of accuracy, spatial extent, and degree of detail with respect to households and dwelling units. National census data are extremely crude for the study of intraurban mobility. Aside from the problem of the five-year time interval in which the likelihood of multiple moves occurring is significant, no information is generally available on the specific tract or dwelling type of origin residence. Census data are retrospective in nature. Households are queried with respect to their location five years ago. All household and dwelling information pertains to the current relocation destination and thus is ex post. Indirect information sources such as commercial city directories, school records, telephone directories, public utility connection records, and electoral registers allow for the annual prospective analysis of intraurban household relocation, but they are ladened with serious shortcomings. One of the basic problems with these sources is that each is incomplete and biased toward particular segments of the population. For example, public utility connection records do not account for renter households whose utilities are included in the rental payments. Second, there is the lack of detail with respect to household and dwelling unit information. Household relocations are generally only detectable by tracing the last names of households across two time periods, so that detailed household and dwelling unit information must be acquired in other ways. Finally, special surveys are a third method of obtaining household relocation data. Although large-scale special surveys allow for great flexibility in the level of household and dwelling unit detail, the procedure is extremely costly and time-consuming. The use of location as a basis for sampling the household population places great demands on required sample sizes. Unless households are queried as to all relevant information on their prior residence, a prospective analysis would require multiple surveys.

The longitudinal household file used in this study has three distinctive features that are not generally found in any of the conventional data sources in the United States. First, the household enumeration is a 100% survey capturing nearly all segments of the population. Second, the survey contains substantial detailed household and dwelling unit characteristics. Finally, because of the longitudinal nature of the data, households may be observed at multiple times, allowing for the prospective analysis of intraurban residential relocation.

5.3. MODEL SPECIFICATION: GENERAL ISSUES

This section discusses the specification of household classes and submarkets used in the empirical analysis. Before examining the particular class and submarket stratifications, however, several general issues regarding the specification of mover households should be discussed.

5.3.1. Temporal Dimensions of the Model

The empirical analyses are conducted within a one-year cross-sectional time period from 1975 to 1976. Since households are observed only at two discrete times, multiple relocations occurring within this one-year period cannot be discerned. The choice of an annual time period not only minimizes the possibility of multiple moves, but also the assumption of a fixed housing stock is more defensible in an annual analysis. In 1975 and 1976 the occupied housing stock in Wichita was 98,797 and 100,507, respectively. Thus, the percentage increase in occupied stock was only 1.8% over the time period. In spite of the theoretical benefits of an annual time specification, there are obvious drawbacks. The number of households moving in any single year is small. In fact, because of the small number of annual relocations in the ownership market, the empirical work had to be focused only on the rental housing market, thus precluding the investigation of relocation differentials across tenure mode and the analysis of tenure changes. Ownership and rental markets, however, are sufficiently independent submarkets that can and have been commonly treated separately in the literature.

5.3.2. The Measurement of Household Relocation

An important distinction in the study of residential relocation is whether the analysis is prospective or retrospective in nature. In retrospective studies households are observed only at the end of some time period, and relocation is detected by query of previous residence. The empirical study here is prospective since households are observed at two times. One of the major advantages of a prospective analysis is that explanatory variables may be causally specified at the beginning of the time period. However, changes in household status or composition occurring between two times due to vital events of life (e.g., marriage, divorce, birth, death) complicate the measurement of relocation. The purposes of this section are to explain how various types of relocation were measured in this study and to present the limitations of the measurement process.

Households were defined in the survey as persons occupying a separate dwelling unit.[3] Households were assigned identification numbers on the basis of the "head of household."[4] Operationally, household relocations were identified by comparing dwelling unit identification codes of households at two sequential times (1975, 1976). A relocation was recorded when a change in occupied dwelling was identified. For households not undergoing a change in household status, no ambiguities were introduced into the measurement of relocation by this headship-matching procedure. However, for households undergoing a change of status by merger or dissolution, some ambiguities did arise. In the case of a merger of two independent households *A* and *B* over the period, either one relocation or no relocation might be recorded. If household *A* physically relocated to the dwelling currently occupied by household *B and retained headship* after the move, a relocation of household *A*, accompanied by an increase in household size, would be recorded. No household record should exist for household *B* in the second time period, and hence the termination of household *B* cannot be distinguished from an outmigration from the system. On the other hand, if household *B* were to retain headship after the merger with household *A*, no relocation would be recorded. Household *A* would be recorded as terminated even though a physical relocation had occurred.[5]

In the case of a dissolution of a single household into two independent households *C* and *D* over the period, similar ambiguities exist. If, for example, the head of household *C* prior to dissolution physically relocated and retained headship, a relocation of *C* accompanied by a change in household composition would be recorded. If *C* did not hold headship prior to the dissolution, then a household record for *C* would only exist in the second time period. This situation would be indistinguishable from an immigration to the system or a "de novo" household formation.

Thus, intraurban relocations encompass only those moves in which a headship is retained at two times. All situations in which a household record existed only in 1975 (but not 1976) were treated as exits from the system, regardless of actual cause. Likewise, all situations in which a household record only existed in 1976 (but not 1975) were treated as entries into the system. In accord with these recording rules, the next section discusses household class specification.

5.4. HOUSEHOLD AND SUBMARKET SPECIFICATION

5.4.1. Household Class Specification

It has already been noted that the scarcity of owner household relocations precluded the investigation of homeowner relocation and renter households switching tenure on relocation. Thus, the empirical analysis is confined to relocations within the rental market. Also, because of problems of sparse data, household class disaggregation varied across different stages of the multistage estimation procedure outlined in chapter 4. In this section, the basic household class stratification over which classes are aggregated in particular stages is presented.

As there is no theory to guide one in the choice of the most appropriate household class stratifications, any specification is ultimately dictated by considerations of data availability and findings of past research. In the context of this study, one must resort to the associations between key household characteristics and movement propensities found in past residential mobility research. In the interest of brevity, the rationale behind particular household attribute specifications is not discussed here. Table 2.2 was presented to summarize Quigley and Weinberg's (1977) review of past findings in the residential mobility literature.

Table 5.2 illustrates the general household class attribute specifications used in various stages of the estimation procedure. There are six renter household class dimensions: (1) race of the head of household, (2) income class, (3) household size class, (4) age class of the head of household, (5) duration of residence class, and (6) change in household size class. Note that since data on the workplace of heads of household were unavailable, households could not be stratified by workplace. This is not likely to be a matter of serious concern, however, due to the relatively small variance in peak hour travel times in Wichita. Travel time surveys by the Metropolitan Area Planning Department of Wichita as recently as 1976 have noted that in peak traffic periods, travel time from all locations in the city to the central core (the predominant employment center) did not exceed fifteen minutes! With such ubiquitous accessibility, it is unlikely that workplace accessibility considerations are dominant factors in relocation choices.[6]

Table 5.2. Renter Household Class Specification

Attribute	*Classes*
Race of head of household	White Nonwhite
Income class[a]	\$0–4,999 \$5,000–9,999 \$10,000–14,999 \$15,000–19,999
Household size	1–2 members 3–4 members ≥5 members
Age class of head of household	≤29 years 30–59 years ≥60 years
Duration of residence	0–5 years ≥6 years
Household size change	Increased from t to t+1 Decreased from t to t+1 Constant from t to t+1

[a]The choice of income class intervals was dictated by the classes contained in the survey data.

With two exceptions, all classes in table 5.2 were defined at the beginning of the time period, or 1975. Household size and changes of household size were specified using end-of-period data. Because of the importance of household size in determining demand for space upon relocation and the findings of past research suggesting that many moves are the result of a rigid stimulus from some vital event of life leading to a change in household size, sole specification of beginning-of-period characteristics would ignore information that might be most relevant in the explanation of a relocation.

Despite the crude level of stratification in table 5.2, 432 potential household classes still exist.[7] Due to obvious problems of sparse data, the actual number of classes defined in any particular estimation stage was considerably smaller. Details of the reasoning behind aggregation over subsets of the 432 classes defined in table 5.2 are deferred to discussion of the estimation of particular stages in forthcoming chapters.

5.4.2. Submarket Specification: Dwelling Types

Because of the heterogeneity of the housing stock, it is essential that dwelling units be stratified into submarkets on the basis of dwelling unit attributes. Although residential submarkets have been defined as groups of internally homogeneous dwelling units that yield identical flows of housing services, limitations of the data and the unwieldy geometric expansion of dwelling types preclude any detailed specification of dwelling types. In the same vein as the previous specification of household classes, a general disaggregation scheme for the rental market is presented. In specific parts of the estimation for which data were sparse, dwelling types were aggregated from this initial specification.

Because of the lack of attention given to characteristics of housing in the study of residential relocation, there is little past research other than the many hedonic house price studies (e.g., Ball, 1973) on which to draw in identifying key dwelling characteristics for the stratification of dwelling types. Because of the diversity in the specific measures of dwelling unit attributes in these studies, it is difficult to cite particular works to support the specification of dwelling unit characteristics. Indeed, nearly all works have suggested that structure type, quality, and size reflect key components of flows of housing services. Accordingly, the following specifications in table 5.3 may capture the most essential characteristics differentiating the rental housing stock.

Structure Type. Nearly all empirical house price studies have suggested that the gross price of housing is determined by its structure type. Single-family and multiunit structures provide different quantity and composition of housing services in terms of many dimensions such as privacy, convenience, yard space, and so forth, and are the basic structural dwelling types delineated in this study.

Number of Bedrooms. Nearly all house price studies suggest that some measure of living space (e.g., floor space, number of rooms, number of bedrooms) is a highly important factor differentiating flows of housing services across dwelling units. Since a household's demand and choice of submarket should be a function of household size (reflecting space requirements), dwelling types should be stratified by some measure of size. As a surrogate of dwelling space, three bedroom classes (table 5.3) were defined roughly in accordance with a sense of space requirements for the household size classes of table 5.2.

Exterior Dwelling Condition. Housing quality is a catch-all term that describes the physical condition of, or amenities produced by, various attributes of a dwelling unit. Although difficult to define empirically in an objective manner, housing quality is an important attribute in the flow of housing services. The

Table 5.3. Dwelling-Type Specification

Attribute	*Classes*
Rental value class[a]	\$0–99/month \$100–199/month
Number of bedrooms	1–2 bedrooms 3 bedrooms ⩾4 bedrooms
Structure type	Single-unit structure Multi-unit structure
Exterior building condition	Sound: rating 1–5 Deteriorated or dilapidated: rating 6–10

[a]The value class intervals were defined by aggregating over the \$50/month classes contained in the survey.

only surrogate measure of quality (other than that reflected in the gross rental value) available for delineation of dwelling types was an "exterior building condition" rating made by enumerators conducting the Wichita survey. These ratings were assigned in accordance with the physical exterior condition descriptions that are illustrated in table 5.4. Although the limitations of subjective ratings of condition or quality measures are well known, the use of the dichotomous categories (suggested by the Sedgwick County assessor) in table 5.3 should reflect the more extreme disparities in the physical condition of dwelling units.

Gross Rental Value. Even though specifying unit prices in the model would have been desirable, only gross rental class data were available. Ideally, gross rental value should embody both unit prices and quantity flow of housing services, but it still serves as an important dwelling attribute due to resource constraints of households. Since households must consume any bundle of housing services in its entirety, gross rental value characterizes the expenditure necessary to consume an entire bundle.

The four basic dwelling dimensions of structure type, number of bedrooms, exterior building condition, and rental class yield twenty-four different dwelling unit types. In certain stages of empirical estimation, categories were aggregated over because of problems of sparse data. Discussion of this aggregation is deferred to later chapters.

Table 5.4. Exterior Building Condition Rating Sheet

Examine the outside walls, roof, eaves, troughs, doors, windows, yard, lawn, and shrubbery at this address. Carefully read down the scale until you come to the description that most closely fits the exterior appearance of the dwelling. If you have trouble choosing between a pair of numbers, read the description above and below the description you are considering, and choose the number in the pair that is closest to the above or below description. Indicate the number that comes closest.

1	Overall excellent condition, like-new appearance, desirable, picturesque condition
2	
3	Exterior walls, roof, eaves, doors and windows with uniform, smooth surfaces, strong, unfaded color: all exterior items well matched, completed and intact
4	
5	Exterior walls faded, dull: roof, eaves, door and window surfaces irregular, tarnished, weathered; windows lacking luster or gloss; one or more conditions in need of repair
6	
7	Spots on exterior walls and trim that are peeling, chipping, or cracking; eaves or roof crooked, rusted, bent, or with ragged edges; windows and doors soiled, rough, work; repairs definitely in order
8	
9	Larger surface areas are generally bare, peeling, cracking, exterior walls or roof show holes, open cracks, or missing materials: parts of eaves or roof loose, hanging, or missing; rotten window sills, or frame; deep wear on stairs or doorsills
10	Overall critical disrepair, destruction, ruin, abandonment or near-abandonment condition

Source: Langston, Kitch and Associates (1974).

5.4.3. Submarket Specification: Spatial Units

In light of the problem of geometric expansion of submarkets with increasing numbers of spatial units, a sample of thirteen spatial units was chosen for the empirical analysis. Since smaller spatial units generally did not have a sufficient household population to sustain disaggregation of households into classes, most spatial units were formed as groups of contiguous census tracts that were relatively homogeneous in terms of median income, rent and value levels, and racial composition.

In selecting spatial units, considerable attention was given to several important factors, including the noncontiguity of spatial units, the range of racial composition represented in the sample, and the geographic distribution of the spatial units. First, only noncontiguous spatial units were chosen. Since the generalized cost indices F_{ij} incorporate spatial distance between submarkets as a surrogate of information availability or awareness, the selection of noncontiguous spatial units minimizes the ambiguity of boundary situations in which intrasubmarket distances may vastly exceed intersubmarket distances at the contiguous boundary. In addition to noncontiguity, a spatial distribution that encompasses most radial sectors and concentric zones of the city was sought. Because historical growth patterns of the city have reflected both sectoral and zonal outward growth, the sample should reflect these patterns of development. More important, a sample of noncontiguous units that are not spatially concentrated should reduce the likelihood of problems emanating from the spatial autocorrelation of population and housing characteristics.[8] Finally, consideration was given to the range of racial composition levels in spatial unit selection in light of the many empirical works (e.g., Kain and Quigley, 1975; Straszheim, 1975; King and Mieszkowski, 1973) which posit that discrimination in the housing market underlies residential segregation patterns by race. Spatial units were selected so that no spatial unit was composed of one racial group; this was done to ensure a sample of units where households of either race should exhibit a nonzero probability of choosing to reside there.

Research works such as Taylor (1969), Monmonier (1973), Golob et al. (1974), and Masser and Brown (1975) have examined objective aggregation or clustering procedures for grouping spatial units, but the complexity due to the multiple criteria used for selection of spatial units precluded their use here. The sampled spatial units are illustrated in figure 5.1. The number of households, media rent, median house value, median income, and nonwhite racial composition of all tracts included within the sample is included in table 5.5. These figures suggest a considerable amount of internal homogeneity in the spatial characteristics of submarkets in spite of the restrictions of the data upon defining spatial neighborhoods.

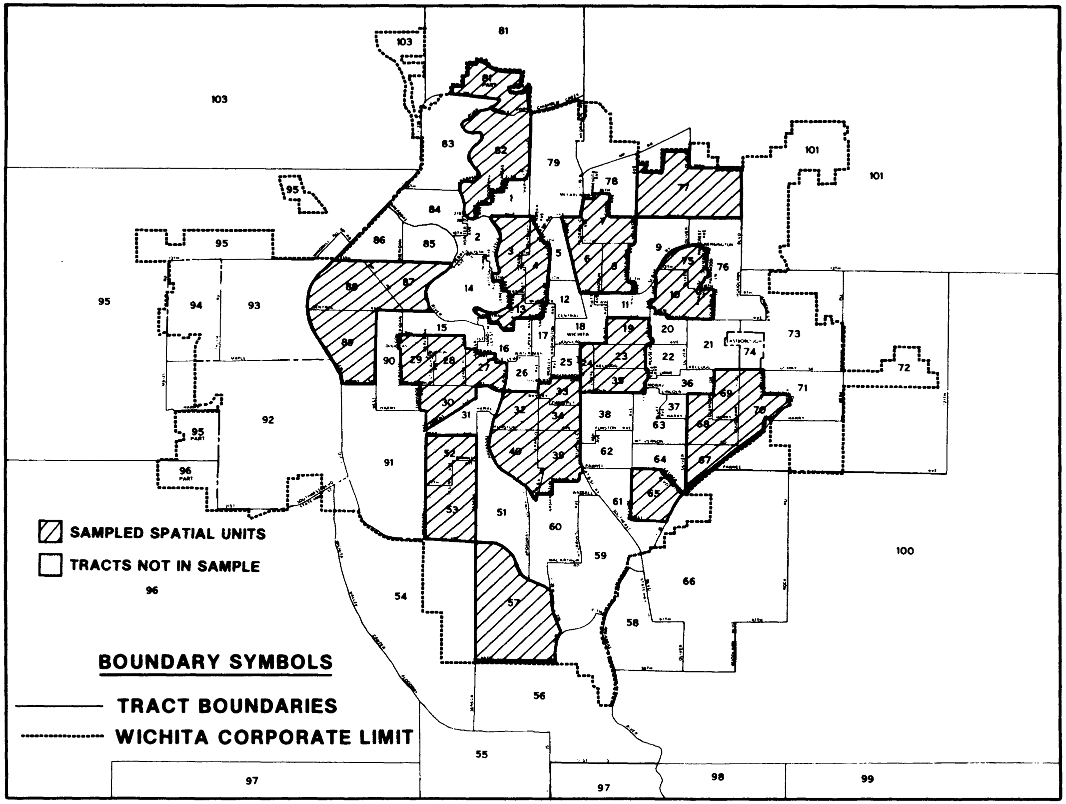

Figure 5.1. Sampled Spatial Units (Source: Wichita-Sedgwick County Metropolitan Area Planning Department, 1977)

Table 5.5. Characteristics of Sampled Spatial Units (1975)

Unit	*Tract*	*Households*	*% NWPOP*	*MEDRENT*	*MEDVAL*	*MEDINC*
I	65	1,634	19.9	79	9,642	9,220
II	81	176	1.0	103	15,642	13,100
	82	2,198	7.7	152	15,336	12,650
III	77	1,187	34.5	217	32,177	17,050
IV	10	1,328	3.4	112	18,421	13,000
	75	1,187	12.7	131	17,960	12,100
V	6	1,066	99.0	79	8,520	7,150
	7	1,629	92.4	77	10,483	10,250
	8	1,112	94.3	77	9,440	6,840
VI	67	889	1.7	148	22,165	13,450
	68	2,276	7.4	127	18,908	9,490
	69	1,199	1.7	139	18,438	12,850
	70	1,675	2.0	150	24,469	12,250
VII	32	1,493	3.4	86	12,834	10,300
	33	842	4.9	89	10,704	9,160
	34	806	4.2	87	11,356	10,050
	39	2,041	2.5	106	14,016	10,850
	40	1,643	3.4	106	13,052	10,650
VIII	52	1,488	5.9	127	18,586	13,300
	53	2,335	1.6	136	18,920	13,100
IX	27	1,087	3.4	83	13,526	8,410
	28	1,486	2.9	89	14,474	10,600
	29	961	1.6	96	13,882	9,940
	30	995	2.8	99	11,940	10,800
X	3	1,923	12.0	85	11,035	7,630
	4	1,244	13.0	83	12,065	10,350
	13	1,022	11.0	92	11,756	12,800
XI	87	1,480	3.1	141	16,899	12,650
	88	1,310	3.2	125	18,758	12,950
	89	1,342	5.0	92	11,796	10,700
XII	19	1,133	2.9	96	13,222	10,550
	23	1,190	1.8	93	15,881	13,550
	24	602	2.0	111	18,955	10,500
	35	1,042	4.1	112	15,853	12,550
XIII	57	1,321	0.8	117	11,934	12,100

Note: %NWPOP, the percentage of nonwhite population; MEDRENT, the median rental value; MEDVAL, the median house value; MEDINC, the median household income.

5.5. SPECIFICATION OF DISTURBANCES IN THE MODEL

To estimate empirically the parameters of the model, disturbance terms must be added to the deterministic theoretical version of the model developed in chapter 3 and the estimation equations in chapter 4. Since all stages of the estimation procedure must conform to the same assumptions concerning the structure and distribution of disturbances, these assumptions will be made explicit here and will not be formally restated within each detailed description in later stages of this chapter. Because the intersubmarket household class flows are the logical units of observation of the model that determine the aggregate housing market phenomena, the disturbances, denoted ϵ_{kij}, should be formally introduced into the household class intersubmarket relocation flow equation (3.18). The disturbance terms should then be carried through the structural properties leading to the estimation equations in chapter 4.

It is unlikely that disturbances of the model (3.18) would be independently distributed in a log-normal distribution; thus the following error component structure is postulated:

$$\log\epsilon_{kij} = \log\epsilon_k + \log\epsilon_i + \log\epsilon_j + \log\epsilon_{ij}. \tag{5.1}$$

Although other structures could be postulated, (5.1) is the simplest specification that reflects the basic structural form of the model. The ϵ_k are disturbances associated with household class specification. ϵ_i and ϵ_j are disturbances associated with origin and destination submarkets. The ϵ_{ij} are disturbances associated with the generalized cost linkages between submarket pairs. It is further postulated that the components of $\log\epsilon_{kij}$ are distributed independently with normal distributions and zero covariances among components:

$$\begin{aligned}
&\log\epsilon_k \sim N(0,\sigma_k^2\bar{\mathrm{I}}), && \mathrm{COV}(\log\epsilon_k \log\epsilon_i) = 0,\\
&\log\epsilon_i \sim N(0,\sigma_i^2\bar{\mathrm{I}}), && \mathrm{COV}(\log\epsilon_k \log\epsilon_j) = 0,\\
&\log\epsilon_j \sim N(0,\sigma_j^2\bar{\mathrm{I}}), && \mathrm{COV}(\log\epsilon_k \log\epsilon_{ij}) = 0,\\
&\log\epsilon_{ij} \sim N(0,\sigma_{ij}^2\bar{\mathrm{I}}), && \mathrm{COV}(\log\epsilon_i \log\epsilon_{ij}) = 0,\\
& && \mathrm{COV}(\log\epsilon_j \log\epsilon_{ij}) = 0.
\end{aligned} \tag{5.2}$$

Even with the simple specification of disturbances in (5.1) and (5.2), their joint effects lead to complex composite disturbances that preclude the obtainment of best linear unbiased parameter estimates in the empirical estimation of the model. The implications are discussed in each particular stage of estimation.

5.6. CONCLUDING REMARKS

This chapter has introduced some basic issues in the empirical estimation of the model. The general characteristics of Wichita, Kansas, suggest that it is particularly well suited for the empirical estimation of the model. The Annual Intergovernmental Enumeration Survey of Wichita, Kansas, has provided an unusually rich source of data for this premier empirical effort to model intersubmarket household flows within an urban area. In accordance with the household class, dwelling unit type, and spatial unit specifications described in the latter part of the chapter, household class relocation flow matrices were constructed for the empirical analyses. Although the survey response rates on all variables used in the study were generally high (i.e., over 90%) the multiplicity of dimensions characterizing households and dwelling units increased the likelihood of observations containing at least one missing or miscoded variable.[9] The longitudinal nature of the file provided a means of editing the raw data. When missing or miscoded data occurred in 1975, the household records for 1976 and preceding years were used to assign values. When data were missing in all years, an allocation procedure assigning the most likely value exhibited by *otherwise identical* households was used. Details of the editing procedure are available on request from the author. Given this general discussion of data, the following chapters describe the empirical estimation of the model.

NOTES

1. Prior to 1950 the nonwhite population of Wichita was about 6% of the total population. The proportion of the nonwhite population has consistently increased since 1950 and accounted for nearly 13% of the 1975 population. Blacks comprise over 80% of the nonwhite population.

2. The general objective of the research of Gale and Moore is to study small-area residential occupancy patterns over time. A brief note on this work is contained in the critical survey of chapter 2. See Gale and Moore (1973) and Moore and Gale (1973) for detailed discussions of their proposed methodology for analysis of residential occupancy patterns.

3. Operationally, living facilities must have separate entrances, plumbing, cooking, and eating facilities to qualify as separate dwelling units in the Wichita survey.

4. Head of household was defined in the Wichita survey by the following hierarchical conditions: (1) the husband of the household unless he was seriously disabled, whereupon the wife was designated as head; (2) the primary wage earner in extended families of more than one generation; and (3) the person paying for accommodations in households of unrelated individuals. If the expenditures were apportioned, the eldest individual was designated as head.

5. If households A and B relocated to a third unit in the course of a merger, then a single relocation would be recorded. The actual relocation recorded would depend on who retained headship after the move.

6. It should be noted, however, that an accessibility index to employment centers was specified as a locational attribute of submarkets in Y_j.

7. The potential number of classes is simply the product of the number of categories within each of the six attribute dimensions.

8. Curry (1972) has argued that because of the continuous nature of the spatial distribution of housing and population characteristics, levels of spatial autocorrelation should decline with distance and hence may be confounded with the estimation of distance-friction effects. This will be discussed further in chapter 6.

9. The exception was the household income. The average response rate for this classification averaged 71% over the six-year period.

6 THE GENERALIZED COSTS OF RELOCATION

The purpose of this chapter is to discuss the estimation of the generalized relocation cost parameters of the relocation model developed in chapter 3. The first three stages of the multistage estimation procedure outlined in chapter 4 (figure 4.1) are also included. The first section of the chapter discusses the concept of generalized relocation costs and questions raised about their effects in the literature. The estimation of intersubmarket generalized cost parameters by the cross-product ratio approach is described in the second section.[1] Since generalized costs are the critical component that distinguishes spatial interaction gravity models, the estimating approach discussed in this section should be of far more general interest than the particular application of this study. The third section of the chapter encompasses the second and third stages of the multistage procedure. The third-stage estimation of intrasubmarket generalized cost parameters is of particular interest. The last section contains a general discussion of the implications of the empirical results and concluding remarks.

6.1. GENERALIZED RELOCATION COSTS: CONCEPT AND IDENTIFICATION

Because of the significance of relocation costs of both the monetary and nonmonetary varieties, households, in general, are unable to relocate freely in order to adjust their consumption of housing continuously to shifts in demand or changes in housing market conditions. One effect of these costs is to create locational inertia for remaining at a current residence that impedes housing consumption adjustment. The costs of relocation may be both monetary and nonmonetary. Monetary costs of intraurban relocation primarily include any transactions costs and the costs of moving household possessions. Although transactions costs for renter households are substantially less than those for owner households, Hanushek and Quigley (1976) maintain that monetary transactions costs for renters still may be of potential significance. These costs, for the most part, involve foregone interest from security or lease deposits and foregone rent discounts attributable to longer-term occupancy. Rent reductions for longer-term occupancy are essentially savings passed on from landlords to tenants because of reductions in both turnover expenditures (e.g., painting, redecorating costs) and the expected vacancy rates of rental units. Empirical evidence of the U.S. Bureau of the Census (1973) suggests that market rents paid by recent movers are, on the average, 8% higher than for nonmovers of longer occupancy. This evidence, along with similar evidence by Kain and Quigley (1975) and Shafer (1979), would suggest that for renters of longer-term occupancy, transaction costs may be substantial.

Aside from these monetary costs, the social, psychic, information, and search costs are likely to be the most substantial source of "generalized" relocation costs for renter households. It has long been argued (e.g., Zorbaugh, 1929; Firey, 1947; Caplow, 1949) that a strong association exists between population mobility rates and levels of social participation and disorganization. Although it is not clear whether length of residence is a determinant or consequence of social participation, it is generally accepted that changes of residence disrupt, and are impeded by, social ties and social participation in neighborhoods over time. In addition to these social costs, the general psychic costs involved in the information, search, and adjustment processes of relocation are likely to be so significant in themselves as to impede any residential relocation.

It has also been argued that in addition to impeding continuous housing adjustment, generalized costs may strongly bias the household's choice of residence submarket upon relocation. Previous empirical research has suggested that household relocation flows exhibit a variety of nonrandom spatial biases, including distance-decay regularities from an origin place (e.g., Simmons, 1974; Moore, 1972), spatial directional biases (e.g., Adams, 1969; Brown and Holmes, 1971), and even "social status" differential barriers (e.g., Goldstein, 1958; Whitelaw and Robinson, 1972). Since particular dwelling units are highly differentiated, a considerable expenditure of time and effort is generally required in the physical inspection of available dwellings. Furthermore, it has often been suggested (e.g., Wolpert, 1965; Lynch, 1960; Tilley, 1967; Adams, 1969) that the spatial awareness of households is limited. The joint effects of the limited spatial awareness of households and the substantial information and search costs of dwelling choice indicate that the search process is mainly confined to those areas that are familiar to households. In other words, because of substantial costs, households may channel their physical search efforts to where sufficient prior information exists.[2]

Although a wealth of empirical work has addressed the measurements of spatial bias in household relocation flows in terms of distance-decay, directional, and sectoral bias (e.g., Adams, 1969; Whitelaw and Robinson, 1972; Brown and Holmes, 1972),[3] serious questions have been raised by Moore (1970), Moore and Brown (1970), and Curry (1972) about the confounding effects of the spatial distribution of relocation opportunities on the identification of spatial generalized cost bias. As long as housing types are not uniformly or randomly distributed across space and housing choice is dictated by demand preferences for residential attributes, some degree of spatial bias should be observed even in the absence of spatial friction costs simply because of the distribution of the housing stock.

The possible confounding effects of the spatial distribution of housing opportunities were formally demonstrated in the works of Moore (1970) and Moore and Brown (1970). Under an assumed normal density distribution of population around a central core that is representative of spatial contact opportunities and a distance-decay preference function (i.e., generalized costs), Moore (1970) demonstrated that the joint density distribution of spatial contacts would exhibit a directional bias toward the central core. Whereas past research (e.g., Adams, 1969) had attributed such spatial bias to a household's greater spatial awareness of places along radial transportation networks due to daily job commuting, the work of Moore (1970) would suggest that this type of directional bias may not be due to generalized cost factors (awareness) at all. As long as spatial contacts are assumed to be proportional to density of opportunities in Moore's model, the central orientation would remain even in the absence of a distance-decay preference function.

Curry (1972) has challenged the common identification of spatial friction effects of generalized costs on the basis of confounding effects of spatially autocorrelated disturbances due to the possible omission of relevant submarket attributes that may vary systematically across space. Curry has reasoned that because of the continuous nature of spatial distributions of population and housing characteristics whereby dissimilarity between places tends to increase with intervening distance, levels of spatial autocorrelation should decline with increased distance. To the extent that relocation flows are governed by demand preferences for spatially related attributes (and presumably since pertinent variables may have been omitted), Curry has emphatically argued that the common "distance-friction" effect found in spatial interaction studies may be hopelessly confounded with effects of spatial autocorrelation. Curry's arguments have been hotly debated by Cliff et al. (1974, 1975, 1976), Curry et al. (1975), Sheppard et al. (1976), and Johnston (1975), with little agreement except that they are more plausible in the context of intraurban relocation.

A related issue that has generated some confusion because of the spatial distribution of housing opportunities is whether "social status" barriers constrain/bias household relocation. Since observed static residential patterns have been characterized as clusters of social status groups (e.g., Timms, 1971; Johnston, 1971), "social status" barriers may constrain households to relocate within certain geographic areas. On the basis of observations that aggregate household relocation flows are greater between areas of similar rather than disparate social status composition, Goldstein (1958) and Whitelaw and Robinson (1972) purportedly found evidence of the constraints imparted by social status composition. On the other hand, Brown and Longbrake (1970), Simmons (1974), and Clark (1976) found no empirical support for this condition. The confusion over the existence of social status bias/constraints stems from failure to control for housing opportunities and aggregation. Clark (1976) quite reasonably suggests that the "social constraints" allegedly biasing household relocation patterns are more likely to be reflections of the constraints imposed by income on housing expenditures. If social status is associated with income, and housing choice is primarily determined by income-constrained demand preferences, then households should naturally exhibit a greater tendency to relocate to units in submarkets vacated by households with socioeconomic characteristics similar to their own.

The confusion surrounding the issue of spatial bias and generalized relocation costs stems largely from a casual interchange of spatial bias and generalized cost bias terms. Clearly relocation patterns will be spatially biased due to the spatial distribution of housing. This is not necessarily generalized cost bias. In chapter 3 "generalized costs" were defined as those factors that bias the household's choice of residential submarkets away from that dictated by income-constrained demand preferences of a frictionless world of costless mobility. A closely related concept that conveys this notion of cost bias is the distinction between market and gross housing prices in the location models of Quigley (1976) and Ingram et al. (1972). Their basic argument is that while all households at different workplaces face the same market prices for housing, they face different gross prices for any unit due to different commuting expenditures. The effects of commuting costs are to spatially bias the locational choices of otherwise identical households at different workplaces away from that due to demand preferences alone. The empirical question of the effects of generalized cost is whether the submarket choices of otherwise identical households at *different origin submarkets* are systematically biased after income-constrained demand preferences for submarkets have been controlled for. The estimation of the parameters of intersubmarket generalized relocation costs by the cross-product ratio procedure is discussed in the next section.

6.2. THE CROSS-PRODUCT RATIO ESTIMATION OF F_{ij}

Given the postulated structure of the generalized cost component of the model stated in (4.5), the first stage of the estimation procedure is to estimate independently the parameters of the spatial intersubmarket generalized cost attributes by the cross-product ratio relationship (4.4), using intersubmarket household relocation flows. In light of the discussion of the confounding effects of the spatial distribution of relocation opportunities, it is important to reiterate the value of the cross-product ratio approach. It was shown in equations (4.2)-(4.4) that the cross-product ratio effectively *controls* for the spatial distribution of housing opportunities. Thus these distorting effects are controlled for in the isolation of F_{ij}. The following section discusses the log-linear specification of the estimation equation and is followed by the discussion of household class and attribute specification.

6.2.1. The Cross-Product Ratio Estimation Equation

By invoking the postulated error component structure of disturbance terms of (5.1)-(5.2), a general log-linear version of (4.4) may be stated upon specification of a functional form for F_{ij}. Under the following postulated functional form for any household class k,

$$F_{ij} = \exp(\sum_s \psi_s f_{sij}), \tag{6.1}$$

where f_{sij} are observable variables/surrogates of generalized relocation costs between an i-j submarket pair, the logarithmic estimation form of (4.4) may be stated as follows:

$$\log\left(\frac{D_{ij}D_{mn}}{D_{in}D_{mj}}\right) = \sum_s \psi_s(f_{sij} + f_{smn} - f_{sin} - f_{smj}) + \log\left(\frac{\epsilon_{ij}\epsilon_{mn}}{\epsilon_{in}\epsilon_{mj}}\right). \tag{6.2}$$

Note that while the household class, origin submarket, and destination submarket error components in (5.1) are effectively canceled out by the cross-product ratio, the submarket pair-specific components remain as a composite disturbance term. This composite disturbance does retain the normality assumption since it is an additive (in logarithms) result of individual disturbance terms that have the postulated structure $\log \epsilon_{ij} \sim N(0, \sigma_{ij}^2 \bar{\mathrm{I}})$. However, it does not satisfy conventional independence assumptions, as the variance-covariance matrix of the disturbances will not be diagonal. This is due to the fact that particular relocation flows will necessarily be repeated over observations in the construction of the $(M\text{-}1)^2$ independent cross-product ratios in (6.2) for any $M \times M$ relocation matrix. Least squares estimation of (6.2) will provide unbiased parameter estimates. However, the consequence of the dependence between composite disturbances is that unless the variance-covariance matrix of disturbances may be a priori specified, least squares estimates of the *variances* of the parameters in (6.2) will be biased in an unknown direction.

It should be clear that the estimation of F_{ij} by the cross-product ratio equation (6.2) involves trade-offs. In chapter 4 it was noted that the recent work of Stetzer (1976) suggested that conventional approaches to estimation of spatial demand models such as (3.9) or (3.18) yield biased parameter estimates when choice sets are misspecified. Given the ambiguities involved in the a priori specification of household submarket choice sets in the study of relocation, conventional estimation approaches are likely to produce biased parameter estimates. Although the cross-product ratio approach circumvents the parameter bias problems of choice set specification, it is saddled with the problem of potentially biased estimates of the variances of parameter estimates. Which source of bias is more serious is a question unanswered by current research.[4]

6.2.2. Specification of Household Classes and Submarkets

Even though the analysis was confined to the more mobile rental market, sparse relocation flow matrices severely limited the degree to which household classes and dwelling units could be disaggregated.[5] Given the conceptual interpretation of F_{ij} as some measure of the search and information awareness costs that spatially bias submarket choice, it was felt that the most crucial household attributes to retain were income class and race. Income class was chosen not only because of the obvious constraints income exerts on submarket choice, but also because it is the single most important demand determinant that interacts with other attributes. Race was chosen under the premise that generalized costs may differ for nonwhites under possible housing market discrimination. All other household class dimensions listed in table 5.2 were aggregated over in this stage of the estimation. In other words, it was formally postulated that household size, changes in household size, age of head of household, and duration of current residence do not affect destination locational choice *after* any variations in the demand for residential attributes reflected in these attributes have been accounted for.

Even at this crude level of disaggregation, the income classes in table 5.2 had to be aggregated over into two classes because of sparsity of data. Ultimately three household classes were defined as follows:

NW-INC1, nonwhite households of income class ($0-9,999);
W-INC1, white households of income class ($0-9,999);
W-INC2, white households of income class ($10,000-19,000).

Lack of data on nonwhite renter households with incomes of $9,999 per annum or more precluded their inclusion in the analysis.

In chapter 4 it was formally demonstrated that the parameters of F_{ij} could be consistently estimated after aggregating across all dwelling unit stratifications as long as the attributes characterizing the spatial bias of generalized costs could be reasonably treated as independent of dwelling type. Given the crude level of household disaggregation, however, destination submarkets were stratified into two rental classes—($0-99/month) and ($100-199/month)—in addition to spatial units. This was done as an attempt to control for systematic irregularities in the spatial distribution of housing that may confound identification of generalized cost bias. Rental class was chosen over other structural characteristics (e.g., number of bedrooms, structure type) to stratify destination submarkets since it was the single attribute most likely to reflect important housing service differentials. Thus thirteen origin submarkets (spatial units) and twenty-six destination submarkets were defined along with three household classes for the first stage of estimation.

6.2.3. A Priori Specification of Attributes of F_{ij}

Two basic variable types were specified as components of F_{ij} in the general exponential form (6.1). First, pure spatial variables (e.g., distance) were specified as surrogates of the information and/or awareness barriers that may bias the destination submarket choices of households. Second, aspatial surrogates of "social status" barriers were specified as submarket pair-specific variables.

Distance was specified as surrogate of generalized costs producing the common distance-decay friction effects in residential relocation patterns. The specific exponential functional forms of the distance (and "social distance") variables included both single and squared terms for interspatial unit airline distance *DIS:*

$$f_{ij} = \exp[\psi_1 DIS_{ij} + \psi_2 (DIS_{ij})^2]. \tag{6.3}$$

The single and squared terms in (6.3) were specified for functional flexibility in the definition of *F.* Tanner (1961) has argued that no single function can adequately represent both the short- and long-distance marginal frictional effects of distance. While a Tanner function (i.e., the product of an exponential and a power function) serves this purpose, it is only sensitive when the range of distances is large. In intraurban relocation it is plausible to hypothesize that the marginal frictional effect of an additional unit of distance (e.g., mile) may decline substantially with increasing distance. Declining marginal frictional effects of distance would be suggested in (6.3) when $\psi_1 < 0$, $\psi_2 > 0$, and $|\psi_1| >> |\psi_2|$. The signs and relative magnitudes of ψ_1 and ψ_2 noted here would suggest that under *ceteris paribus* conditions the most likely destination of households would be "next door" to their current residence. It is more plausible to expect threshold effects in which distance may not matter within some range of distance (figure 6.1). Alternatively, one might expect a quadratic relation in which $\psi_1 > 0$, $\psi_2 < 0$, as shown in figure 6.2. Under the quadratic relationship, distance would matter only after a threshold distance is reached. Since there is little past empirical evidence to guide our expectations of the precise form of the distance-decay relationships, (6.3) and the dummy variable *SAME* are quite flexible for empirical estimation purposes.

The second class of variables specified in *F* were surrogates of social status barriers to relocation. As noted earlier, the concept of social status "constraints" has been somewhat muddled in the residential mobility literature. This is not really surprising given the ambiguities in even defining just what "social class" means (Hodges, 1964). The existence of "social status" constraints in residential relocation becomes relevant under the premise that a household's social status is at least partially determined by that of its neighborhood. Kahl (1957) defines social class in terms of common attitudes, values, and life styles. He writes of social class that "people who share a given style of life tend to have more personal contact or interaction with one another than those who live differently" (Kahl, 1957, p. 9). Under this type of social class definition, one would expect that if social status exerts a bias on residential choice, the *relative* submarket choices of otherwise identical households should be systematically dependent on or biased by the social status composition of the *origin* submarket.

There is little agreement over the precise measurement of social status. Hodges (1964) notes that it is a slippery, fuzzy term that connotates altogether different things to different people. Yet most sociologists would agree that it is a "blended

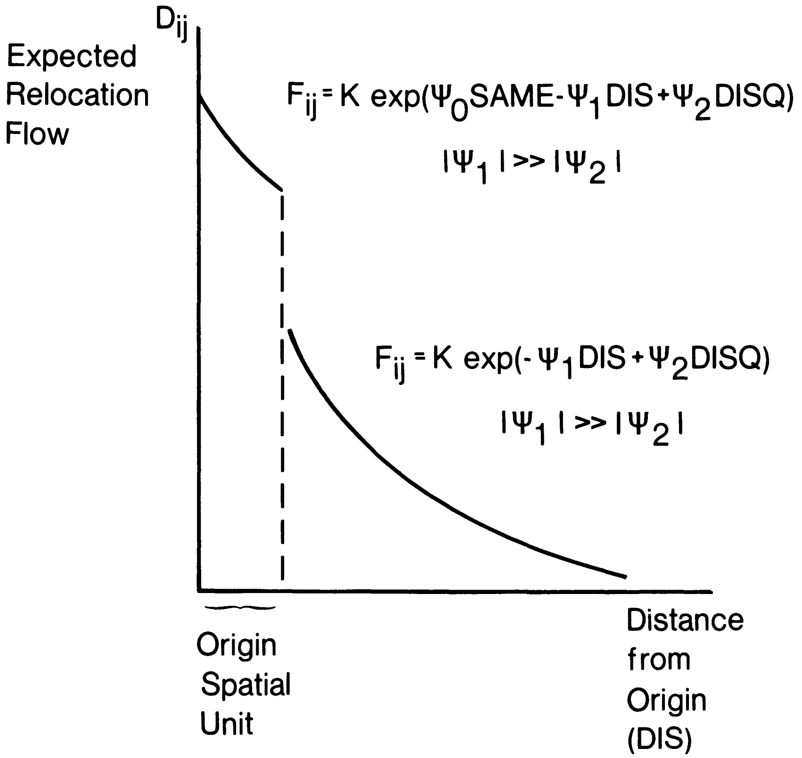

Figure 6.1. A Typical Representation of a Distance-Friction Function with a Discrete Threshold Level (adapted from Porell, 1982)

product of shared and analogous occupational orientations, educational backgrounds, economic wherewithal, and life experiences" (Hodges, 1964, p. 13). The three dimensions of education, occupation, and income should be highly intercorrelated; still, there is no theoretical basis for retaining one dimension over another. Further, the construction of a composite index (e.g., by factor analysis) involves weighting schemes that are largely ad hoc. Thus all three dimensions were retained as surrogates of social status.

Three social status differential variables (*EDUCDIFF, OCCDIFF, INCDIFF*) were specified in terms of the absolute value of the difference between education, occupation, and income composition of the spatial units of origins and destinations. When defined as a component of *F* in this manner, the influence of the social status composition of the origin is not entirely canceled out by the cross-product ratio. Whereas all households of a household class may exhibit similar preferences for submarkets of higher social status composition, *ceteris*

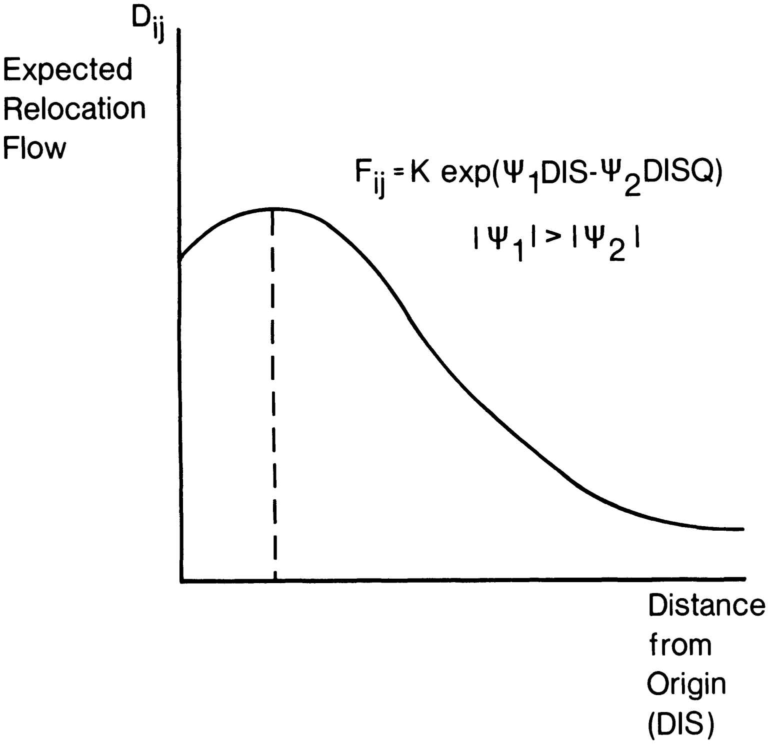

Figure 6.2. A Typical Representation of a Quadratic Distance-Friction Relationship (adapted from Porell, 1982)

paribus, the general hypothesis is that after these demand preferences are controlled for, the greater the disparity between the social status composition of a potential submarket and that of the current submarket, the lesser is the expected relocation flow.

The functional form for the social status differential variables was exponential with single and squared terms as in (6.3). If no threshold effects are evident, then $\psi_1 < 0$, $\psi_2 > 0$, and $|\psi_1| >> |\psi_2|$ are expected. Alternatively, a quadratic relationship in which $\psi_1 > 0$ and $\psi_2 < 0$ would suggest that social status differentials do not reflect barriers to choice until a threshold level is reached.[6] Since absolute values of differences are specified, both positive or negative differentials are constrained to impede relocation flows in the same way in (6.3). Social status differentials (both positive and negative) may bias relocation choice, but Goldstein (1958) and Speare et al. (1974) have suggested that residential mobility may be a vehicle for social mobility and hence biased toward higher social status submarkets. To test for this, dummy variables (*+EDUCDIFF, +OCCDIFF, +INCDIFF*) were specified for submarket pairs for which the social status composition of the destination exceeded that of the origin. The expected effects are to shift the relationship between relocations and social status differentials upward for positive differentials.

Finally, dummy variables (*NW-W*, *W-NW*) were specified between submarket pairs for which large disparities in racial composition existed. The reasons for their specification are analogous to that of the social status variables. After controlling for racial composition preferences in *W*, greater disparities in racial composition may impede relocations due to real or imagined barriers in the housing market. Table 6.1 summarizes the variable specifications and the a priori hypotheses concerning expected signs and differences across income and racial classes. While threshold effects may occur, the single and squared terms of (6.3) were all specified as $\psi_1 < 0$ and $\psi_2 > 0$ in table 6.1 for consistency. There is little past research to guide our expectations concerning household class differentials. Nevertheless, because of the predominance of racial segregation and real or imagined housing market discrimination, nonwhites may experience greater generalized costs than whites, *ceteris paribus*. Likewise, one would expect that white households of greater income would be less sensitive to generalized cost barriers than lower income white households, *ceteris paribus*.

6.2.4. Presentation and Discussion of Empirical Results

The parameters of the cross-product ratio equation (6.2) were estimated by ordinary least squares techniques for the three household classes. The independent cross-product ratios were formed by modifying the selection method of Goodman (1969) to use a truncated sample of nonzero cells. The row and column with the fewest null cells was selected to obtain the *i-j*th cell in (6.3). Holding this *i-j* cell constant, *m* and *n* were varied in (6.3) to create independent ratios. Since zeros cause obvious problems in any logarithmic model, only those ratios involving nonzero cells were retained. This procedure yielded 102, 93, and 42 cross-product ratio observations for the *W-INC1*, *W-INC2*, and *NW-INC1* household classes, respectively. It is recognized that the truncated sample may impart some bias to parameter estimates. However, the common ad hoc practices for dealing with zero cells, such as adding one to all cells, are of questionable value when cell counts are small.[7] The empirical results are presented in table 6.2. Because of possible bias in the variances of the estimates, the implications of all estimates will be discussed. Caution is exercised toward those with larger standard errors.

DIS, SAME. The parameters of distance variables *DIS* were consistent with a priori expectations within and across all three regressions. With the exception of the squared distance parameter of the *W-INC2* class, all parameters were

Table 6.1. Specification of F_{ij}

Variable	*Expected Signs*	*Description*
DIS *DISQ*	<0, *NW*<*W*, *INC1*<*INC2* >0, *NW*<*W*, *INC1*<*INC2*	Distance and squared distance between centroids of spatial units
SAME	>0, *NW*>*W*, *INC1*>*INC2*	Dummy variable equal to unity for intraspatial unit relocation flows and zero otherwise
INCDIFF *INCDIFFSQ*	<0, *NW*<*W*, *INC1*<*INC2* >0, *NW*<*W*, *INC1*<*INC2*	The absolute value of difference in median incomes of spatial units and the squared difference measured in $1,000s
+INCDIFF	>0, *NW*<*W*, *INC1*<*INC2*	Dummy variable equal to unity for submarket pairs for which the destination median income exceeds that of the origin and zero otherwise
OCCDIFF *OCCDIFFSQ*	<0, *NW*<*W*, *INC1*<*INC2* >0, *NW*<*W*, *INC1*<*INC2*	The absolute value of the difference in white-collar/blue-collar occupation ratio of submarkets and the squared difference
+OCCDIFF	>0, *NW*<*W*, *INC1*<*INC2*	Dummy variable equal to unity for submarket pairs for which the white-collar/blue-collar occupation ratio of destination exceeds that of the origin and zero otherwise
EDUCDIFF *EDUCDIFFSQ*	<0, *NW*<*W*, *INC1*<*INC2* >0, *NW*<*W*, *INC1*<*INC2*	The absolute value of the difference in the percentage of population 25 years or older with a high school education between submarkets and the squared difference
+EDUCDIFF	>0, *NW*<*W*, *INC1*<*INC2*	Dummy variable equal to unity for submarket pairs for which the proportion of high

Table 6.1. Specification of F_{ij} (*continued*)

Variable	*Expected Signs*	*Description*
		school educated population of the destination exceeds that of the origin and zero otherwise
NW-W	<0	A dummy variable denoting submarket pairs for which the origin racial composition is $>90\%$ nonwhite and the destination racial composition is $<35\%$ nonwhite (specified only for *NW* households)
W-NW	<0	A dummy variable denoting submarket pairs for which the racial composition of the origin is $<5\%$ nonwhite and the destination racial composition is $>15\%$ nonwhite (specified only for *W* households)

statistically significant at the 0.05 level. The smaller positive signs of the squared distance parameters support the hypothesis that the strong impedance effects of distance are dampened upon increased distance. The strong impedance effects of distance friction-related generalized costs are more easily seen by examining some implications of the parameters. The estimates suggest that *W-INC2, W-INC1,* and *NW-INC1* households are about 1.8, 2.3, and 3.8 times more likely to relocate one mile from their current residence than four miles, *ceteris paribus.* Alternatively stated, the results would suggest that *W-INC2* households implicitly discount (by their revealed behavior) submarket attributes in *W* at four miles by almost twice that at one mile. The results suggest that for white households, factors associated with income diminish the impedance effects of distance. Finally, a comparison across race suggests the distance/generalized cost barriers faced by nonwhite households are more pervasive than their low-income white household counterparts. The positive parameters for *SAME* suggest that there may be threshold effects whereby distance does not matter for short distances less than the 0.7 mile maximum intraspatial unit distance. Although the

Table 6.2. Empirical Results of Cross-Product Ratio Estimation of F_{ij}

	NW-INC1		*W-INC1*		*W-INC2*	
Variable	β	*t*	β	*t*	β	*t*
DIS	-0.984	(2.54)*	-0.406	(2.98)*	-0.265	(3.69)*
DISQ	0.108	(2.19)*	0.026	(1.97)*	0.012	(0.91)
OCCDIFF	0.029	(0.10)	0.787	(1.93)	0.149	(4.15)*
OCCDIFFSQ	-0.048	(0.28)	-0.518	(2.06)*	-0.830	(3.58)*
+OCCDIFF	0.242	(0.89)	0.118	(0.62)	0.230	(1.11)
EDUCDIFF	-0.108	(0.51)	-0.018	(0.69)	-0.020	(0.64)
EDUCDIFFSQ	0.002	(1.34)	0.001	(0.28)	0.001	(0.53)
+EDUCDIFF	-1.439	(3.21)*	-0.285	(1.59)	0.527	(2.81)*
INCDIFF	0.174	(0.57)	-0.431	(2.60)*	0.076	(0.54)
INCDIFFSQ	-0.045	(1.02)	0.084	(2.34)*	-0.122	(0.46)
+INCDIFF	45.210	(0.10)	17.310	(0.93)	34.300	(1.62)
SAME	0.716	(1.00)	0.212	(0.48)	1.201	(3.29)*
NW-W (*W-NW*)	-2.244	(4.34)*	-0.544	(1.23)	-0.739	(1.62)
CONSTANT	-0.577		-0.656		-0.928	
No. of observations	42		102		93	
R^2	0.90		0.55		0.69	
F	7.37		8.27		13.99	

*Significant at >0.05 level
Note: *W, NW:* (white, nonwhite); *INC1, INC2:* ($0–9,999), ($10,000–19,999).

larger (statistically significant) parameter for *W-INC2* households did not conform with a priori expectation, the large standard errors for the parameters of the other two classes preclude a definitive comparison across classes.

OCCDIFF, +OCCDIFF. The estimated parameters of the occupational composition variables suggested threshold effects similar to those depicted in figure 6.2. The maxima of the quadratic relationships for the *NW-INC1, W-INC1,* and *W-INC2* classes were 0.302, 0.759, and 0.089, respectively. All were quite smaller than the potential maximum differentials in the sample.[8] Although the signs of the parameters were consistent for all classes, only in the case of *W-INC2* households were both parameters statistically significant at conventional significance levels. The interpretation of the parameters again may be conveyed best by example. The *NW-INC1* parameters would suggest that for households whose residence submarket white-collar/blue-collar ratio is 0.3 (i.e., 23% white-collar occupation), the relocation choices are biased toward submarkets of increasingly different occupational composition until the ratio of a potential destination reaches 0.6 (i.e., about 37.5% white-collar occupation). After this point increasing white-collar composition differentials bias choices away from these submarkets, *ceteris paribus*. For *W-INC1* and *W-INC2* households the parameters suggest that white-collar occupation differentials act as barriers when the difference in the percentage of white-collar workers is in the order of 6–20% and 2–5%, respectively. The ranges are reported since differences in percentages of white-collar workers corresponding to differences in white-collar/blue-collar ratios vary inversely with the absolute magnitude of the origin ratio.[9] This is noted because of the implications of the estimated parameters toward household class differences. Contrary to expectations, the parameters suggest that *W-INC2* households are more sensitive to white-collar composition differences than *INC1* households of either race. Further, because households of greater income levels tend to reside in submarkets of greater white-collar composition, this sensitivity is reinforced by the relationship between ratio and percentage differentials noted above. One might surmise that this greater sensitivity of *W-INC2* households may be due to the fact that they already reside in the highest rent levels of the rental market and that upward mobility requires a shift to the owner market. Note that despite their large standard errors, there is little difference in the general magnitudes of the parameters of *+OCCDIFF* for all household classes. On an overall basis the parameters suggest that real or perceived barriers associated with occupation composition bias relocation patterns.

EDUCDIFF, +EDUCDIFF. Although the parameters of *EDUCDIFF* conformed to a priori expectations, standard errors were quite large and there was little variation in their absolute magnitudes across household classes. The general magnitudes of the parameters further suggest education level composition barriers are only of substance when there are large disparities between the percentages of adults with at least a high school education. As for *+EDUCDIFF*, only the parameters of the *W-INC2* household class conformed with a priori expectations. The estimates suggest that *W-INC2* households are about 1.7 times more likely to relocate to submarkets of greater percentages of high school graduates than those with lesser or same percentages, *ceteris paribus*. The negative estimated parameters for both *INC1* classes were inconsistent with expectations. The statistically significant parameter for the *NW-INC1* class suggests that these households are about four times more likely to move to submarkets of lesser or equal educational composition than higher, *ceteris paribus*. On face value these latter results suggest that low-income households (particularly nonwhites) may face substantial real or perceived barriers to upward social mobility with regard to educational composition.

INCDIFF, +INCDIFF. The parameters of *INCDIFF* largely conformed to a priori expectations. The parameters of the *W-INC2* and *NW-INC1* households exhibited quadratic relationships akin to that shown in figure 6.2 with maxima of \$311 and \$1,933, respectively. They were statistically insignificant, however. The statistically significant parameters for *W-INC1* households suggest income differential barriers may be of substance. For example, the estimates suggest that *W-INC1* households are about 1.4 times more likely to relocate to submarkets with a \$500 differential in median income than submarkets of \$2,000 median income differential, *ceteris paribus.* The parameters of *+INCDIFF* were consistent in sign but their large magnitudes do not seem credible, particularly given their large standard errors.

NW-W, W-NW. The estimated parameters of the dummy variables denoting large disparities in the racial composition of submarket pairs were all consistent with expectations. The parameters suggest that *W-INC1* and *W-INC2* residing in racially segregated submarkets are about *half* as likely to relocate to racially integrated submarkets than are comparable households already residing in racially integrated submarkets. The counterpart statistically significant parameter for *NW-INC1* households suggests that those residing in racially segregated submarkets are about *one-tenth* as likely to relocate to racially integrated submarkets than otherwise comparable households residing in racially integrated submarkets. These estimates suggest that real or perceived barriers (e.g., psychic costs) may substantially impede relocations when large disparities exist in racial composition, or possibly that households in racially integrated submarkets differ by a self-selection process from households of similar income in segregated submarkets.

Before closing this section, several group statistical tests should be noted. Visual inspection of the results suggested substantial parameter variations across classes. Two Chow tests (Chow, 1960) were performed to test for equality of the set of coefficients across race or income class. The $F_{102,29} = 3.735$ and $F_{93,88} = 3.02$ were both statistically significant at greater than the 0.01 level, so that the null hypothesis of coefficient equality across race and income, respectively, were rejected. As already noted, none of the occupation, education, and income surrogates alone is likely to be reflective of social status. Yet the low statistical significance of several variables is likely to be at least partially due to multicollinearity.[10] The parameters of the social status difference variables were tested as a group for statistical significance for each household class by conventional analysis of variance methods (Johnson, 1972). The null hypothesis that social status differentials as a group did not contribute to the explanatory power of the model was rejected at the 0.05 level for all classes.[11] Thus, overall, the results suggest that not only do spatial and social status factors bias relocation patterns after demand preferences have been controlled for, but also that their impacts may vary across household classes. The policy and research implications of the results will be discussed further in chapter 8.

6.3. THE EFFECTS OF INTRASUBMARKET GENERALIZED COSTS

The purpose of this section is to describe the second and third stages of the multistage estimation procedure culminating in estimates of the intrasubmarket generalized costs parameters of the model. As noted in the first section of this chapter, generalized relocation costs impede the continuous adjustment of housing consumption by relocation. These costs bias residential choice in the sense that by choosing to remain in their current residence, households may not consume their "optimal" housing of a frictionless world of costless mobility. Although direct measures of the generalized costs creating locational inertia were unavailable, the objective of this section is to identify indirectly the effects of these costs through their correlation with household attributes. The estimation equation used to estimate these effects was derived in chapter 4. It is repeated below to reiterate the general estimation strategy described in chapter 4:

$$\left(\frac{D_{kii}}{D_{ki*}D_{k*i}}\right) = A_{ki}^{-1}B_{ki}^{-1}F^{-\delta_k}. \tag{6.4}$$

Equation (6.4) is the focal point for estimating the intrasubmarket generalized costs parameters of the model. However, to utilize (6.4) in this manner one must first have estimates of A_{ki}^{-1} and B_{ki}^{-1} at least up to a scale factor. This is the purpose of the second stage of estimation to be discussed next, followed by a discussion of the third estimation stage utilizing the results of the second estimation stage in (6.4).

6.3.1. Estimation of the Relative Values of A_{ki}^{-1} and B_{kj}^{-1}

The analytical steps leading to the estimation equation (4.19) for the second stage estimation of A_{ki}^{-1} and B_{kj}^{-1} have been discussed in detail in section 4.2.2. The point of departure for this discussion is the log-linear restatement of (4.19) below that incorporates the postulated structure of disturbance terms in (5.1) and (5.2):[12]

$$\log\left(\frac{\tilde{D}_{kij}F_{ij}^{\hat{\delta}_k}}{\tilde{D}_{ki*}\tilde{D}_{k*j}}\right) = \log(A_{ki}^{-1}) + \log(B_{kj}^{-1}) + \log\epsilon_k^{-1} + \log\epsilon_{ij}. \tag{6.5}$$

The tilde is used to denote observed values in (6.5). Thus $\tilde{D}_{kij}$, $\tilde{D}_{ki*}$, and $\tilde{D}_{k*j}$ are observed intersubmarket relocation flows, total observed outmover households, and total observed inmover households. These totals do not include nonmover households. However, they do include movers to or from all other submarkets within Wichita not included in the sample of submarkets used for intersubmarket flows. In other words, $\tilde{D}_{ki*}$ and $\tilde{D}_{k*j}$ are the marginal totals over all submarkets other than nonmovers in Wichita over the time period. The $F_{ij}^{\hat{\delta}_k}$ are the calibrated generalized cost scores using the parameters from the first estimation stage.

Estimates of the relative values of A_{ki}^{-1} and B_{kj}^{-1} may be obtained through the following statistical "fixed effects" model equivalent of (6.5):

$$\log\left(\frac{\tilde{D}_{kij}F_{ij}^{\hat{\delta}_k}}{\tilde{D}_{ki*}\tilde{D}_{k*j}}\right) = \log\mu + \sum_{l=1}^{K} \lambda_l G_l + \sum_{m=1}^{M} \psi_m G_m + \sum_{n=1}^{M} \theta_n G_n + \sum_{l=1}^{K}\sum_{m=1}^{M} \beta_{lm} G_{lm} + \sum_{l=1}^{K}\sum_{n=1}^{M} \alpha_{ln} G_{ln} + \log(\epsilon_k^{-1}\epsilon_{ij}), \tag{6.6}$$

where

$$G_l = \begin{cases} 1 & \text{if } l = k, \\ 0 & \text{otherwise;} \end{cases} \qquad G_{lm} = \begin{cases} 1 & \text{if } l = k \text{ and } m = i, \\ 0 & \text{otherwise;} \end{cases}$$

$$G_m = \begin{cases} 1 & \text{if } m = i, \\ 0 & \text{otherwise;} \end{cases} \qquad G_n = \begin{cases} 1 & \text{if } l = k \text{ and } n = j, \\ 0 & \text{otherwise;} \end{cases}$$

$$G_n = \begin{cases} 1 & \text{if } n = j, \\ 0 & \text{otherwise.} \end{cases}$$

It should be apparent that restrictions must be imposed on the parameters of (6.6) to avoid complete linear dependence among the columns of the dummy variables that would preclude parameter estimation. Under the following sets of restrictions imposing that the sum of all parameters within classes is equal to zero, estimates of the relative values of A_{ki}^{-1} and B_{kj}^{-1} may be obtained through estimation of (6.6). It may be more formally stated that under the following restrictions,

$$\sum_{l=1}^{K} \lambda_l = \sum_{m=1}^{M} \psi_m = \sum_{n=1}^{M} \theta_n = \sum_{l=1}^{K} \beta_{lm} = \sum_{m=1}^{M} \beta_{lm} = \sum_{l=1}^{K} \alpha_{ln} = \sum_{n=1}^{M} \alpha_{ln} = 0,$$

log-linear estimation of (6.6) yields the following estimates:

$$\hat{\mu} = \log(\bar{A}^{-1}) + \log(\bar{B}^{-1}),$$
$$\hat{\lambda}_k = [\log(\bar{A}_{k*}/\bar{A})^{-1} + \log(\bar{B}_{k*}/\bar{B})^{-1}],$$
$$\hat{\psi}_i = \log(\bar{A}_{i*}/\bar{A})^{-1},$$
$$\hat{\theta}_j = \log(\bar{B}_{*j}/\bar{B})^{-1},$$
$$\hat{\beta}_{ki} = \log(A_{ki}/\bar{A}_{i*})^{-1} - [\log(\bar{A}_{k*}/\bar{A})^{-1} + \log(\bar{B}_{k*}/\bar{B})^{-1}],$$
$$\hat{\alpha}_{kj} = \log(B_{kj}/\bar{B}_{*j})^{-1} - [\log(\bar{A}_{k*}/\bar{A})^{-1} + \log(\bar{B}_{k*}/\bar{B})^{-1}]. \tag{6.7}$$

All terms with bars are logarithms of the geometric means of either A_{ki}^{-1} or B_{kj}^{-1}:

$$\log(\bar{A}^{-1}) = \sum_{k=1}^{K} \sum_{i=1}^{M} \log(A_{ki}^{-1})/K \times M,$$

$$\log(\bar{B}^{-1}) = \sum_{k=1}^{K} \sum_{j=1}^{M} \log(B_{kj}^{-1})/K \times M,$$

$$\log(\bar{A}_{k*}^{-1}) = \sum_{i=1}^{M} \log(A_{ki}^{-1})/M,$$

$$\log(\bar{B}_{k*}^{-1}) = \sum_{j=1}^{M} \log(B_{kj}^{-1})/M,$$

$$\log(\bar{A}_{i*}^{-1}) = \sum_{k=1}^{K} \log(A_{ki}^{-1})/K,$$

$$\log(\bar{B}_{*j}^{-1}) = \sum_{k=1}^{K} \log(B_{kj}^{-1})/K. \tag{6.8}$$

From (6.7) and (6.8) it is easily shown that estimates of A_{ki}^{-1} and B_{kj}^{-1} (in logarithms) relative to their mean values are:

$$\hat{\lambda}_k + \hat{\psi}_i + \hat{\beta}_{ki} = \log(A_{ki}/\bar{A})^{-1}, \tag{6.9}$$
$$\hat{\lambda}_k + \hat{\theta}_j + \hat{\alpha}_{kj} = \log(B_{kj}/\bar{B})^{-1}. \tag{6.10}$$

Although the log-linear fixed effects model (6.6) has been specified as a regression equation, the number of parameters to be estimated (and hence the size of matrix to be inverted), would be extremely large at any meaningful level of household disaggregation. Since all independent variables are dummy variables, however, all parameter estimates can be obtained without matrix inversion by use of conventional analysis of variance methods. Defining X_{kij} as the dependent variable in (6.6), all estimates in (6.7) may be obtained as deviations of conditional means of the dependent variable from grand means:

$$\hat{\mu} = \sum_{k}^{K} \sum_{i}^{M} \sum_{j}^{M} X_{kij}/K \times M \times M,$$

$$\hat{\lambda}_k = \sum_{i}^{M} \sum_{j}^{M} X_{kij}/M \times M - \hat{\mu},$$

$$\hat{\psi}_i = \sum_{k}^{K} \sum_{j}^{M} X_{kij}/K \times M - \hat{\mu},$$

$$\hat{\theta}_j = \sum_{k}^{K} \sum_{i}^{M} X_{kij}/K \times M - \hat{\mu},$$

$$\hat{\beta}_{ki} = \sum_{j}^{M} X_{kij}/M - [\hat{\mu} + \hat{\lambda}_k + \psi_i],$$

$$\hat{\alpha}_{kj} = \sum_{i}^{M} X_{kij}/M - [\hat{\mu} + \hat{\lambda}_k + \hat{\theta}_j]. \qquad (6.11)$$

Inserting the estimates of (6.11) into (6.9) and (6.10) yields the following estimates as deviations of conditions means from the grand mean:

$$\sum_{j}^{M} X_{kij}/M - \hat{\mu} = \log(A_{ki}/\bar{A})^{-1}, \qquad (6.12)$$

$$\sum_{i}^{M} X_{kij}/M - \hat{\mu} = \log(B_{kj}/\bar{B})^{-1}. \qquad (6.13)$$

Thus because the parameters of F_{ij} were estimated independently in the first stage, the dummy variable fixed effects structure in (6.6) provides a simple and direct way of estimating relative values of the systemic factors A_{ki}^{-1} and B_{kj}^{-1}.

Estimates for relative values of A_{ki}^{-1} and B_{kj}^{-1} were obtained through (6.12) and (6.13) for a set of household classes and submarkets defined for the third estimation stage. This was important since they were to be used as inputs into that estimation stage. Although the actual classifications will be discussed in the next section of this chapter, it should be noted that 108 household classes and 26 submarkets (2 rent classes X 13 spatial units) were defined. These classifications produce a potential number of parameters in this estimation stage of 5,416! The actual number of parameters estimated was much smaller due to problems of sparse data. In a large number of cases no mover households matched potential classifications. Since logarithms of zero cells are undefined, only nonzero flows were used in the computation of conditional means. Also, no conditional means were utilized where the number of nonzero flows averaged over was less than nine.[13] As in the case of the first-stage cross-product ratio estimation, it is not clear what degree of bias this truncated sample imparts on the parameter estimates. However, no other viable alternative existed.

Despite problems of sparse data, the number of estimates obtained was still 318. As a result, individual estimates cannot be presented here.[14] Table 6.3

Table 6.3. Geometric Mean Values of $(A_{ki}/\bar{A})^{-1}$ and $(B_{kj}/\bar{B})^{-1}$ for Households by Race, Income, and Spatial Unit (in logarithms)

Spatial Unit	*W-INC1*		*W-INC2*		*NW-INC1*	
	$(A_{ki}/\bar{A})^{-1}$	$(B_{kj}/\bar{B})^{-1}$	$(A_{ki}/\bar{A})^{-1}$	$(B_{kj}/\bar{B})^{-1}$	$(A_{ki}/\bar{A})^{-1}$	$(B_{kj}/\bar{B})^{-1}$
1	-0.3276	-0.1624	I	I	2.6764	3.1188
2	0.9818	1.3490	1.0897	1.3673	I	I
3	I	I	-0.3660	-0.2940	I	I
4	1.1794	0.3652	0.6027	0.0063	I	I
5	I	I	I	I	0.6082	0.5707
6	-1.0795	-0.9572	-1.0292	-0.8822	3.6774	3.6270
7	-0.2789	-0.2280	-0.0953	-0.0047	I	3.2898
8	0.7120	0.3616	-0.0881	-0.1900	I	I
9	-0.3509	-0.3280	0.0471	0.1577	3.3197	2.9885
10	-0.3133	-0.7651	0.6882	0.4103	3.1337	4.2698
11	0.5107	0.4210	0.2016	0.2646	-2.0108	I
12	-0.6554	-0.7329	-0.3348	-0.2931	I	I
13	1.0552	0.7477	0.7505	0.3541	I	I

Note: *W,NW:* (white, nonwhite); *INC1, INC2:* (\$0-9,999), (\$10,000-19,999); I: Insufficient data to compute estimates.

summarizes the mean values by the household classes of the first estimation stage by spatial unit. A possible check on their consistency stems from their cross-sectional proportionality to mean generalized costs measures as noted in chapter 4.[15] A casual inspection of table 6.3 does suggest greater mean costs for nonwhite households. Their comparison across income classes for white households is less clear. They do appear consistent in the spatial dimension as the estimates of $\log(\hat{A_{ki}}/\bar{A})^{-1}$ and $\log(\hat{B_{kj}}/\bar{B})^{-1}$ are generally similar in magnitude for any spatial unit. Overall, the results exhibit consistency. Since they were estimated to provide inputs into the third estimation stage, no real effort is made to interpret substantively the results in detail here. The next section describes the third estimation stage.

6.3.2. Estimation of the Parameters of F

Given the estimates of $\log(\hat{A_{ki}}/\bar{A})^{-1}$ and $\log(\hat{B_{kj}}/\bar{B})^{-1}$, the third estimation stage utilized them as inputs into a log-linear fixed effects version of (4.30) to obtain relative estimates of the parameters of $F^{-\delta_k}$ across household classes. The household class and submarket specification will be discussed first, followed by a discussion of the fixed effects model and a presentation and discussion of empirical results.

Household Class and Submarket Specifications. Although direct measures of the generalized costs impeding relocations were unavailable, indirect estimates of their effects should be identifiable if cost differentials are associated with household attributes. The clearest example is the inertia associated with duration of residence. Although we cannot measure the social and psychic costs of leaving familiar surroundings or observe tenure discounts due to long-term occupancy, it is plausible to postulate that these costs increase with duration of residence. Thus households with longer duration of residence should exhibit a greater likelihood of staying after controlling for demand preferences due to increased costs.

Submarkets were defined on the basis of the thirteen spatial units defined in chapter 5 and two rent classes [i.e., (\$0-99/month), (\$100-199/month)]. Households were stratified into 108 classes on the basis of six attribute dimensions. These dimensions are summarized in table 6.4 along with a priori expectations concerning class differentials.[16] There is little theory or past research from which to substantiate the expected differentials in generalized costs incurred by household class. The expectations in table 6.4 are based largely on the findings of past residential mobility research regarding exhibited movement propensities. The general hypothesis is that even after demand preferences are controlled for, households that are experiencing greater generalized relocation costs exhibit lower movement propensities.

Table 6.4. Household Class Attribute Dimensions for Estimation of F and Expected Class Differentials

Household Attributes	*Expected Costs of Moving Differentials*
WHITE *NONWHITE*	*NONWHITE* > *WHITE*
INC1: (\$0–9,999) *INC2:* (\$10,000–19,999)	*INC1* > *INC2*
SIZE1: (⩽2 persons, *t*) *SIZE2:* (⩾3 persons, *t*)	*SIZE2* > *SIZE1*
AGE1: (head ⩽29 years old) *AGE2:* (head 30–59 years old) *AGE3:* (head ⩾60 years old)	*AGE3* > *AGE2* > *AGE1*
YEARS1: (⩽5 years duration of residence) *YEARS2:* (⩾6 years duration of residence)	*YEARS2* > *YEARS1*
HHCON: (household size constraint *t*,*t*+1) *HHINC:* (household size increased *t*,*t*+1) *HHDEC:* (household size decreased *t*,*t*+1)	*HHCON* > *HHDEC* > *HHINC*

Fixed Effects Model. Under the assumption that any interaction effects among the household class attributes were zero, the following equation for *nonmover households* is the log-linear fixed effects model equivalent to (6.4):

$$\log\left(\frac{\tilde{D}_{kii}(\hat{A}_{ki}/\bar{A})(\hat{B}_{ki}/\bar{B})}{\tilde{D}_{ki*}\tilde{D}_{k*i}}\right) = \mu + \sum_{l=1}^{2} \alpha_l G_l + \sum_{m=1}^{2} \beta_m G_m + \sum_{n=1}^{2} \gamma_n G_n + \sum_{o=1}^{3} \delta_o G_o + \sum_{p=1}^{2} \psi_p G_p + \sum_{r=1}^{3} \lambda_r G_r + \log(\epsilon_k^{-1}\epsilon_{ii}), \tag{6.14}$$

where

$$G_l = \begin{cases} 1 & \text{if household class } k \text{ is of income class } l, \\ 0 & \text{otherwise;} \end{cases}$$

$$G_m = \begin{cases} 1 & \text{if household class } k \text{ is of race } m, \\ 0 & \text{otherwise;} \end{cases}$$

$$G_n = \begin{cases} 1 & \text{if household class } k \text{ is of household size class } n, \\ 0 & \text{otherwise;} \end{cases}$$

$$G_o = \begin{cases} 1 & \text{if household class } k \text{ is of age class } o, \\ 0 & \text{otherwise;} \end{cases}$$

$$G_p = \begin{cases} 1 & \text{if household class } k \text{ is of duration of residence class } p, \\ 0 & \text{otherwise;} \end{cases}$$

$$G_r = \begin{cases} 1 & \text{if household class } k \text{ is of household size change class } r, \\ 0 & \text{otherwise.} \end{cases}$$

In order to avoid complete linear dependence among the columns of the matrix of independent variables, restrictions were imposed on the parameters within each household attribute group in (6.14). For each group, one parameter was set equal to zero so that the estimated parameters reflected differences in $F^{-\delta_k}$ across two classes within an attribute. For example, by setting the β parameter of the dummy variable corresponding to white households equal to zero (i.e., $\beta_{\text{white}} = 0$), the estimated race parameter is interpreted as the effect of generalized costs experienced by nonwhite households relative to white households, *ceteris paribus.* Parameters of the following attributes of table 6.4 were set equal to zero: *WHITE, INC1, SIZE2, AGE2, YEARS2, HHDEC.*

The fixed effects model (6.14) was estimated by ordinary least squares regression. The presence of zero values in any terms comprising the dependent variable precluded its use. By exclusion of zero or undefined measures of the dependent variable, a truncated sample of 136 observations remained. As noted in discussion of earlier estimation stages, there is no way to a priori evaluate whether these omissions seriously biased the parameter estimates.

Empirical Results. The empirical results from estimation of (6.14) are presented in table 6.5. Before commenting on them, a note on their interpretation is in order. First, household demand preferences are controlled for by the structure of the equation. Thus the results pertain to the effects of generalized costs. Second, note that relative values of the complete score $F^{-\delta_k}$ are estimated. Since F is an unobservable measure of cost, $F^{-\delta_k}$ is actually a measure of the facility of *staying* in one's current residence and thus is reflective of greater effects of generalized costs of moving. Finally, since neither F nor $-\delta_k$ is directly observable, one cannot infer whether a household class actually incurs greater costs or is more sensitive to costs than other classes.

Table 6.5. Empirical Results of the Parameter Estimates of *F*

Variable	*β*	*t-Statistic*
SIZE1	-0.2037	0.18
HHCON	1.3657	5.82*
HHINC	0.0065	0.03
YEARS1	-1.2551	2.30*
AGE1	-1.2533	2.65*
AGE3	0.8878	1.46
INC1	-1.3704	2.79*
NONWHITE	0.9216	0.09
CONSTANT	1.6955	
No. of Observations	136	
R^2	0.573	
F	21.2	

*Significant at >0.01 level.

SIZE1. The parameter of *SIZE1* was consistent with a priori expectations but statistically insignificant. The magnitude of the parameter itself suggests that household size exerts little effect on the household's facility of staying in the current residence. The parameter suggests that households of one or two members are about 0.8 times as likely to stay in their current residence than larger households, *ceteris paribus.*

HHCON. The parameter *HHCON,* reflecting the relative effect of no change in household size to a recent decrease in household size, was of correct sign and highly significant. The magnitude of the parameter suggests that households not undergoing a recent change in household size are nearly four times more likely to stay than households undergoing a decrease in household size.

HHINC. The parameter of *HHINC* was both small and statistically insignificant. The parameter suggests that there is virtually no difference in the facility of staying between households undergoing an increase versus a decrease in household size.

YEARS1. The estimated parameter of *YEARS1* suggests that duration of current residence exerts a strong influence on the propensity to stay. The magnitude of the parameter suggests that households of less than or equal to five years duration at the current residence are almost one-third less likely to remain in their current residence than households with duration of residence exceeding five years, *ceteris paribus.* This parameter suggests that the attachment to the current residence is strongly enhanced by increased social ties, and so forth over time.

AGE1, AGE3. The parameter of *AGE1* suggests that a household whose head is less than or equal to thirty years of age is about one-third less likely to remain in its current residence, *ceteris paribus,* than a household whose head is thirty-one to fifty-nine years of age. The parameter of *AGE3* was of correct a priori sign but was statistically insignificant. One aspect of past residential mobility research has been the general uncertainty of whether age independently affects movement propensities or surrogates the changes of household composition occurring through the family life cycle. The large effects of age found here are of particular significance since changes of household size are controlled for.

INC2. The parameter of *INC2* was of correct a priori sign and statistically significant. The magnitude and sign of the parameter suggest that higher income households are about one-fourth as likely to stay in their current residence than lower income households, *ceteris paribus.* This suggests that income exerts a positive effect on a household's ability to adjust its consumption of housing.

NONWHITE. The parameter of *NONWHITE* was of correct a priori sign, but its *t*-value was of such small magnitude to warrant caution against overinterpretation. The small magnitude of the parameter suggests that there is little difference in the facility of staying across racial groups.

Overall, the empirical results of this stage suggest substantial variance across household classes in the locational inertia impeding relocation. The true significance of these results lies in the fact that by use of the ratio form of the estimation equation (6.4), variations in household class demand attributes have been explicitly controlled for. Whereas Quigley and Weinberg (1977) have argued that observed household attribute correlates of mobility are largely due to housing consumption disequilibrium and moving costs, these results suggest that generalized relocation costs may vary over household classes at similar levels of housing consumption disequilibrium. These results support the contention of Mayo et al. (1979) that moving costs differentials are of considerable importance in explaining mobility decisions and as such are consistent with the view of relocation as a rational process in which benefits and costs are weighed in decisions.

6.4. CONCLUDING REMARKS

This chapter has sought to identify the effects of generalized costs on residential relocation. The empirical results have supported the proposition that generalized costs exert significant biases on household relocation choices. The cross-product ratio estimation of the first estimation stage suggested that distance-related and social status generalized costs exert a strong influence on spatial patterns of residential relocation flows, even after demand preferences for attributes nonuniformly distributed across space have been controlled for. The results of the third estimation stage suggested that the effects of generalized costs on relocation anywhere varied substantially by household class after demand preferences were controlled for.

Overall, the results of this chapter have imparted useful empirical insight into the impact of generalized costs on residential choice. In particular, the results raise serious questions about empirical works based on costless mobility assumptions. The results also raise many questions for future mobility research. No data were available to measure these costs directly. Most researchers would attribute the powerful distance deterrent effects found in this study to a variety of factors, such as the limited spatial awareness of households, the costs of information and search, moving costs, the psychic costs of breaking social ties, or to institutional barriers such as housing market discrimination in the case of nonwhite households. Since these individual information and social costs could not be directly specified in this study, it was impossible to discern to what degree each or any of these factors contributed to the powerful distance effect. Likewise, it was impossible to discern whether the household class differentials in generalized moving costs were due to incurrence of greater costs or greater sensitivity to costs. In spite of the limitations posed by the inability to specify generalized costs measures directly, the results of this study have produced an initial insight into the nature of generalized cost bias in residential choice. The general policy implications of the results will be discussed further in chapter 8.

NOTES

1. The first two sections of this chapter draw heavily from the work of Porell (1982). Given the context of the multistage estimation procedure, the rationale for use of the cross-product ratio has been discussed fully in chapter 4 and thus is not discussed in detail here.

2. Brown and Moore (1970) and Wolpert (1965) conceptualized the idea of mental maps or images of the city in terms of "awareness space" or "action space," respectively. Clark (1969) attempted to measure this concept quantitatively by using data on distance consumers traveled for several commodities to produce "mean information field" measures (Marble and Nystuen, 1963).

3. Directional bias is generally viewed as the degree to which relocations are likely to terminate in a particular direction away from an origin. Sectoral bias is generally defined as the degree to which relocations are biased toward locations along a single axis through an origin. See Brown and Holmes (1971) for a clarification of their measurement.

4. Stetzer (1976) estimated a gravity-type model that was structurally analogous to the household demand equation (3.9) by the approach of Nakanishi and Cooper (1974). The approach circumvents the nonlinearity problems of the choice set in (3.9) at the expense of

introducing covariances among disturbance terms. Stetzer (1976) found that use of ordinary least squares produced estimates with less bias and smaller mean square error than a generalized least squares procedure accounting for the dependencies among disturbances. Why this occurred is not clear. However, it may be the result of *estimated* covariances introducing error rather than reducing it.

5. The flow matrices are available from the author.

6. It is important to note that a quadratic relationship exists as long as $\psi_1 > 0$ and $\psi_2 < 0$, regardless of the relative magnitudes of the absolute values of the parameters. Whether the quadratic relationship is meaningful depends on the range of the differential variables. For example, if all differentials exceed unity, then a quadratic relationship such as that in figure 6.2 is only relevant if $|\psi_1| >> |\psi_2|$. Alternatively, if $|\psi_2| > |\psi_1|$, then the maximum of the quadratic relationship lies between 0 and 1.

7. Stetzer (1976) found that incrementing all flows by unity arbitrarily in gravity models of the form (3.9) produced parameter estimates with greater bias and larger mean square error than by omission in small samples. Baxter (1979) defends omission of zero flows on the ground that their variances are large and thus little weight should be attached to them.

8. The mean white-collar/blue-collar ratio in the sample was 1.275, with a standard deviation of 0.925. The minimum and maximum values were 0.325 and 3.58 respectively.

9. For example, the differential in percentage of white-collar composition between two submarkets with white/blue-collar ratios of 0.325 (24.5% white-collar) and 1.325 (56.9% blue-collar) is 32.4%. However, the differential in percentage of white-collar composition between two submarkets with ratios of 1.325 and 2.325 (69.9% white-collar) is only 13%.

10. The simple correlation between the cross-product ratio of *OCCDIFF* and *EDUCDIFF* and *INCDIFF* were 0.543 and 0.645, respectively. The simple correlation between *EDUCDIFF* and *INCDIFF* was 0.655. The entire correlation matrix is available from the author.

11. The F-values were $F_{9,28} = 2.96$(*NW-INC1*), $F_{9,88} = 2.52$(*W-INC1*), and $F_{9,79} = 2.67$(*W-INC2*).

12. If one repeats the steps leading to (4.19) incorporating the disturbance terms in (5.1), the systemic factors A_{ki}^{-1} and B_{kj}^{-1} encompass disturbances as well by their additive structure. It is easy to show that all other disturbances other than those in (6.5) are canceled out by division.

13. For nonwhite households, sparse data required retaining all conditional means in which destinations or origins exceeded 4.

14. The estimates are available from the author.

15. In chapter 4 the cross-sectional proportionality of the systemic factors L_{ki}^{-1} and M_{kj}^{-1} to mean generalized costs was noted. Since intrasubmarket stayers are not included in the estimation of A_{ki}^{-1} and B_{kj}^{-1}, the proportionality is with mean costs borne by mover households.

16. The dimensions in table 6.4 actually produce 144 classes. Since nonwhite households with annual incomes greater than $10,000 were omitted in the first estimation stage, they were excluded from all further estimation stages.

7 DEMAND FOR SUBMARKET ATTRIBUTES

This chapter discusses the estimation of the demand parameters for residential attributes of the model developed in chapter 3 and includes the last two stages of the multistage estimation procedure outlined in chapter 4 (figure 4.1). Although the focal point of the chapter is the estimation of residential attribute parameters by the total inflow equation (4.28), estimates of the relative values of the systemic variables M_{kj} must first be obtained. The next section summarizes their estimation by a statistical fixed effects model. This is followed by a more comprehensive discussion of the fifth stage of estimation in the second section. The last section contains brief concluding remarks.

7.1. ESTIMATION OF RELATIVE VALUES OF M_{kj}

Since the analytical steps leading to the estimation equation (4.22) of the fourth estimation stage have been discussed already in section 4.2.3, this discussion begins with its log-linear restatement incorporating the postulated structure of disturbance terms in (5.1) and (5.2):

$$\log\left(\frac{\tilde{D}_{kij}F_{ij}^{\hat{\delta}_k}}{\tilde{H}_{ki}\tilde{D}_{kj}}\right) = \log(L_{ki}^{-1}) + \log(M_{kj}^{-1}) + \log(\epsilon_k^{-1}\epsilon_{ij}). \tag{7.1}$$

As before, the tilde and circumflex are used to denote observed and calibrated values, respectively. It is important to distinguish the difference between (7.1) and the log-linear equation (6.5) used to estimate relative values of A_{ki}^{-1} and B_{kj}^{-1}. Note that a statistical fixed effects model version of (7.1) was estimated from observations on both mover and stayer households. Accordingly, $\tilde{H}_{ki}$ is defined as total households observed to reside in submarket i at the beginning of the time period, and $\tilde{D}_{kj}$ is defined as the total observed households residing in submarket j at the end of the time period. Also, $F_{ij}^{\hat{\delta}_k}$ denotes calibrated values of generalized cost scores from both the first and third estimation stages.

Estimates of the relative values of M_{kj}^{-1} were obtained through the following statistical fixed effects model representation of (7.1):

$$\log\left(\frac{\tilde{D}_{kij}F_{ij}^{\hat{\delta}_k}}{\tilde{H}_{ki}\tilde{D}_{kj}}\right) = \log\mu + \sum_{l=1}^{K} \alpha_l G_l + \sum_{m=1}^{M} \beta_m G_m + \sum_{n=1}^{M} \gamma_n G_n + \sum_{l=1}^{K}\sum_{m=1}^{M} \psi_{lm} G_{lm} + \sum_{l=1}^{K}\sum_{n=1}^{M} \lambda_{ln} G_{ln} + \log(\epsilon_k^{-1}\epsilon_{ij}), \tag{7.2}$$

where

$$G_l = \begin{cases} 1 & \text{if } l = k, \\ 0 & \text{otherwise;} \end{cases} \qquad G_{lm} = \begin{cases} 1 & \text{if } l = k \text{ and } m = i, \\ 0 & \text{otherwise;} \end{cases}$$

$$G_m = \begin{cases} 1 & \text{if } m = i, \\ 0 & \text{otherwise;} \end{cases} \qquad G_{ln} = \begin{cases} 1 & \text{if } l = k \text{ and } n = j, \\ 0 & \text{otherwise;} \end{cases}$$

$$G_n = \begin{cases} 1 & \text{if } n = j, \\ 0 & \text{otherwise.} \end{cases}$$

Imposing the same restrictions used to estimate the relative values of A_{ki}^{-1} and B_{kj}^{-1} in chapter 6—that is, the sum of all parameters within any dummy variable group in (7.2) equals zero—the parameter estimates of (7.2) correspond to those presented in (6.7)-(6.8) with L_{ki} and M_{kj} substituted for A_{ki} and B_{kj}, respectively. Using analysis of variance methods, relative estimates of M_{kj}^{-1} were computed as conditional means of the dependent variable of (7.2) relative to the grand mean, as was shown earlier in (6.11)-(6.13). That is,

$$\hat{\alpha}_k + \hat{\gamma}_j + \hat{\lambda}_{kj} = \log(M_{kj}/\bar{M})^{-1} = \sum_{i=1}^{M} X_{kij}/M - \hat{\mu}, \tag{7.3}$$

where

$$X_{kij} = \log\left(\frac{\tilde{D}_{kij} F_{ij}^{\hat{\delta}_k}}{\tilde{H}_{ki} \tilde{D}_{kj}}\right),$$

$$\hat{\mu} = \sum_{k=1}^{K} \sum_{i=1}^{M} \sum_{j=1}^{M} X_{kij}/K \times M \times M,$$

$$\log \bar{M}^{-1} = \sum_{k=1}^{K} \sum_{j=1}^{M} \log(M_{kj}^{-1})/K \times M.$$

Since the estimates of relative values of M_{kj} were to be used as inputs into the final stage of the estimation procedure, household classes and submarkets were defined to conform to those described in the next section. Because of the logarithmic structure of (7.3), only nonzero flows were used in the computation of conditional means. Conditional means were retained only when the number of nonzero flows averaged over exceeded five, or when all households residing in a submarket at the end of the time period were nonmovers. Given the sparsity of the intersubmarket flow matrix and the simple dominance of nonmover households in numbers in any year, the estimates of M_{kj} were clearly dominated by nonmover households and the effects of the intrasubmarket generalized costs estimates $F^{-\delta_k}$ of the third estimation stage. Aside from this dominance of nonmovers, the degree of bias this truncated sample imparts on the parameter estimates is unclear. Yet no other viable alternative was apparent.

Since 1,490 estimates of $\log(M_{kj}/\bar{M})^{-1}$ were obtained through (7.3), obvously individual estimates cannot be presented here. Table 7.1 contains a summary of mean values of estimates for the fourteen household classes and thirteen spatial units defined in the fifth estimation stage. Since the primary purpose of obtaining these estimates was for their use as controlled inputs into the fifth estimation stage, no substantive interpretation of the results is provided here.

7.2. ESTIMATION OF SUBMARKET ATTRIBUTE PARAMETERS

Given the estimates of $\log(\hat{M}_{kj}/\bar{M})^{-1}$ from the fourth estimation stage, they were used as inputs into a log-linear version of (4.28). The household class and submarket specifications for this final estimation stage are discussed next, followed by the specification of residential attributes in the model. The presentation and discussion of empirical results complete this section.

Table 7.1. Geometric Mean Values of $(M_{kj}/\bar{M})^{-1}$ for Household Classes and Spatial Units (in logarithms)

Household Class	$(M_{kj}/\bar{M})^{-1}$	*Spatial Unit*	$(M_{kj}/\bar{M})^{-1}$
NW-INC1-SIZE2	-1.3726	1	-0.3830
NW-INC1-SIZE3	-1.7587	2	0.5357
NW-INC2-SIZE2	-1.2022	3	1.3815
NW-INC2-SIZE3	-1.7435	4	0.3279
W-INC1-SIZE1	-1.0653	5	-1.2236
W-INC1-SIZE2	-0.3398	6	0.0963
W-INC1-SIZE3	-0.7476	7	-0.0189
W-INC2-SIZE1	-0.2268	8	0.2820
W-INC2-SIZE2	-0.0428	9	-0.0355
W-INC3-SIZE1	0.7283	10	-0.0580
W-INC3-SIZE2	0.9021	11	0.3168
W-INC3-SIZE3	0.4480	12	-0.1538
W-INC4-SIZE1	0.7587	13	0.5881
W-INC4-SIZE2	0.7584		

Note: *W,NW:* (white, nonwhite); *INC1, INC2, INC3, INC4:* ($0–4,999), ($5,000-9,999), ($10,000–14,999), ($15,000-19,999); *SIZE1, SIZE2, SIZE3:* (≤2 persons), (3–4 persons), (≥5 persons).

7.2.1. Household Class and Submarket Specification

Although the use of the total flow equation (4.28) substantially reduced the problem of sparse cell counts, the large number of household and dwelling classes defined in tables 5.2 and 5.3 necessitated some aggregation over household classes. Given the importance of submarket attributes in the theoretical development of the model and the relatively smaller number of dwelling type classifications—that is, twenty-four dwelling types—only household attributes were aggregated over. Thus all twenty-four dwelling types in table 5.3 were used. Race (*W,NW*) was retained as a household classification for the purpose of examining racial differentials in housing demand, given the possibility of racial discrimination in the housing market. Income class was retained with four categories (*INC1:* [$0–4,999]; *INC2:* [$5,000-9,999]; *INC3:* [$10,000-14,999]; *INC4:* [$15,000-19,999]), because of its obvious importance as a primary determinant of housing demand and its likely interactions with other housing demand attributes. Household size was retained with three categories (*SIZE1:* [1-2 persons]; *SIZE2:* [3-4 persons], *SIZE3:* [≥5 persons]), because of its obvious effects on demand for space.[1]

The other classes in table 5.2 were aggregated over under the explicit assumption of parameter homogeneity for residential attributes in the duration of residence, change of household size, and age of head of household classes.[2] The least plausible assumption is parameter homogeneity over age class, given the family life cycle concept. However, further disaggregation of classes was precluded by problems of sparse data. In any event, much of the information imparted by age should be reflected in the joint classification of households by income and household size.[3] Although the potential number of household classes was twenty-four (i.e., 2 × 4 × 3), insufficient data reduced the actual number to fourteen. Nonwhite households with incomes exceeding $10,000 were excluded since no estimates of generalized costs were available for the computation of M_{kj} in the fourth estimation stage. In addition, there were insufficient observations on nonwhite households of one to two persons and white households with more than four persons with incomes of ($5,000-9,999) or ($15,000-19,999). The next section discusses model specification.

7.2.2. Model Specification

The estimation equation (4.28) for the final estimation stage is restated below in logarithmic form with disturbances added due to the postulated error structure in (5.1)-(5.2):

$$\log\left(\frac{\tilde{D}_{kj}(\hat{M_{kj}}/\bar{M})^{-1}}{\tilde{S}_j}\right) = \log a_{kj} + \alpha_k \log Y_j - \gamma_k \log T_{kj} + \log(\epsilon_k \epsilon_j). \quad (7.4)$$

Given the theoretical discussion on parameter identification in chapter 4, it is worth reiterating some important assumptions underlying the estimation of (7.4). The most important assumption stems from the fact that the systemic factor R_j in (3.18) (arising from the imposition of the short-run equilibrium conditions [3.10]) could not be identified. As a result, it was necessary to specify rent class in Y_j as an instrumental variable under the assumption that it was uncorrelated with the disturbances in (7.4). Second, note that since (7.4) results from rearranging the total inflow equation (4.1), the constants $\log(a_{kj})$ cannot be identified. The number of a_{kj} equals the number of total inflow equations. Thus it was necessary to assume invariance of a_{kj} across all j submarkets. Finally, since no data on household workplaces were available, commuting costs, or T_{kj}, could not be specified by household class. In a crude effort to account for workplace commuting effects and employment access, the variable was specified as a residential attribute in Y_j.

The residential attributes comprising Y_j were specified as a multiplicative series of characteristic attributes of both the dwelling unit and the spatial environment of the submarket. Attributes of the dwelling (inclusive of rent class) were specified by dummy variables corresponding to the dwelling-type dimensions used to define submarkets. Environmental variables were defined as aggregate measures characterizing the spatial dimension of submarkets at the beginning of the time period, or 1975. Definitions of all residential attributes and their a priori expected signs are summarized in table 7.2.

The expected signs of the attributes in table 7.2 are based on the general premise that households should prefer more housing services to less under *ceteris paribus* conditions. Thus the expected sign of *LRENT* is somewhat ambiguous because of its gross level of classification. If the attributes describing submarkets are comprehensive, then households should clearly prefer lower to higher rents for the same bundle of housing services. Alternatively, it is possible that the gross dichotomous classification of rent class may surrogate unspecified housing service quantity differentials. In this latter case the sign of *LRENT* would be dependent on the income class of households. With the exception of *EMPACCS*, the spatial environmental attributes in table 7.2 were specified as surrogates of "neighborhood quality." Their expected signs are based on the simple premise that higher-quality neighborhoods are preferred to those of lower quality, *ceteris paribus.*

Although most of the expected signs are self-evident, a note on *NWPERC* is in order. For white households the expected sign is based on the supposition that because of prejudice whites prefer racially segregated submarkets. For nonwhite households the expected sign is less clear. If nonwhite households are not restricted by housing market barriers, then the signs of *NWPERC* would also reflect prejudices/preferences for racial composition. Under the general premise that under *ceteris paribus* conditions households prefer submarkets with racial composition similar to their own, a positive sign is expected for nonwhite households. However, a positive sign for *NWPERC* for nonwhites could also reflect the constraining effects of market barriers on choice.

The a priori expectations concerning household class differentials are also summarized in table 7.2. Specifying a priori these differentials is difficult in many cases because they are hypothesized under *ceteris paribus* conditions. For example, higher-income households tend to reside in peripheral areas of cities in which job accessibility is low. This is not evidence of a lesser sensitivity to commuting costs, however, and prices should be lower in peripheral areas allowing greater consumption of land. In addition, one might argue that possible housing market discrimination would lead one a priori to expect lesser revealed demand by nonwhite households for submarkets offering greater quantities of housing services. Yet there is no inherent reason to expect that race affects housing tastes per se. Thus no firm a priori expectations across race are stated.

Table 7.2. A Priori Specification of Residential Attributes

I. Dwelling attributes

Variable	*Expected Sign*	*Definition*
SF-STRUCT	>0; *SIZE3* > *SIZE2* > *SIZE1*; *INC4* > *INC3* > *INC2* > *INC1*; *W?NW*	Dummy variable equal to unity if dwelling is a single-family structure; zero otherwise (i.e., a multiunit structure)
3BED	>0; *SIZE3* > *SIZE2* > *SIZE1*; *INC4* > *INC3* > *INC2* > *INC1*; *W?NW*	Dummy variable equal to unity if dwelling has three bedrooms; zero otherwise (base variable is 1–2 bedrooms)
4BED	>0; >*3BED*; *INC4* > *INC3* > *INC2* > *INC1*; *SIZE3* > *SIZE2* > *SIZE1*; *W?NW*	Dummy variable equal to unity if dwelling has 4 or more bedrooms; zero otherwise (base variable is 1–2 bedrooms)
SOUND	>0; *SIZE1* > *SIZE2* > *SIZE3*; *INC4* > *INC3* > *INC2* > *INC1*; *W?NW*	Dummy variable equal to unity if exterior building condition of dwelling is sound; zero otherwise (i.e., deteriorating or dilapidated condition)
LRENT	>0; *SIZE3* > *SIZE2* > *SIZE1*; *INC1* > *INC2* > *INC3* > *INC4*; *W?NW*	Dummy variable equal to unity if rent is ($0–99/month); zero otherwise [i.e., ($100–199/month)]

II. Environmental attributes

Variable	*Expected Sign*	*Definition*
MEDINC	>0; *INC4* > *INC3* > *INC2* > *INC1*; *SIZE3* < *SIZE2* < *SIZE1*; *W?NW*	Median household income in a spatial unit

Table 7.2. A Priori Specification of Residential Attributes (*continued*)

Variable	*Expected Sign*	*Definition*
EDUC	>0; *INC4* > *INC3* > *INC2* > *INC1*; *SIZE3* < *SIZE2* < *SIZE1*; *W?NW*	The percentage of spatial unit population greater then 25 years of age with a high school education
WC/BC	>0; *INC4* > *INC3* > *INC2* > *INC1*; *SIZE3* < *SIZE2* < *SIZE1*; *W?NW*	The white-collar/blue-collar occupation ratio of residents of a spatial unit
EMPACCS	>0; *INC1* > *INC2* > *INC3* > *INC4*; *SIZE3* ? *SIZE2* ? *SIZE1*; *W?NW*	A weighted accessibility index to employment locations from a spatial unit. $EMPACCS_j = \Sigma_n E_n / DIS_{jn}$, where E_n = the employment by place of work in unit n, if total employment exceeds 2,000. DIS_{jn} = the distance from submarket j to employment center n
PERCSUB	<0; *INC1* > *INC2* > *INC3* > *INC4*; *SIZE3* > *SIZE2* > *SIZE1*; *W?NW*	The percentage of a spatial unit's dwellings in deteriorating or dilapidated condition
SCHOOL[a]	>0; *SIZE3* > *SIZE2* > *SIZE1*; *INC4* > *INC3* > *SIZE2* > *INC1*; *W?NW*	The mean of the median grade equivalent scores on the Iowa Test of Basic Skills battery administered to sixth-grade students in all schools located within the spatial unit of a submarket
PERCSF	>0; *INC4* > *INC3* > *INC2* > *INC1*; *SIZE3* ? *SIZE2* ? *SIZE1*; *W?NW*	The percentage of dwelling units of a spatial unit which are single-family units

Table 7.2. A Priori Specification of Residential Attributes (*continued*)

Variable	*Expected Sign*	*Definition*
PCRIME[b]	<0; *SIZE3* < *SIZE2* < *SIZE1* *INC4* < *INC3* < *INC2* < *INC1*; *W?NW*	The property crime rate in the spatial units expressed as the number of reported Part I Uniform Crime Reporting Offenses per 1,000 population
NWPERC	<0; *W*; *?NW*; *INC4* < *INC3* < *INC2* < *INC1*; *SIZE3* ? *SIZE2* ? *SIZE1*; *W?NW*	The percentage nonwhite racial composition of the spatial unit

[a] A grade equivalent indicates the grade level of a typical student making a particular raw score on the test. For example, a 6.7 would indicate a raw score of a typical pupil in the sixth grade at the end of the seventh month. The source of this data was Wichita Public School System (1975).

[b] Property crimes include burglary, larceny-theft, and motor vehicle theft.

The expectations concerning income class are largely self-evident under the premise that income exerts a positive effect on demand for housing services. On the other hand, expected differentials across household size classes are less clear. With the exception of *SF-STRUCT*, *3BED*, and *4BED*, for which household size differentials should reflect demand for space, the size class differentials specified deserve comment. For *SOUND*, *PERCSUB*, *MEDINC*, *EDUC*, and *WC/BC*, it was hypothesized that larger households should be less sensitive to these dwelling or neighborhood "quality" variables. The rationale is that because of more demanding space requirements, larger households may trade off "quality" for space. Thus larger households may be less sensitive to "quality" differentials than smaller households. The expectations for *PCRIME* and *SCHOOL* were specified under the common intuitive belief that larger households (with families) exhibit greater demand for "school quality" and safe neighborhoods. In other variables no clear expectations were evident and thus no hypotheses are stated.

The parameters of Y_j were estimated for fourteen household classes via (7.4). Only observations with nonzero flow totals were used. Ordinary least squares regression was used to estimate the equations for each class. Under the postulated disturbance structure in (5.1)-(5.2), these estimates are less efficient than those obtained under generalized least squares procedures, but still should retain the property of being unbiased.

7.2.3. Presentation and Discussion of Empirical Results

The empirical results for the final estimation stage are presented in table 7.3. A casual inspection of the results suggests reasonably good statistical fits and a general consistency with a priori expectations. Interpreting and discussing all parameters on an individual basis, however, would be quite a cumbersome task. One would quickly lose sight of the overall meaning of the results. Thus a more meaningful way of interpreting the parameters in table 7.3 is to seek out regularities in the parameter estimates and to comment explicitly on a subset of individual parameters. This approach will yield less precise statements about household demand for particular attributes and their variation across classes, but it is pursued here in the interests of clarity.

An initial way of assessing the empirical results is to examine how each of the dwelling and environmental parameter estimates fared in terms of consistency with a priori expectations of signs summarized in table 7.2. Table 7.4 provides a general summary of the number of consistent and inconsistent parameters for each residential attribute variable across household classes. In addition, the number of parameters statistically significant at greater than the 0.05 level is enclosed in parentheses. The results of table 7.4 clearly indicate that the parameters of the dwelling attribure variables were of correct sign in nearly all cases, with the bulk of the parameters statistically significant at the 0.05 level. On the other hand, with the exception of *NWPERC* (for white households) and *PERCSUB*, the spatial environmental variables did not fare as well with regard to consistency with a priori expectations. Given this general overview, it is useful to examine some particular variables in further detail.

Dwelling Attributes. In general, the empirical results suggested that under *ceteris paribus* conditions, households prefer low rent to high rent units, single-family units to multiunit structures, dwellings of sound exterior condition to deteriorating or dilapidated dwellings, and units with more bedrooms to those with less bedrooms. Given the discrete nature of the dummy variable specifications, the interpretation of the results may be best compared by example. The general magnitude of *LRENT* (i.e., about 0.35 on average) suggests that renter households are on the average about 1.4 times more likely to choose a unit renting for $0-99/month over one renting for $100-199/month, *ceteris paribus.* Likewise, the general magnitude of *SOUND* (about 0.40 on the average) suggests that households on the average are about 1.5 times more likely to choose dwellings with sound exterior condition over those of deteriorating exterior condition, *ceteris paribus.* The general magnitude of *3BED* (i.e., about 1.5 on average) suggests that demand for space is quite sensitive. On the average, renter households are about 4.5 times more likely to choose a unit with three bed-

Table 7.3. Empirical Results of Parameter Estimates of Residential Attributes

	NW, INC1, SIZE2		*NW, INC1, SIZE3*		*NW, INC2, SIZE2*		*NW, INC2, SIZE3*		*W, INC1, SIZE1*	
Variable	β	t	β	t	β	t	β	t	β	t
LRENT	0.338	(1.54)	0.319	(1.52)	0.380	(1.98)*	0.378	(2.39)*	1.047	(6.21)*
SOUND	0.267	(1.07)	0.084	(0.37)	0.769	(3.74)*	0.425	(2.24)*	0.170	(0.95)
SF-STRUCT	0.899	(3.87)*	0.745	(3.14)*	0.803	(3.92)*	0.691	(3.98)*	0.299	(1.84)
3BED	0.924	(2.21)*	2.008	(5.91)*	1.277	(4.54)*	1.764	(7.07)*	1.822	(2.80)*
4BED	1.162	(4.71)*	2.203	(7.39)*	1.820	(4.86)*	1.957	(9.63)*	1.857	(8.17)*
EMPACCS	-8.315	(2.92)*	-1.765	(3.29)*	3.090	(0.51)	0.976	(1.83)	0.726	(2.38)*
PCRIME	6.371	(4.84)*	1.174	(2.49)*	-5.135	(0.54)	0.986	(1.59)	-0.566	(1.94)
EDUC	14.166	(3.25)*	-0.474	(0.20)	-1.502	(0.14)	4.290	(2.08)*	-5.734	(3.83)*
WC/BC	-1.214	(1.46)	0.014	(0.11)	1.819	(0.36)	-1.898	(3.38)*	-1.501	(4.93)*
SCHOOL	-33.985	(4.07)*	0.803	(0.26)	-2.330	(0.41)	4.724	(1.40)	-1.614	(0.97)
MEDINC	-14.664	(2.34)*	1.787	(1.08)	-1.985	(0.35)	0.800	(0.58)	-1.128	(1.09)
NWPERC	-0.208	(0.90)	0.458	(3.50)*	1.132	(1.66)	0.366	(3.44)*	-0.299	(2.53)
PERCSUB	-0.513	(1.17)	-0.871	(2.22)*	0.958	(0.45)	-0.153	(0.32)	-0.576	(3.05)*
PERCSF	1.672	(1.25)	1.532	(2.63)*	1.875	(0.59)	-0.900	(1.80)	-0.501	(1.46)
CONSTANT	44.259		0.957		0.870		36.144		34.468	
No. of observations	46		91		72		94		153	
R^2	0.84		0.75		0.78		0.86		0.56	
F	13.00		16.67		18.79		35.82		12.29	

Table 7.3. Empirical Results of Parameter Estimates of Residential Attributes (*continued*)

	W, INC1, SIZE2		*W, INC1, SIZE3*		*W, INC2, SIZE1*		*W, INC2, SIZE2*		*W, INC3, SIZE1*	
Variable	β	t	β	t	β	t	β	t	β	t
LRENT	0.353	(2.09)*	0.259	(1.21)	0.151	(1.27)	0.281	(2.26)*	0.011	(0.10)
SOUND	0.493	(2.94)*	0.636	(3.12)*	0.167	(1.15)	0.612	(4.38)*	0.106	(0.76)
SF-STRUCT	0.777	(4.75)*	0.168	(0.62)*	0.968	(7.96)*	0.916	(6.84)*	0.524	(4.74)*
3BED	1.480	(5.43)*	1.629	(7.23)*	1.480	(5.32)*	1.065	(5.88)*	0.619	(2.44)*
4BED	1.580	(3.59)*		( )[a]	1.570	(9.64)*	1.420	(6.64)*	1.603	(10.36)*
EMPACCS	-0.994	(2.60)*	-0.714	(1.12)	0.602	(2.74)*	-0.024	(0.11)	-1.180	(5.05)*
PCRIME	0.156	(0.47)	0.439	(0.86)	0.227	(1.11)	0.213	(0.91)	0.420	(1.59)
EDUC	-1.410	(0.88)	4.550	(1.90)	1.990	(1.76)	2.737	(2.22)*	-10.700	(7.18)*
WC/BC	-0.005	(0.09)	0.190	(0.33)	-5.493	(2.61)*	-1.130	(4.70)*	4.750	(7.88)*
SCHOOL	-0.567	(0.33)	1.437	(0.63)	2.560	(1.85)	1.084	(0.82)	-3.070	(2.51)*
MEDINC	1.010	(0.86)	-1.225	(0.61)	1.975	(2.79)*	1.035	(1.28)	3.325	(2.52)*
NWPERC	0.094	(0.71)	-0.143	(0.77)	-0.505	(7.07)*	-0.353	(3.65)*	-0.413	(5.08)*
PERCSUB	-0.241	(1.14)	0.003	(0.03)	-0.266	(1.88)	-0.112	(0.73)	-0.365	(2.64)*
PERCSF	-0.371	(0.96)	-0.326	(0.65)	-1.370	(5.93)*	-1.477	(4.61)*	5.454	(5.61)*
CONSTANT	4.545		-20.490		-17.330		-13.340		37.420	
No. of observations	104		77		166		150		151	
R^2		0.56		0.66		0.66		0.67		0.68
F		8.04		8.34		20.82		19.59		20.23

Variable	*W, INC3, SIZE2*		*W, INC3, SIZE3*		*W, INC4, SIZE1*		*W, INC4, SIZE2*	
	β	t	β	t	β	t	β	t
LRENT	0.437	(4.08)*	0.437	(2.31)*	−0.094	(0.05)	0.253	(1.32)
SOUND	0.558	(4.74)*	0.785	(4.25)*	0.068	(0.36)	0.679	(3.33)*
SF-STRUCT	1.160	(10.10)*	0.869	(2.88)*	1.175	(7.26)*	1.368	(6.92)*
3BED	1.426	(9.31)*	1.515	(8.19)*	4.042	(7.82)*	1.445	(5.15)*
4BED	1.744	(8.46)*	1.833	(4.02)*	1.793	(4.66)*	1.490	(1.90)
EMPACCS	-1.681	(8.06)*	-1.100	(2.36)*	-0.819	(2.33)*	-1.095	(2.65)*
PCRIME	0.220	(0.94)	0.699	(1.52)	0.874	(2.46)*	0.046	(1.48)
EDUC	-1.703	(1.24)	-3.200	(1.53)	-6.141	(2.36)*	6.397	(2.10)*
WC/BC	1.010	(2.58)*	1.467	(1.27)	2.140	(2.07)*	2.299	(1.79)
SCHOOL	1.311	(1.15)	1.023	(0.49)	1.190	(0.64)	1.666	(0.69)
MEDINC	-1.951	(2.83)*	-0.808	(0.57)	1.214	(1.07)	0.476	(0.34)
NWPERC	−0.124	(0.86)	−0.187	(1.15)	−0.112	(0.81)	−0.096	(0.61)
PERCSUB	−0.095	(0.73)	−0.197	(0.85)	−0.775	(3.48)*	−0.596	(2.29)*
PERCSF	1.620	(3.62)*	2.736	(1.68)	2.220	(2.13)*	3.180	(1.79)
CONSTANT	3.348		1.960		4.932		8.035	
No. of observations	146		76		86		78	
R^2	0.78		0.76		0.73		0.75	
F	35.12		13.97		14.04		13.81	

Note: *W, NW:* white, nonwhite; *SIZE1, SIZE2, SIZE3:* (1–2 persons), (3–4 persons), (≥5 persons); *INC1, INC2, INC3, INC4:* ($0–4,999), ($5,000–9,999), ($10,000–14,999), ($15,000–19,999).

[a]No households of this class resided in 4-bedroom units.

*Significant at >0.05 level.

Table 7.4. A Summary of the Consistency of Parameter Estimates with A Priori Expectations

Attribute Variable	*Correct Sign*	*Significant Cases*	*Incorrect Sign*	*Significant Cases*
LRENT	13	(6)	1	(0)
SOUND	14	(8)	0	(0)
SF-STRUCT	14	(12)	0	(0)
3BED	14	(14)	0	(0)
4BED[a]	13	(12)	0	(0)
EMPACCS	3	(1)	11	(9)
PCRIME	3	(0)	11	(1)
EDUC	6	(4)	8	(3)
WC/BC	7	(3)	7	(4)
SCHOOL	9	(0)	5	(2)
MEDINC	8	(2)	6	(2)
NWPERC[b]	9	(4)	1	(0)
PERCSUB	12	(5)	2	(0)
PERSCF	7	(4)	7	(2)

[a] Does not include *W-INC1-SIZE3* households.

[b] The four nonwhite household classes are not included here due to ambiguity in expected sign. In three of the four nonwhite household classes the coefficient was positive, of which two were statistically significant.

rooms over one with one to two bedrooms, *ceteris paribus.* Finally, the general magnitude of *SF-STRUCT* (i.e., about 0.80 on average) would suggest that on the average renter households are about 2.2 times more likely to choose a single-family unit over a multiunit structure, *ceteris paribus.*

Although interesting, these results must be interpreted with caution. Since dwelling unit attributes are not generally separable, one may not always be able to vary attributes realistically on a *ceteris paribus* basis. Thus, even though single-family units may be greatly preferred over multiunit structures at the same rent, single-family units may in general command higher rents due to greater housing services. Although caution is expressed, these results strongly suggest that dwelling attributes *do matter* in residential choice, and that use of expenditure differentials as a sole measure of housing service differentials is likely to conceal important information regarding relocation decisions. The results here suggest that households relocation decisions are likely to be far more sensitive to housing disequilibrium due to space requirements than to "quality" factors such as exterior building condition.

Environmental Attributes. The estimated spatial environmental variables did not as a whole fare well in terms of consistency with a priori expectations. The variable *PERCSUB* showed the greatest consistency with correct signs in twelve of the fourteen regressions. The parameters suggest that households exhibit greater demand for spatial units of higher "physical quality" stock as reflected in lower percentage composition of units with deteriorating or dilapidated exterior building condition. Yet the small absolute magnitude of the parameter estimates (all were less than unity in absolute value) suggest that demand for "physical quality" neighborhoods is inelastic with respect to marginal changes in stock quality. The other variable that was largely consistent with a priori expectations was *PERCNW.* The estimated parameters for white households suggest that all classes exhibit demand for increasingly racially segregated submarkets. However, this demand is suggested to be relatively inelastic to marginal changes in nonwhite racial composition. For nonwhite households, the parameters of *NWPERC* for three of the four classes would suggest that nonwhite households exhibit greater demand for increasingly segregated submarkets of nonwhite racial composition. However, it cannot be discerned whether this exhibited demand reflects actual preferences or discriminatory barriers in the housing market that impede access to housing in integrated submarkets.

Two environmental variables deserve attention because of the high number of cases in which the sign of the parameter was opposite to a priori expectations. The parameters of *EMPACCS* and *PCRIME* were not of anticipated sign in eleven of fourteen cases. The positive parameters of *PCRIME* suggest the implausible result that nearly all household classes exhibit greater demand for submarkets with greater property crime rates, *ceteris paribus.* The lack of statistical significance in all cases but one, however, suggests that this unexpected result is likely to be attributable to multicollinearity among the independent variables. The sign of *EMPACCS* was not totally unexpected. The a priori hypothesis behind the specification of *EMPACCS* was that households should exhibit greater demand for submarkets with greater accessibility to major employment centers, *ceteris paribus.* In Wichita, the greatest spatial concentration of civilian employment is in the central business district (CBD). As a result, the weighted employment accessibility index is strongly correlated with distance from the CBD. Because of the easy access to the central core in Wichita, land rents are not likely to decline substantially with increasing distance from the center city. Yet any variations in land rents would allow for the trade-off of accessibility for greater land consumption in outlying areas in accordance with the theories of Alonso (1964). Thus *EMPACCS* may actually be capturing effects of lower land prices (and hence rents) and the demand for land.

The signs of most of the remaining parameter estimates for the environmental attributes fluctuated widely across household classes. This fluctuation warrants against any further attempts to interpret these parameters on an individual basis. The poor performance of individual environmental attributes does not suggest, however, their lack of importance in explaining residential choice. "Neighborhood quality" is an ambiguous multidimensional concept that eludes precise measurement. No single variable or group of variables is likely to capture the full essence of neighborhood quality. For this reason multiple surrogate variables were specified in the model. However, each variable does not impart independent information as surrogates of quality. As the correlation matrix in table 7.5

Table 7.5. Correlation Matrix of Residential Attribute Variables

	LRENT	*SOUND*	*SF-STRUCT*	*3BED*	*4BED*	*EMPACCS*	*PCRIME*
LRENT	1.00						
SOUND	-0.200	1.00					
SF-STRUCT	0.255	-0.313	1.00				
3BED	-0.094	-0.265	-0.265	1.00			
4BED	-0.097	-0.006	0.121	-0.147	1.00		
EMPACCS	0.268	-0.494	-0.531	-0.353	-0.473	1.00	
PCRIME	0.110	0.040	-0.121	-0.128	0.009	0.400	1.00
EDUC	-0.179	-0.002	0.110	0.144	-0.035	0.551	-0.731
WC/BC	-0.087	-0.041	-0.005	0.044	0.018	-0.572	-0.405
SCHOOL	-0.189	0.176	0.102	0.099	-0.114	-0.275	-0.416
MEDINC	-0.098	-0.078	0.040	0.105	0.018	-0.494	-0.622
NWPERC	0.036	-0.078	-0.219	0.177	-0.026	0.531	0.561
PERCSUB	0.145	-0.043	-0.075	-0.099	0.079	0.415	0.631
PERCSF	-0.096	0.205	-0.086	-0.009	0.044	0.120	0.169

	EDUC	*WC/BC*	*SCHOOL*	*MEDINC*	*NWPERC*	*PERSUB*	*PERCSF*
LRENT							
SOUND							
SF-STRUCT							
3BED							
4BED							
EMPACCS							
PCRIME							
EDUC	1.00						
WC/BC	0.769	1.00					
SCHOOL	0.619	0.397	1.00				
MEDINC	0.857	0.838	0.395	1.00			
NWPERC	-0.548	-0.642	-0.284	-0.697	1.00		
PERCSUB	-0.868	-0.791	-0.672	-0.800	0.651	1.00	
PERCSF	-0.027	-0.220	-0.155	-0.056	0.168	-0.065	1.00

Note: All continuous variables are measured in logarithms.

shows, many of the individual variables vary across spatial units in much the same way. There simply is not enough variation across variables to distinguish statistically their independent effects.

Faced with an apparent problem of multicollinearity, a series of joint hypothesis tests was performed to test whether the spatial environmental variables as a group significantly contributed to the explanatory power of the model. The results of the fourteen *F*-tests are summarized in table 7.6. In all cases the *F*-ratio was statistically significant at greater than the 0.10 level, with significance exceeding the 0.01 level for eleven cases. This evidence supports the general premise that spatial environmental variables as a whole are important determinants of residential choice even though the effects of specific factors cannot be reliably identified.

In addition to the joint tests of significance, the estimated parameters of the environmental variables were used to generate "neighborhood attraction" indices for the thirteen spatial units and fourteen household classes. The purpose of this exercise was to detect whether there were regularities in the revealed preferences of the household classes for the thirteen spatial units. Table 7.7 contains a summary of computed attraction scores for the spatial units in terms of deviations from the mean score for each household class. When presented in this way, the scores reflect the *relative* preferences for spatial units revealed by the household

Table 7.6. Summary of *F*-Statistics for Testing the Significance of Spatial Environmental Variables

Household Class	*F*	*Degrees of Freedom*	*Significance Level*
NW,INC1,SIZE2	10.876	(9,32)	>0.01
NW,INC1,SIZE3	9.015	(9,76)	>0.01
NW,INC2,SIZE2	14.405	(9,57)	>0.01
NW,INC2,SIZE3	26.506	(9,79)	>0.01
W,INC1,SIZE1	9.160	(9,138)	>0.01
W,INC1,SIZE2	2.128	(9,89)	>0.05
W,INC1,SIZE3	1.938	(9,63)	>0.10
W,INC2,SIZE1	15.153	(9,151)	>0.01
W,INC2,SIZE2	12.550	(9,135)	>0.01
W,INC3,SIZE1	14.315	(9,136)	>0.01
W,INC3,SIZE2	14.490	(9,131)	>0.01
W,INC3,SIZE3	2.613	(9,61)	>0.05
W,INC4,SIZE1	7.732	(9,71)	>0.01
W,INC4,SIZE2	5.840	(9,64)	>0.01

classes. In addition to the deviation scores, the highest, lowest, mean, and median rankings of the spatial units are presented by racial group in table 7.7.

An examination of the rankings reveals mixed results. On the one hand, the median and mean rankings suggest a considerable degree of consistency in the relative rankings of spatial units when racial groups are treated separately. A conservative interpretation of these measures is that *most* household classes by race reveal similar relative rankings of submarkets in terms of attraction scores. Accordingly, this consistency would suggest that the environmental variables as a group are reasonably good indicators of "neighborhood quality" attraction in the context of residential choice. On the other hand, with the exception of spatial units X and XIII for whites and II for nonwhites, the range of rankings was generally quite large. For example, even though seven of ten white household classes reveal the lowest ranking of thirteen for spatial unit V, it was ranked second for *W-INC2-SIZE1* households. There were "outlier" rankings for nearly all spatial units. There did not seem to be any consistent pattern in these disparate rankings other than the widely fluctuating estimates of certain attributes across classes.

The rankings of spatial units by racial groups are presented separately in table 7.7 because the rankings tended to be consistently different across racial groups. The most obvious example is that the highest-ranking spatial unit for nonwhite households (i.e., V) was the lowest-ranked unit for white households. Since spatial unit V had the highest nonwhite racial composition and spatial unit XIII, ranked highest for white households, had the smallest percentage nonwhite racial composition, it would appear that racial composition strongly influences the rankings and residential preferences of nonwhite households are distorted by market barriers. Such strong conclusions may be premature, but the differential rankings by race are of such magnitude that further examination is warranted. The issue of parameter differentials across household classes will now be examined in further detail.

Parameter Differentials across Household Classes. Because of the difficulties in comprehending the simultaneous variation of the three attributes used to define household classes, mean values of the residential attribute parameters were computed for each income class and size class for both white and nonwhite households. Since the effects of the attribute averaged over should largely be "washed out," parameter trends not immediately evident by visual inspection are likely to be exposed in this manner. Table 7.8 summarizes the parameter means. The patterns across income, household size, and race will be discussed in turn.

By comparing the a priori hypotheses concerning income class differentials in table 7.2 it is evident that only in the case of *LRENT* for white households did the parameter magnitudes strictly conform with expectations. The parameter

Table 7.7. Computed Attraction Scores by Spatial Unit and Household Class

Household Class	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*IX*	*X*	*XI*	*XII*	*XIII*
NW,INC1,SIZE2	2.31	2.21	-4.40	-10.46	3.69	0.68	0.37	-1.94	2.34	-1.56	-3.25	-4.43	4.81
NW,INC1,SIZE3	-2.27	-0.37	2.35	-0.27	-0.09	0.14	-0.86	1.47	-0.89	-1.21	0.27	-0.62	2.02
NW,INC2,SIZE2	1.23	0.26	1.29	5.07	1.66	-0.48	-1.13	0.45	-0.68	-0.51	0.51	-0.52	-7.14
NW,INC2,SIZE3	1.79	-0.46	-0.96	-1.14	3.16	-1.38	0.31	-0.97	0.17	0.98	-1.32	-0.17	0.01
W,INC1,SIZE1	2.48	0.17	-3.64	-1.73	1.00	1.52	1.48	0.33	0.81	0.01	0.68	-1.78	1.71
W,INC1,SIZE2	0.27	0.19	0.56	-0.51	-0.43	0.02	-0.03	0.25	-0.46	-0.32	0.32	-0.49	0.62
W,INC1,SIZE3	0.06	-0.40	0.43	0.08	-0.99	1.10	-0.52	0.46	-0.11	-0.91	-0.16	-0.05	1.02
W,INC2,SIZE1	5.48	0.09	-6.03	-2.95	2.59	-3.11	1.29	0.53	1.46	-1.47	0.33	-1.39	3.17
W,INC2,SIZE2	1.21	-0.46	-0.60	-0.38	-1.07	0.26	0.01	0.25	0.01	-0.66	0.03	0.25	1.15
W,INC3,SIZE1	-0.91	1.44	3.66	+1.84	-4.17	0.88	-0.07	1.85	-0.16	-0.17	1.51	1.79	1.51
W,INC3,SIZE2	0.66	0.45	0.15	-0.13	-0.84	0.70	0.06	0.80	0.15	-0.72	0.21	0.80	1.62
W,INC3,SIZE3	0.78	0.53	0.57	0.10	-0.82	0.39	0.11	0.85	0.36	-0.27	0.19	0.03	1.72
W,INC4,SIZE1	-0.95	0.08	2.06	0.98	-1.63	0.46	-0.08	1.52	-0.12	-0.20	0.30	0.64	1.93
W,INC4,SIZE2	-0.85	-0.92	5.05	3.30	-4.54	3.11	-2.35	3.17	-1.04	-2.92	0.49	1.48	2.00
White households													
Highest rank	1	5	1	2	3	1	4	2	4	9	3	25	1
Lowest rank	13	10	13	13	13	12	11	8	11	12	8	12	5.5
Mean rank	6.00	7.30	5.60	7.70	12.00	5.90	8.00	4.00	7.70	10.70	6.20	8.10	2.50
Median rank	4	8	4	9	13	6	9	3	8	11	7	7	2
Nonwhite households													
Highest rank	2	5	1	1	1	5	4	3	3	3	4	7	1
Lowest rank	13	8	11	13	6	13	12	10	11	12	12	12	13
Mean rank	5.25	7.25	6.25	8.00	2.75	7.75	8.25	7.00	7.75	8.00	7.75	9.25	5.50
Median rank	4	7.5	5.5	9	2	7	8.5	7.5	8	8.5	7.5	9.5	5

Table 7.8. A Summary of Parameter Means for Household Class Attributes

Variable	*NW*	*W*	*W,INC1*	*W,INC2*	*W,INC3*	*W,INC4*	*W,SIZE1*
LRENT	0.354	0.314	0.553	0.316	0.295	0.079	0.279
SOUND	0.386	0.427	0.433	0.390	0.483	0.374	0.128
SF-STRUCT	0.785	0.822	0.415	0.942	0.851	1.272	0.742
3BED	1.493	1.652	1.644	1.273	1.187	2.743	1.991
4BED	1.786	1.654	2.219	1.495	1.727	1.641	1.706
EMPACCS	-1.504	-0.773	-0.811	0.289	-1.320	-0.957	-0.531
PCRIME	0.849	0.287	0.010	-0.007	0.446	0.760	0.125
EDUC	3.155	-1.321	0.865	2.363	-5.201	0.128	-5.146
WC/BC	-0.320	0.335	-0.565	-3.311	2.409	2.220	-0.026
SCHOOL	-7.697	0.502	-0.248	1.822	-0.245	1.428	-0.233
MEDINC	-3.516	0.392	-0.448	1.505	0.189	0.845	1.346
NWPERC	0.437	-0.214	-0.116	-0.429	-0.241	-0.104	-0.332
PERCSUB	-0.145	-0.322	-0.271	-0.189	-0.219	-0.686	-0.496
PERCSF	1.045	1.217	-0.399	-1.424	3.270	3.200	1.701

	W,SIZE2	*W,SIZE3*	*NW,INC1*	*NW,INC2*	*NW,SIZE2*	*NW,SIZE3*
LRENT	0.331	0.348	0.329	0.379	0.348	0.359
SOUND	0.586	0.711	0.351	0.597	0.255	0.518
SF-STRUCT	1.055	0.519	0.822	0.747	0.718	0.851
3BED	1.354	1.572	1.566	1.521	1.886	1.101
4BED	1.559	1.934	1.683	1.889	2.080	1.491
EMPACCS	-0.948	-0.907	-5.040	2.033	-0.394	-2.613
PCRIME	0.309	0.569	3.770	2.074	1.080	0.618
EDUC	1.505	0.675	6.046	-0.536	-0.022	6.332
WC/BC	0.544	0.638	-0.600	-0.039	-0.942	0.303
SCHOOL	0.874	1.230	-17.394	1.197	2.764	-18.158
MEDINC	0.143	-1.016	-6.439	-0.593	1.294	-8.324
NWPERC	-0.120	-0.165	0.125	0.749	0.412	0.462
PERCSUB	-0.261	-0.097	-0.692	0.402	-0.512	1.223
PERCSF	0.738	1.205	1.602	0.488	0.316	1.774

means suggest that higher-income renter households are increasingly less sensitive to rent class differentials and that the largest differentials occur in the extreme income classes. For example, the difference in means between *W-INC1* and *W-INC4* households suggests that the relative likelihood of a *W-INC1* household's choosing a lower rent versus a higher rent dwelling, *ceteris paribus*, is about 1.6 times the relative likelihood for a *W-INC4* household. On the other hand, the relative choice likelihood between *W-INC2* and *W-INC4* households is suggested to be about 1.25 times. Differentials between *W-INC2* and *W-INC3* households were negligible. It is impossible to infer anything about price elasticities from the results here because of the discrete nature of the data. Nevertheless it should be noted that the results appear reasonably credible in light of Maisel and Winnick's (1966) estimate of 0.075 for the marginal housing expenditure propensity of households. By taking midpoints of income classes, *INC4* household income should exceed *INC1* household income by $15,000 on average. Applying the marginal expenditure propensity as a constant, *INC4* households would be expected to spend about $94/month more on housing than *INC1* households. This amount is quite close to the $100/month differential in the midpoints of rent classes.

The parameter differentials across income classes for other dwelling and/or environmental variables (for both races) were less consistent with expectations. Usually only two, and sometimes three, of the four mean parameters were consistent with expectations in both magnitude and sign. The most curious pattern was that of the parameter means for *WC/BC*. For the two lower-income classes of both races, the parameter means were negative. The parameters were positive, however, for the two higher-income classes. In contrast to the expectation that white-collar submarkets would be preferred by all household groups as a surrogate of higher social status submarkets, the pattern suggests that to the extent income, occupational composition, and social status are associated, households tend to choose submarkets of similar social status composition, *ceteris paribus*.

The mean parameters across household size classes did not generally conform strictly with a priori expectations. The most consistent pattern was between the two larger household size classes and their relative demand for units with four or more bedrooms over three bedrooms. With regard to the hypothesized trade-off between space and quality by larger households, the results were mixed. The parameter means of *LRENT* for both races suggest that larger households are most sensitive to rent differentials. Likewise, the parameter means for *PERCSUB* of white households suggest that larger households are less sensitive to the "physical quality" of the neighborhood. For both races, however, large households exhibited greater sensitivity to the physical quality of their own unit as reflected in larger positive parameters for *SOUND*.

The mean parameter differentials across race were quite interesting. The parameter differentials for *LRENT, SOUND, SF-STRUCT*, and *3BED* were consistent with the conclusion that nonwhite renter households consume lesser housing services than white renters. However, the differentials were quite small. On the other hand, with the exception of *PERCSF* and *PERSUB*, which are consistent with the above conclusion, the bulk of environmental parameter means bore inconsistent a priori signs. In light of the general conformity of dwelling unit demand parameters, the general incongruity of spatial variables strongly suggests that the locational choices of nonwhite households are constrained. Demand for spatial residential attributes is highly distorted. The consistent parameter signs for dwelling attributes suggest rational choice within these constraints. Yet dwelling choices are slightly biased toward units offering lesser housing services than those consumed by white households.

A final series of tests were performed to assess whether there were significant differences among the total demand relationships across the fourteen household classes. The tests were performed by restricting parameter homogeneity across one household class attribute dimension at a time. The fourteen classes, defined by two race categories, four income classes, and three household-size categories, yielded the fourteen cases shown in table 7.9. To aid in the explanation of table 7.9, the household class *NW,INC1* would denote the test of the null hypothesis that the parameters of nonwhite households of income $0–4,999 were invariant across the three household-size classes. In addition to these tests, all household classes were merged, and the null hypothesis that there were no differences in the overall relationships of all classes was tested for. The results suggest that the null hypothesis of invariant household demand relationships be rejected in all but two cases at the 0.05 level. This evidence offers additional support that fuller insight into the residential relocation process requires stratification by household class.

Table 7.9. A Summary of *F*-Statistics for Testing Differences Among Household Classes

Household Class	*F*	*Degrees of Freedom*	*Significance Level*
NW,INC1	2.003	(14,108)	>0.05
NW,INC2	2.028	(14,136)	>0.05
W,INC1	9.960	(28,306)	>0.01
W,INC2	8.340	(14,214)	>0.01
W,INC3	9.880	(28,402)	>0.01
W,INC4	3.905	(14,135)	>0.01
NW,SIZE2	1.235	(14,76)	-
NW,SIZE3	4.116	(14,153)	>0.01
W,SIZE1	8.810	(56,496)	>0.01
W,SIZE2	6.140	(56,419)	>0.01
W,SIZE3	1.204	(28,123)	-
INC1,SIZE2[a]	3.100	(14,121)	>0.01
INC2,SIZE3	4.320	(14,139)	>0.01
INC2,SIZE2	16.620	(14,192)	>0.01
ALL	7.520	(182,1491)	>0.01

[a]Tests across race could obviously only be made for those classes for which both white and nonwhite household equations existed.

7.3. CONCLUDING REMARKS

In summary, the bulk of parameter estimates were found to be consistent with the a priori hypotheses. Considerable variations were found in the estimated parameters over household class and residential attributes. It should be noted here that although the parameter differentials across class did not generally conform to the a priori hypotheses, their precise interpretation may be muddled by tenure shifts. Higher-income larger households exhibit higher rates of home ownership. Since this analysis focused solely on rental housing, it is not clear what impact the absence of owner household had on interpretation of class differentials. In any event the parameter estimates of the dwelling unit attributes were more consistent with a priori expectations than the parameter of the spatial environmental variables. The poorer estimates of the spatial variables were most likely due to insufficient independent spatial variation of the bulk of spatial variables, which made it difficult to distinguish statistically their independent effects. As a group, the spatial environmental variables were highly significant, suggesting that "neighborhood quality" does affect residential relocation decisions. The next chapter summarizes the general implications of all the empirical results and discusses their potential policy implications.

NOTES

1. For households undergoing a change in size over the period, the size at the end of the period was used to determine size class.

2. Since microlevel data were used to define classes, the intrasubmarket generalized cost parameters of F were utilized in the estimation of relative values of M_{kj} in the fourth estimation stage. This is important since duration of residence, change of household size, and age class showed substantial variations in the propensity to stay.

3. Earnings patterns of households over time should be correlated with age-household size classification. In fact the conventional family life cycle stages described in Timms (1971) use earnings cycle as an explanatory factor.

8 SYNTHESIS AND CONCLUSIONS

This final chapter synthesizes the developments of this study and pulls together the general implications of the empirical results of the individual estimation stages. The first section presents a general discussion of the policy implications of empirical results. Particular attention is devoted to the policy issues of racial residential segregation and the effects of rent subsidies on mobility. The second section reviews several of the modeling problems faced in this study and suggests directions for future research. The final section offers closing remarks.

8.1. A SYNTHESIS OF THE EMPIRICAL RESULTS

The empirical analysis of this study is a significant contribution to the study of relocation in the sense that it is the first empirical effort to address the relocation flows of disaggregate household classes between submarkets jointly defined by dwelling type and location. The estimated parameters of the model have imparted important insights into the complex nature of the residential relocation process. The complexity of the process is suggested by the fact that while conventional housing demand factors are of obvious importance as determinants of relocation, their effects are strongly influenced by a variety of generalized cost factors about which our current level of understanding is quite limited. The results of this study suggest that the relocation choices of households are strongly biased by not only locational inertia arising from the magnitude of these costs but also by spatially related costs. These generalized costs significantly distort the residential choice process expected in conventional economic frictionless worlds of costless mobility. Since the interpretation of individual parameters has been discussed in the last two chapters, it is more useful here to examine the general implications of the results for several current public policy issues.

8.1.1. Residential Segregation by Race

Residential segregation by race is a ubiquitous phenomenon of urban America exacerbating a multitude of widely recognized social problems. Since the aggregate spatial phenomenon of residential segregation by race is largely the accumulative result of intraurban household movement, the explanation of the determinants of the residential relocation patterns of nonwhites should increase our understanding of residential segregation.

Residential segregation is a spatial phenomenon. Observation of residential segregation itself implies nothing at all about the existence of discrimination in the housing market. Although there are several theories of residential segregation, two are counterpoles in the residential segregation literature. One of these theoretical approaches is based on the premise that discrimination in the housing market (i.e., market separation) is the underlying cause of residential segregation. In general, these approaches presuppose a form of housing market discrimination (e.g., exclusion of nonwhites, collusion by sellers, price discrimination) and logically argue how segregation patterns result from these discriminatory market operations (e.g., Becker, 1957; Downs, 1960; Kain and Quigley, 1975). In contrast, the prejudice theories of Bailey (1959) and Muth (1969, 1973) (sometimes called the customer's choice hypothesis) hold that observed patterns of residential segregation arise primarily from the *voluntary* market transactions of households motivated by preferences for submarkets of racially homogeneous residents. The common empirical approach for addressing this issue has been the analysis of total price differentials of housing, housing consumption expenditure differentials, and tenure choice differentials by race. Despite a multitude of empirical works in these areas, none of these empirical approaches has produced compelling evidence to resolve the issue.

The basic problem in clarifying this issue is that the ex post observation of residential segregation provides no clue to its underlying causes. Both of the two theoretical approaches demonstrate that under particular assumptions regarding housing market discrimination and/or racial homogeneity preferences, it is possible to arrive logically at an "explanation" of racially segregated residence patterns. However, it has not been possible to reverse the steps of logical reasoning and deduce the underlying cause of residential segregation from its observation. The root of the problem seems to be the same as for the problem of identifying unit prices of housing services. Ex ante intentions cannot be observed. We can only observe the ex post realization of housing consumption decisions. Unless all parameters can be fully identified (particularly price), it is impossible to discern to what degree ex post realization of housing consumption patterns are attributable to demand preferences versus supply effects in a housing market situation.

Because of this identification problem, the empirical analysis undertaken in this study cannot resolve the crucial issue of whether residential segretation is primarily the result of discrimination in the housing market or voluntary market transactions motivated by preferences for racial homogeneity. Given these reservations, however, the dynamic aspects of the residential relocation process still provide some new insight into the nature of the phenomenon. Several aspects of the empirical results are useful in this context. Since household classes have been stratified (at least minimally) by race and income class, the implications of the parameter differentials for both residential attribute parameters and generalized cost parameters should be reexamined here.

It should first be reiterated that *NWPERC* was specified as a residential attribute of submarkets under the premise that households exhibit preferences for racial composition. For whites, the estimated parameters suggested that white households on the average exhibit lesser demand for submarkets of increasing nonwhite racial composition, *ceteris paribus.* At the same time, the parameters of the same variable for nonwhites suggested that nonwhites exhibit a greater demand for submarkets of increasing nonwhite racial composition, *ceteris paribus.* The small absolute magnitudes of the parameters for both classes suggest that demand preferences for racial composition are relatively inelastic with respect to marginal changes in racial composition. Thus the results would suggest (at least in the rental market) that the rapid racial transition of neighborhoods due to the outflow of white households on entry by nonwhites is unlikely. Examining parameter differentials across income and household size classes for white households indicates that there were few consistent regularities with regard to which types of households are most likely to leave in submarkets experiencing racial transition. The largest parameters (in absolute value) were found for white households of one to two persons of income class \$5,000-9,999 and \$10,000-14,999. Whereas one might expect that larger households (presumably with children) are more sensitive to changes in racial composition, the results of this study suggest that the "more mobile" smaller white households are more likely to move in the event of marginal racial transitions.

Although both races were found to be relatively insensitive to marginal changes in racial composition, the results suggest that racial composition may weigh heavily in relocation choices among submarkets with large differences in racial composition. For example, the mean white household parameter of -0.214 for *NWPERC* suggests that under *ceteris paribus* conditions white households are about 1.6 times more likely to choose a submarket of 10% nonwhite racial composition versus one of 90% nonwhite racial composition. On the other hand, the mean *NWPERC* parameter value of 0.437 would suggest that nonwhites are about 2.6 times more likely to choose a submarket of 90% nonwhite racial composition versus one of 10% nonwhite racial composition, *ceteris paribus.* These results provide some interesting implications for the study of the statics/dynamics of racial composition and relocation. However, these results alone provide little new insight into the nature of residential segregation since they are consistent with both prejudice and discrimination theories.

Other estimated parameters of the model provide additional implications for the study of residential segregation. The estimated parameters of the generalized cost variables of F_{ij} suggest that the spatial/information and "social status" barriers faced by nonwhite households exceed those faced by comparable white households. The likely result of these real or imagined barriers is that nonwhite households constrain (or are constrained by) their residential choice to particular submarkets. Although cost linkages could not be directly specified in this study, the more powerful spatial friction effects found here are quite consistent with Cronin's (1979) findings that minority households spend more days in search, search fewer neighborhoods, and search units at closer distances than nonminority households.

A most interesting finding from the generalized cost empirical results concerned the influence of the racial composition of a household's current residence on relocations between submarkets with large disparities in racial composition. The parameters suggested that nonwhite renters currently residing in submarkets of less than 90% nonwhite racial composition are about ten times more likely to relocate to an "integrated" submarket with less than 35% nonwhite racial composition than nonwhite households in "segregated" submarkets of greater than 90% nonwhite racial composition, *ceteris paribus.* Further, the results suggested that white households residing in submarkets of greater than 5% nonwhite racial composition are about twice as likely to relocate to "integrated" submarekts of greater than 15% nonwhite racial composition than white households residing in "segregated" submarkets of less than 5% nonwhite racial composition, *ceteris paribus.* In essence these results suggest that the strong racial composition preference effects noted earlier may be compounded by social or psychic barriers to integration. Whereas the earlier implications suggested that white households are about 1.6 times more likely to choose a submarket of 10% nonwhite racial composition than 90% nonwhite, *ceteris paribus,* these results would suggest that for white households currently residing in highly segregated submarkets this relative likelihood is increased to about 3.2 times. For nonwhite households these results suggest that residence in highly segregated submarkets increases their likelihood of choosing a submarket with 90 versus 10% nonwhite racial composition from 2.6 times to about 26 times!

It is difficult to draw precise policies from these results because of a possible self-selection bias. Households of either race residing in less segregated submarkets may simply have weaker preferences for racial homogeneity. If a self-selection process is not operating, the results suggest that the social and psychic costs of integration are so substantial that any prospects for rapid changes in residential segregation are dim. On the other hand, the results may bear positive implications. If households residing in less segregated submarkets exhibit weaker preferences for racial homogeneity as a result of their current residence experience, then the results may suggest that strong racial homogeneity preferences are the result of ignorance, and *long-run* prospects for stable desegregated residence patterns may be more positive.

Clearly the implications noted above about prospects for desegregated residence patterns are highly speculative. They rest on the interpretation of racial homogeneity preferences as voluntary market transactions. Given the recent study by Wienk et al. (1979) indicating substantial differential treatment experienced by whites and minority households in housing markets, to expect that housing market discrimination does not occur would seem implausible. In fact, the empirical results do suggest that nonwhite renter households are spatially restricted to certain submarkets in Wichita. The most suggestive empirical results in this regard were the remarkably small differentials across race in the demand parameters for dwelling attributes concurrent with large differentials in the parameters of *spatial* environmental attributes. Although the smaller nonwhite demand parameters for dwelling attributes suggest that nonwhite households consume less housing than comparable white households, the close conformity with those of white households suggests (at least in the rental market) that nonwhite households exhibit dwelling unit preferences that are highly similar to those of white households. However, the large racial differentials in the estimated demand parameters for spatial attributes suggest that the spatial locational preferences of nonwhites either differ substantially from those of comparable whites or are distorted by real or imagined barriers in the housing market. Since it is implausible to argue that nonwhites prefer lower-"quality" to higher-"quality" neighborhoods, the differentials spatial preferences concurrent with consistent dwelling preferences are suggestive of the dual housing market thesis of Stengel (1976). That is, because of real or imagined barriers, nonwhite households are in effect constrained to certain housing submarkets. The consistent dwelling attribute parameters suggest that relocation choices *within* these submarkets manifest true market preferences for dwelling consumption. Their smaller magnitudes, however, suggest that spatial constraints lead households to consume lesser housing than would be expected if access to all spatial submarkets was not impeded.

Overall, the estimated parameters of the model suggest that residential segregation by race is the result of residential choice influenced by not only racial prejudice preferences for homogeneous submarkets but also market restrictions. It was impossible to identify the nature of these restrictions in the sense that it could not be discerned whether nonwhites were actually excluded from certain submarkets or chose to constrain their choices because of psychic cost-feared discriminatory treatment. The importance of these psychic costs is suggested by the previously discussed generalized cost parameters indicating the influence of current submarket racial composition on relocations from segregated to integrated submarkets. These parameters pertain to households of the same race. Since the prior residence location of households of the same race should not matter to discriminating landlords, these results suggest that psychic costs may be substantial and play a significant role in channeling submarket choice and maintaining market separation.[1]

Although the empirical results could not provide definitive evidence on market discrimination, the results still provide some implications for policy approaches advanced to combat residential segregation. Meyer (1969) characterizes these alternative strategies as (1) continuation of present policies, (2) housing enrichment programs, (3) integrated core policies, (4) segregated dispersal efforts, and (5) integrated dispersal efforts. Each of these strategies is likely to have different effects on residential segregation patterns. The empirical findings can provide some insight into the potential effectiveness of these various strategies.

Present policies toward residential segregation for the most part are centered on enforcement of prior "open housing" legislation. They have been founded largely on the premise that residential segregation is primarily the result of discriminatory actions on the part of sellers of housing. Although this study (for the aforementioned reasons) could provide no definitive evidence in support of the premise of racial discrimination in the housing market, the increasing concentration of residential segregation in recent years itself suggests that current policies for combating residential segregation are inadequate.

Enrichment programs are essentially "housing allowance"-type programs whose objectives are to enable lower-income households to increase their consumption of housing within the normal operations of the housing market. These programs could only affect residential segregation indirectly, to the extent that residential segregation is associated with the spatial concentration of poor households of which the bulk are nonwhite. The small parameter differentials across the two income classes of nonwhite households, and the large differentials across racial groups controlling for income, suggest that programs designed to increase household income effectively by increased housing consumption are likely to have negligible effects on residential segregation patterns.

The third strategy was called the "integrated core" strategy by Meyer (1969). In effect, the integrated core strategy reflects the housing "supply-oriented" approach of urban renewal. By providing improved housing attractive to income classes of both races, these programs would hope to retain and attract white households in integrated areas. The estimated parameters of the model suggest that such a program may be of some value in retaining white households currently residing in integrated areas whose racial composition is changing if the upgrading does not significantly cause rents to rise. The parameters of *SOUND*, reflecting demand for dwellings with sound exterior condition, suggest that white households exhibiting demand for sound versus deteriorating quality units is about 1.5 times higher in relative terms under *ceteris paribus* conditions. However, the estimated parameters of the generalized cost variables of F_{ij} regarding the relocation of households from segregated areas to integrated areas suggest that such programs will do little to attract households currently residing in segregated areas in integrated areas. At best, such programs would seem to retain status quo of residential segregation patterns.

The aim of "segregated dispersal" strategies is to provide clusters of housing to nonwhites widely scattered about metropolitan areas. In effect, this strategy is to reduce large concentrations of nonwhite racially segregated housing by attracting nonwhites to areas of "pocket segregation." The estimated parameters of the generalized cost parameters of the model suggest that unless information flows and the spatial awareness of nonwhite households are increased, such programs are likely to be ineffective. Regardless of race, the estimated distance parameters suggest that spatially related information barriers significantly impede housing relocations to geographically distant submarkets.

Finally, the integrated dispersal strategy seeks to integrate households of both races into mixed residential spatial patterns. The governmental mechanisms and commitments necessary to promote racial integration by such a large-scale effort are unclear. However, it is interesting to comment on the implication of the estimated parameters for the subsidy strategy suggested by Ira Lowry mentioned in Pascal (1970). The essence of the strategy is to subsidize the housing of households whose relocation promotes racially integrated residence patterns. That is, white households may be provided subsidies to relocate in nonwhite areas, and vice versa. Although such a program would surely be burdened with a multitude of difficult social equity and legal issues, the estimated model parameters suggesting that the likelihood of relocations between submarkets with large disparities in racial composition is low. In addition, the small parameters for

LRENT, which suggest that households are not very sensitive to rent differentials, indicate that subsidy levels necessary to make housholds indifferent to racial composition would be substantial.[2]

In summary, the estimated parameters of the model suggest that residential segregation by race is a strongly embedded spatial phenomenon and that governmental efforts to reduce residential segregation are unlikely to produce rapid changes in levels of residential segregation. It is additionally suggested that distance-related information barriers strongly impede integrative residential relocations as long as current segregated residence patterns exist. Programs to increase the spatial information awareness of households seem to be a critical element underlying the potential effectiveness of programs to reduce residential segregation. As long as information and spatial awareness barriers channel household relocations to nearby areas, residential segregation patterns are unlikely to be effectively reduced by governmental efforts of any sort.

8.1.2. Rental Subsidies, Residential Relocation, and Neighborhood Change

In recent years urban housing policy in the United States has been gradually shifting toward programs aimed at the demand side of housing markets. The large-scale Housing Assistance Supply Experiment, sponsored by the U.S. Department of Housing and Urban Development (see U.S. Department of Housing and Urban Development, 1980) is evidence of the shift in housing policy directions. The general purpose of rent subsidy allowance programs is to allow households to increase their consumption of housing services through normal housing market channels. The general argument for such subsidies is that because of limited incomes, households demand low-quality housing that is supplied as a response of the supply sector of the housing market. Given additional income or reduced effective market prices, households could demand higher-quality housing. The overall goals of such a program are threefold: (1) to increase efficiently the housing consumption of lower-income households; (2) to stimulate indirectly the maintenance and expansion of adequate housing accessible to lower-income households; and (3) to enhance freedom of choice in housing markets by earmarking subsidies to households rather than to dwelling units.[3] Wichita, Kansas, is not an experimental site for the Housing Allowance Experiments. No data on rental subsidies exist in the Wichita data. Nevertheless, the implications of the general empirical findings of this study are quite consistent with the preliminary findings of the Housing Allowance Experiments regarding the impact of subsidies on mobility summarized in U.S. Department of Housing and Urban Development (1980).

It is important to reiterate several important general findings of this empirical study. First, the results in chapter 6 suggest that generalized relocation costs exert significant impact on relocation behavior. Generalized costs not only create strong locational inertia that impedes housing consumption adjustment through relocation but also strongly bias submarket choice in the course of relocations that do occur. The large effects suggested by the parameter models would suggest that normal market incentives to mobility and submarket choice are severely diminished by these costs. Second, the demand parameters for residential attributes in chapter 7 suggest that renter households are far more sensitive to quantity (space) differentials in housing services than to rent or "quality" differentials. The significant impact of generalized relocation costs, compounded by the lesser sensitivity of households to rent and "quality" differentials, would suggest that rent subsidies would not have significant impact on the mobility behavior of households without concurrent programs to neutralize the effects of generalized relocation costs.

The preliminary findings from the allowance experiments are summarized in U.S. Department of Housing and Urban Development (1980) and Bendick and Zais (1978). Thus far it appears that the effects of rent subsidies on mobility have had little impact on breaking the inertia of existing patterns of mobility and submarket choice in low-income housing markets. Preliminary results suggest that housing allowances do not *significantly* increase movement propensities. This result is of particular interest since when a household's current dwelling did not meet program standards, moving was often necessary to meet housing requirements for the subsidy.[4] Allowances have also had no significant impact on the likelihood of search and the locational choices of households that did move. Spatial relocation patterns have reflected historical patterns rather than new patterns because of increased market access to opportunities due to the increased purchasing power of the allowances.

The preliminary findings suggested that generalized relocation costs (as defined in this study) were a primary factor explaining the negligible impact of allowances on mobility. For example, the single variable significantly associated with the likelihood of program participation was a relocation within the past three years (U.S. Department of Housing and Urban Development, 1980, p. 17). The apparent reason for the positive association between participation and mobility rates was that recent movers were more willing to move again when their current unit did not meet program standards. This duration of residence effect is consistent with the findings in chapter 6 concerning generalized costs inertia. The strong inertia effects of generalized costs were further exemplified by examining the major reasons cited by income eligible households that did not search, even though their current housing did not meet program standards. Nearly a third of these households never bothered to search, even though the typical allowance would reduce the average percentage of income spent on housing from 40 to 25% for the average household. The major categorical reasons for not searching were (1) satisfaction with their current unit, (2) strong attachments to the current neighborhood, and (3) disbelief that with the additional money they could find housing providing equal satisfaction (U.S. Department of Housing and Urban Development, 1980, p. 37). Further, about one-quarter of all households whose current housing did not meet program standards terminated their participation in the program. For those who did not terminate participation, the preferred alternative was generally repair of the current dwelling. Only when the number of structural defects exceeded four was moving preferred to repair. Of those recipients who did move, the distance was generally short, averaging about 1.6 miles (U.S. Department of Housing and Urban Development, 1980, p. 40).

Given the empirical findings of this study, these results are not surprising. Program standards for dwellings units were structural in nature. The results of this study suggest that although households were highly sensitive to space requirements as reflected in numbers of bedrooms, they were rather insensitive to "quality" differentials. Also, the strong distance-decay effects found in this study suggest the overriding importance of information/awareness in residential choice. Thus the preliminary results of the Experimental Housing Allowance Program support the credibility of the results of this study.

8.1.3. Implications for Future Research

The most obvious important direction for future research suggested by the results of this study is the need to devote further attention to the generalized costs of relocation. Although this study has clearly demonstrated that these costs impart substantial biases to the residential relocation process, no data were available to specify directly these cost variables other than as surrogate variables. Given the substantial impact of these costs, it is imperative to probe further into issues such as how information is acquired and utilized in residential choice. Accordingly, it is imperative to investigate what factors determine the relevant choice sets of households. Further research along the lines of Cronin (1978, 1979), (which attempts to specify cost measures directly) in a spatial context should be pursued. The results suggest, however, that we may have to probe even deeper into the behavioral processes involved in residential choice. The impact of social status barriers suggested here raises interesting questions about why they occur. Since social status or class is associated with differences in lifestyle, are the social status biases the result of greater spatial awareness due to greater social contact with individuals residing in places of similar social status? Or are these biases due not to awareness at all, but rather to deeper attitudes that constitute the concept of social class itself? Clearly many important questions about residential relocation remain. Nevertheless, this study has provided important theoretical and empirical insights that should provide a foundation for future research.

8.2. MODELING ISSUES

This study has made theoretical, methodological, and substantive contributions to the study of intraurban residential relocation. Its major theoretical contribution lies in the integration of structural and substantive characteristics of the housing market into the modeling of residential relocation. Founded on the rational utility-maximizing behavior of households, both demand and supply characteristics of a multisubmarket housing market have been explicitly introduced via a general economic equilibrium framework. Although analytical aggregation problems and the unobservability of unit prices of housing services precluded full identification of the model, structural properties of the model were invoked to achieve partial identification of the model. Furthermore, any postulates invoked for further identification of the model were explicitly stated and are open to theoretical and empirical scrutiny.

An obvious problem associated with the model of this study is the geometric expansion of household classes and submarkets and sparsity of data as finer levels of stratification are used. This problem is not peculiar to the model of this study; it is inherent in all disaggregate spatial models, particularly disaggregate spatial interaction models. The problem of sparse data was particularly severe in this study and affected the empirical analysis in two major respects. The first was the omission of owner households from the empirical analysis and the aggregation across renter household classes in various stages of the estimation process. In an annual time period, too few owner households relocated between submarkets to perform an estimation of the parameters of the facility of relocation F_{ij} at a meaningful level of disaggregation. For renter classes, assumptions of parameter homogeneity across certain household classes were approached with hesitation and only after careful a priori reasoning with regard to the attributes over which aggregation was most defensible. Nevertheless, aggregation inevitably requires parameter restrictions, which should be empirically tested for rather than artificially imposed.

The second way the expansion of classes and data sparsity affected the analysis was in the large number of zero observations that were by necessity excluded from the log-linear estimations. Although the inability to deal with zero observations is attributable to the log-linear estimation rather than the number of classes, the excessive amount of zero observations excluded was due to data sparsity. The effects of excluding such a large number of potential observations on the estimated parameters of the model are unclear. However, one may speculate that less sparse data matrices are likely to produce greater variation in cell counts and better parameter estimates.

Although I cannot offer any concrete suggestions about tackling the problem of expanding classes and sparse data in disaggregate spatial models, at this time three possible avenues of future research may be fruitful. A most expedient means of reducing the sparsity of intersubmarket flow matrices at any given set of household and dwelling unit classes is to expand the time period of observation from an annual period to a multiyear cross section. A casual inspection of the data for owner households suggests that a cross-sectional period of three to four years may produce enough intersubmarket relocations to estimate parameters for owner households at the same levels of aggregation used in this study for renters. Although expansion of the time interval should generate more observations on mover households, several issues of concern arise with this expansion. The most critical issue is the defensibility of the short-run assumption of a fixed housing stock. The greater the time interval, the less defensible this assumption is as supply responses to demand shifts become realized. Longer time intervals require that explicit attention be given to modeling the supply of housing services as a function of price and input costs. Modeling the supply sector of the housing market is complex and is underdeveloped in the current housing literature. Considerable research effort is needed in this area before it can reasonably be introduced within a residential relocation model as structurally complex as the one in this study. Aside from the problems of modeling the supply sector, the expansion of the time interval introduces a greater likelihood of multiple relocations within the time period (particularly in the rental market). How does one treat multiple moves within the time interval? In addition to this question, changes in household characteristics are most likely over longer periods of time. At what time should household characteristics be specified? Inmigrating and outmigrating households would enter and leave the residential system at multiple times. How would inmigrant and outmigrant households be treated in the model? Clearly the expansion of the time interval would introduce conceptual problems with regard to the proper causal treatment of the time dimension. These issues need further attention before a full assessment may be made of whether expanding the time interval of observation is a feasible means of reducing data sparsity without affecting the number of classes by aggregation.

A second potential area for future research, which may be more useful in tackling the problem of expanding cell classifications and sparse data, is a systematic examination of different aggregation levels similar to the information analysis performed by Turner (1975). Turner investigated the relative contributions of four household characteristics and origin income in reducing the uncertainty in predicting the destination location at two levels of spatial origin and destination aggregation. A comprehensive expansion of the work of Turner to address origin and destination dwelling types and additional household class attributes could provide invaluable insight into methodologically determining what aggregation levels generate the most information with a minimum number of class stratifications.

Certainly the exploratory multidimensional contingency table analyses proposed by Moore and Gale (1973) and Gale and Moore (1973) are potentially also very useful approaches to addressing these aggregation issues. The approach proposed by Gale and Moore seems to be most fitting to the examination of these aggregation and cell classification issues. The multidimensional contingency table approach entails a great flexibility in addressing key household and dwelling-type classification issues such as the following:

1. What household characteristics can be best used to capture the essence of the family life cycle effects on movement propensities?
2. What dwelling unit characteristics are most important in differentiating housing consumption differentials across household classes?
3. What joint classifications of household classes, dwelling types, and spatial units are most stable over time for addressing occupancy patterns and their change over time?

Certainly the approach proposed by Gale and Moore is only in its infancy, but it may prove to be extremely fruitful for methodological stratification in disaggregate spatial models.

The approach proposed by Gale and Moore (1973) and the work of Turner (1975) cannot truly rectify the root of the problem: expanding cell classifications. The essence of these approaches is the acceptance of the cell expansion problem and the investigation of aggregation levels to reduce redundancy of information and still capture the essential variations across household classes and dwelling types, which motivates the disaggregation itself. A third area of future research, which may truly combat the problem of expanding cell classifications and sparse data, is to extend the works of Hyman (1970) and Choukroun (1975) in parameterizing distributions of parameters across household classes. Hyman (1970) explores the possibilities of translating certain discrete household class stratifications into continuous distributions of household class parameters. The potential benefits of such an approach are obviously the reduction of parameters and cell classifications. Only the parameters of the distribution function of the household class parameters would be needed to obtain consistent aggregate predictions of household relocation flows. While analytical problems preclude direct application of these approaches, further research is imperative given the gravity of the cell expansion problem.

8.3. CONCLUDING REMARKS

This research has sought to provide a general modeling framework for the study of residential relocation. The study supports the general premise that to understand better the residential relocation process it must be analyzed within the framework of the local housing market. After a careful review of the somewhat mutually exclusive past research on residential mobility and residential location, a relocation model was developed integrating many facets of the two disparate lines of research. This initial study has shown that the potential fruits of this integration should be substantial. This study has also made significant contributions toward the estimation of systemic spatial interaction models. A rather general multistage procedure was proposed. The logic of the multistage procedure is applicable to spatial interaction models in many fields of study in which system delineation is ambiguous. Although the study has advanced our theoretical and empirical understanding of the complex process of residential relocation, it has also raised many questions. It is hoped that this study has laid the groundwork for future research.

NOTES

1. The vaguest aspect of discrimination theories is how market separation or exclusion is maintained if the housing market is competitive. Courant (1978) demonstrates that if households consider the expected likelihood of experiencing discrimination, they may find it rational not to search certain submarkets even though the housing may be compatible with demand. The results here are consistent with these arguments.

2. Although a definite figure cannot be arrived at, comparison of the relative parameters of *LRENT* (in table 7.3) and *W-NW* and *NW-W* (in table 6.2) would suggest that on the average a rent subsidy that would in effect shift a dwelling unit from middle- to low-rent class would not offset the psychic costs of integration suggested by *W-NW* and *NW-W* to a significant degree.

3. Although subsidies were tied to households, households would be required to reside in housing that meets program standards to receive a subsidy.

4. Controlling for other factors, allowance payments increased the probability of moving by about 7% overall. This was dominated by households whose current housing did not meet program standards. Allowances increased the movement propensities of this latter group by over 10%.

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