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Regional Dimensions

Jing Zhang

Foreign Direct Investment, Governance, and the Environment in China

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Jing Zhang
University of Nottingham

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List of Abbreviations

AR	Autonomous Region
AR(1)	autoregressive process of order one
BI	Business International
BLUE	Best Linear Unbiased Estimator
BOD	Biochemical Oxygen Demand
CBS	Copenhagen Business School
CC	Construction Committee
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPC	Communist Party of China
CPI	Corruption Perception Index
CSPP	China's Supreme People's Procuratorate
DM	Davidson–MacKinnon test
EDB	Economic Development Bureau
EKC	Environmental Kuznets Curve
EJV	Equity Joint Venture
EPB	Environment Protection Bureau
EPL	Environment Protection Law
FCPA	Foreign Corrupt Practices Act
FDI	Foreign Direct Investment
FGLS	Feasible Generalized Least Square
FIE	Foreign Invested Enterprise
G2SLS	Generalized Two-Stage Least Square
GDP	Gross Domestic Product
GLS	Generalized Least Square
GMM	Generalized Method Of Moment
HTM	Hong Kong, Taiwan, Macau
IAACA	International Association of Anti-Corruption Authorities
ICAC	Independent Commission Against Corruption
ICRG	International Country Risk Guide
IMD	Institute for Management Development
IMF	International Monetary Fund
IPE	Institute of Public and Environmental Affairs
IV	Instrumental Variable
M&A	Merger and Acquisition

MEP	Ministry of Environmental Protection
MNC	multinational corporation
MWR	Ministry of Water Resources
NBS	National Bureau of Statistics (China)
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxide
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Square
PB	Planning Bureau
PCI	Per Capita Income
PHH	Pollution Haven Hypothesis
PM_{10}	Particulate Matter less than 10 microns in diameter
PPP	Purchasing Power Parity
R&D	Research and Development
RMB	renminbi (currency of the mainland of China)
SEPA	State Environmental Protection Administration
SEZ	Special Economic Zone
SO_2	Sulphur Dioxide
SPM	Suspended Particulate Matter
STD	standardized value of government efficiency indices
TI	Transparency International
2SLS	two-step-least squares
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
USD	US dollar
WDR	Word Development Report
WIPS	World Investment Prospects Survey
WTO	World Trade Organisation

1
Introduction

1.1 Introduction

Environmental pollution and corruption have been inseparable twin evils in modern day China. The immediate motivation for this book is to link the environment and corruption with large inflows of foreign direct investment (FDI) to China. It investigates the effects of economic development and foreign investment on pollution in China; the effects of corruption and governance quality on FDI location choice in China; and the relationship between environmental regulation stringency and FDI, as well as the role corruption plays in this relationship.

Since 1978 the Chinese government has been reforming its economy from a centrally planned to a market oriented economy, known as socialism with Chinese characteristics. The result of this dramatic transformation has been the generation of wealth on a previously unimagined scale and the removal of millions from absolute poverty, bringing the poverty rate down from 84 per cent in 1981 to 13 per cent in 2008 (World Bank).[1] China is the fastest growing country with a consistent annual gross domestic product (GDP) growth rate above 8 per cent. By the end of 2010, China had overtaken Japan as the second largest economy in the world when measured by nominal GDP (RMB 40.12 trillion, or $5.93 trillion, see Figure 1.1 for the nominal GDP growth of China from 1978 to 2010).[2] Removing the impact of inflation, China's real GDP in 2010 was 20 times as much as that in 1978. The nominal per capita GDP has also increased from RMB 381 to RMB 29,992 (about $4,430), which means a growth of 14.7 times in real terms. This rapid growth has been drawing worldwide attention to China, including from academics in a number of research areas.

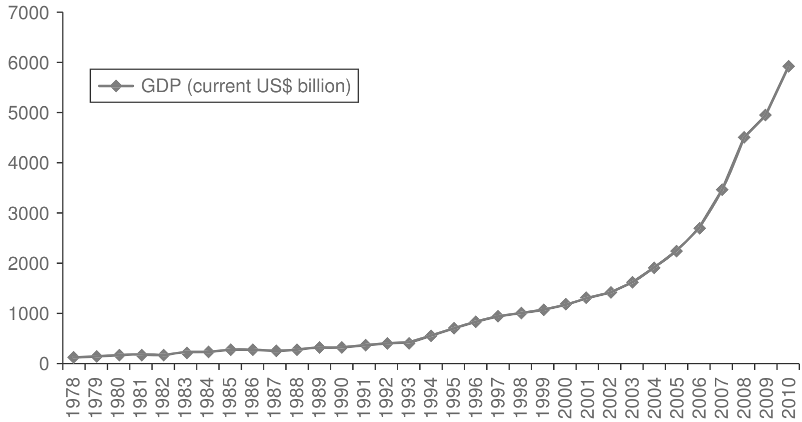

Figure 1.1 China's nominal GDP 1978–2010
Source: World Development Indicators database, The World Bank.

Much of China's success has been driven by a tremendous growth in exports coupled with equally impressive increases in FDI. According to statistics from China's National Bureau of Statistics (NBS), the value of China's exports grew by an average of 14.7 per cent a year between 1980 and 2000 and by 27.3 per cent a year between joining the World Trade Organization (WTO) in 2001 and the world financial crisis in 2008. At the end of 2010 China's global trade exceeded $2.97 trillion, with exports of $1.58 trillion. After 2010 China surpassed Germany as the world's largest exporting nation and was the second largest importer after the United States (US). In addition, China's trade surplus was stable at around $30 billion between 1999 and 2004 but surged rapidly afterwards (varying between $102 billion and $298 billion). In terms of FDI, by 2010 China's inward FDI flows had reached $105.7 billion, up from an average of $30.10 billion between 1990 and 2000. FDI stock has increased similarly, rising from $20.69 billion in 1990 to $1048.38 billion in 2010.

The Chinese government launched a range of policies to encourage FDI inflows. In 1979, the government introduced legislation and regulations designed to encourage foreigners to invest in high priority sectors and regions. The government eliminated restrictions and implemented permissive policies in the early 1980s. It established Special Economic Zones in 1980 and then opened up coastal cities and development regions in coastal provinces in the mid-1980s. More favourable regulations and treatment have been used to encourage FDI inflows to these regions. In the 1990s, the policies began to promote high-tech and capital intensive FDI projects in accordance with domestic industrial objectives. Preferential tax treatments were granted for investment in selected economic zones or in projects encouraged by the government, such as energy, communications and transport. These preferential policies have resulted in an overwhelming concentration of FDI and rapid economic development in the east. Spillover effects from coastal to inland provinces are limited and therefore the gap in regional development has widened.

Rapid export driven economic growth enhanced by large investment inflows from abroad has come at a cost. A harmful by-product of globalization has been increased pollution. The State Environmental Protection Administration (predecessor to the Ministry of Environmental Protection) reported that two-thirds of Chinese cities are considered polluted according to the air quality data. Respiratory and heart diseases related to air pollution are the leading causes of death in China. Almost all the nation's rivers are polluted to some degree and half the population lacks access to clean water. Water scarcity occurs most in northern China and acid rain falls on 30 per cent of the country. The World Bank estimated that pollution costs about 8–12 per cent of China's GDP each year. Environmental degradation and the increase in poor health are all signs that China's current growth path is unsustainable.[3]

There have been numerous theoretical and empirical studies that examined the relationship between economic growth and various indicators of environmental degradation. The aim of this research is to examine the existence of the *Environmental Kuznets Curve* (EKC), initially developed by Grossman and Krueger (1991). The hypothesis of EKC indicates that the environmental impact of economic growth initially increases, reaches a peak and then falls, as illustrated in Figure 1.2. In addition, some researchers have started to use empirical methods to examine the effects of FDI on environmental quality, especially in developing countries. However, the majority of studies on both the environmental effects of economic growth and FDI, are cross-country analyses and the results are often inconsistent.

Therefore, in the case of China, the following questions are worthy of consideration. Does the EKC hold for particular pollutants? If it does, what is the threshold income level and how many regions have passed it? As an important driving force for economic growth in China, does FDI benefit or harm environmental quality? These questions have attracted relatively little research; what research there has been has used different datasets and methodologies, with mixed results.

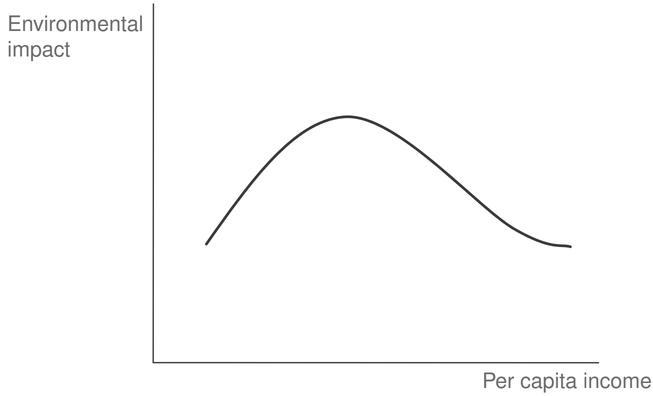

Figure 1.2 Environmental Kuznets curve

The huge amount of FDI inflow and its unbalanced geographical distribution has attracted several studies investigating the determinants of FDI location choice in China (see for example Wei *et al.*, 1999; Coughlin and Segev, 2000; Cheng and Kwan, 2000; Amiti and Smarzynska-Javorcik, 2008). In addition to preferential policies, many factors may have affected where foreign investors located their production facilities within China, such as labour costs, potential market size, market access, supplier access, infrastructure, productivity, education level, location, and spatial dependence. However, these studies all omitted certain structural determinants of FDI, including environmental regulation stringency and government quality.

Some environmental economists and environmentalists claim that firms in developed countries may relocate their 'dirty' industries to developing countries to take advantage of less stringent environmental regulations (see for example Pearson, 1987; Dean, 1992; Copeland and Taylor, 1994). Such a point of view is known as the *pollution haven hypothesis* (PHH).

In China, the legal system has lagged far behind overall economic development. Although it has established a comprehensive environmental regulatory framework with a range of laws, regulations and standards, the strength and enforcement of the regulations are much weaker than in developed countries. An important issue in the enforcement of environmental regulations is that of the government itself violating the law. Some local governments protect polluting enterprises in the name of local interest. Situations like land appropriation, excessive mining and the failure to carry out environmental impact assessments continue due to the lack of the environmental awareness among local government officials. Environmental enforcement also suffers from a lack of public participation and social supervision, as well as low awareness amongst citizens (Ma, 2007). The differences in performance between local governments and the behaviour of the public means that environmental stringency varies among the regions.

Multinational corporations (MNCs) could be attracted by the weak environmental regulations in China. Ma Jun, director of the non-governmental Institute of Public and Environmental Affairs (IPE), announced in August 2007 that since 2004 over a hundred multinational corporations had been punished by the government for their violation of the environmental laws and regulations on water pollution (People.com.cn, 2007; 21cbh.com, 2008). In January 2008 this figure increased to 260 corporations for water pollution and more than fifty corporations for air pollution (Xinhuanet, 2008). The exposed companies included subsidiaries of world renowned corporations such as American Standard, Panasonic, Pepsi, Nestlé, 3M, Whirlpool, Bosch, Carlsberg, Samsung, Nissin Foods and Kao. These corporations are mostly from Japan, US and Europe. One third of their polluting subsidiaries are located in Shanghai, and others scattered over the country. Liu (2006) reported that according to Lo Sze Ping, campaign director of Greenpeace China, the words of multinationals are often better than their deeds. Multinationals are more willing to invest in public relations than in actually cleaning up the manufacturing process. Local governments seek to attract more FDI and hence do not take strict measures to address the pollution from multinational corporations. Lo also observes that since multinational corporations typically perform better environmentally than domestic enterprises, their activities do not attract the attention of the environmental authorities, and hence avoid the supervision.

Therefore, the regional differences in environmental stringency may have a significant impact on the choice of FDI location in China, that is to say, an intra-country pollution haven effect may exist. Previous empirical studies have adopted different approaches to investigating the PHH (see for example Levinson, 1996a, 1996b; List and Co, 2000; Keller and Levinson, 2002; Xing and Kolstad, 2002; Eskeland and Harrison, 2003; Fredriksson *et al.,* 2003; Dean *et al.,* 2005; Smarzynska-Javorcik and Wei, 2005). The results are mixed and do not provide robust evidence to support the existence of PHH. However, these studies have several methodological weaknesses and are mostly centred on US data, a few studies look at developing countries and only Dean *et al.* (2005) look at China. Therefore, by addressing the weaknesses of previous studies, this book makes some contribution to the literature on PHH.

Rapid economic growth combine with the slow development of the legal system has resulted in a serious social problem in China, corruption. The transition to a market-based economy has resulted in considerable changes in how firms operate within the new commercial environment. The huge increase in opportunities in the private sector, combined with the traditional power of local and national officials, led to a proliferation of corruption at all levels of the Chinese economy. Corruption has been recognized as an emerging challenge to China's economic and social reforms.

Corruption is widely recognized as a deterrent to foreign investment but is only considered in a few empirical studies on a cross-country basis (see for example Wheeler and Mody, 1992; Hines, 1995; Wei, 2000; Smarzynska-Javorcik and Wei, 2000). Although China has received a high volume of foreign capital, corruption has deterred FDI inflows, especially those from Europe and the US. Wei (1997) notes that FDI from the ten largest s ce countries in the world, all of them members of Organization of Economic Co-operation and Development (OECD), accounts for a relatively small portion of the total FDI going to China, because investors from the major source countries prefer to go to less corrupt countries. Similarly, the corruptibility of local government in China may affect the location of FDI. Moreover, corruption should not be considered in isolation and is strongly correlated with the quality of government (see Globerman and Shapiro, 2002, 2003; Globerman *et al.,* 2006; Fan *et al.*, 2007), which makes government quality another important determinant of FDI inflows. Therefore, this book is the first to examine the effects of inter-regional differences in corruption and government quality on FDI location choice within a large developing country.

Corruption is also associated with environmental regulations. A common limitation in pollution haven studies is that they only consider the impact of environmental regulations on FDI, few have considered the endogeneity of environmental regulations. This book is the first to consider that environmental stringency may be influenced by both corruption and the level of FDI.

1.2 Structure of the book

Combining various aspects within the broad area of FDI, governance and the environment, this book is structured as follows. Chapter 1 is the introduction, which outlines the background in China, research questions and a brief analytical framework of this book. Part I of the book includes four substantial chapters looking at the effects of economic development and FDI on the environment in China. Chapter 2 examines China's economic growth and the nature and development of inward FDI from its opening up in 1978. Chapter 3 examines China's natural environment and its environmental pollution. Particular attention is paid to the pollution of water, air and solid waste pollution, and the cost of pollution. Chapter 4 reviews the theoretical and empirical research on EKC and the impact of FDI on the environment, particularly the research using Chinese data. Chapter 5 examines the relationship between economic growth and a range of industrial pollution emissions in China using data on 112 major cities between 2001 and 2004. After separating out investment from Hong Kong, Macao, and Taiwan from the investment of other foreign economies, we also observe the environmental effects of different ownership groups of investment. The results provide some evidence that economic growth induces more pollution at current income levels in China, and that the environmental effects vary across investment groups.

Part II of this book contains three chapters that consider environmental regulatory stringency as a structural determinant of FDI. Chapter 6 introduces China's environmental protection legal framework and its implementation. It shows regional differences in terms of investment in environmental protection and analyses the reasons for a generally weak enforcement of environmental regulations in China. Chapter 7 reviews the theories and empirical studies on PHH. Chapter 8 tests whether pollution havens exist in China using socioeconomic and environmental data for 30 Chinese regions over the period from 1999 to 2003. We address the methodological weaknesses in the previous literature and employ a feasible generalized least square method that controls for both autocorrelation and heteroskedasticity. The findings provide some evidence to support the existence of a pollution haven effect within China.

Part III of this book consists of four chapters that examine the impact of regional government corruption and governance quality on FDI inflows, as well as the impact of FDI and corruption on environmental regulation stringency. Chapter 9 defines corruption and the measures of corruption. It also reviews relevant studies on corruption and governance quality, particularly the evidence that explores their impact on FDI location choice. Chapter 10 introduces the problem of corruption in China, its extent and types, as well as China's anti-corruption effort. The lack of a perceptions index for regional government corruption leads us to develop two objective indices, measuring the effort of local government in fighting against corruption and local government efficiency. The methodology and results of these indices are also reported in Chapter 10. Chapter 11 contains the empirical evidence to show that government anti-corruption effort and efficiency are both significant determinants of FDI. After considering how government characteristics affect environmental stringency, it becomes clear that an intra-country pollution haven effect still exists in China. The empirical study in Chapter 12 confirms that an increase in FDI inflows reduces the stringency of environmental regulations but that this impact can be mitigated by regional anti-corruption effort.

Chapter 13 concludes with a review of the results, a discussion of the limitations and improvements in data and methodology, and how the findings contribute to the literature, challenges and policy implementations. It also points out areas for future research.

Part I

The Effects of Growth and FDI on the Environment in China

2
Economic Growth, FDI, and the Environment in China

2.1 Introduction

The Beijing Olympic Games in 2008 and Shanghai Expo 2010 were great showcases for China's success and its emergence as the second largest economy on Earth. Over the previous 30 years China maintained an average ten per cent growth rate while the global economic crisis did not significantly affect China's pace of development. China's emergence has changed the global balance. Over the first ten years of the twenty-first century, China's share of world GDP and international trade more than doubled.[1] Correspondingly, that of the US and Japan declined.

However, China is still far behind Japan and the US in terms of per capita GDP. By the end of 2010, China's per capita GDP was about $4,433, which was less than half the world average, 10.3 per cent of Japan's and 9.5 per cent of the US's. Even using the purchasing power parity (PPP) method, China's per capita GDP was $7,520, still 40 per cent lower than the world average, one fifth of that of Japan and one seventh of that of the US. In addition, China is still backward in many other areas, such as technology, education, legal framework, healthcare, environmental quality, and so on. Therefore, China is still a developing country even though it is a large aggregate economy.

Furthermore, although China's total wealth has increased, the wealth gap is large and widening. The Gini coefficient, which measures the inequality of wealth, has reached 0.47, overtaking the warning level of 0.4 (China Daily, 2010). Income inequalities exist between residents in rural and urban areas, between households in different regions, between employees in the same industry and even people in the same region and same industry. Residents in China have not benefited equally from the achievement of rapid economic growth.

Since 1978, China has received enormous amounts of FDI. In 2010, it received FDI in actually used value of $105.7 billion compared with $0.64 billion in 1983 (China Statistical Yearbook, 2011).[2] China has been the second largest recipient of foreign capital ranked after the US. According to the World Investment Prospects Survey (WIPS), respondents from multinational enterprises have strongly suggested China as the top destination for FDI since 2005 (UNCTAD, 2011). Foreign Invested Enterprises (FIEs) have been the dominant producers of export goods. Data from China's General Administration of Customers showed that exports by FIEs have supplied more than 50 per cent of the national total since 2001. Like GDP, FDI has grown fast, particularly after entry to the WTO. But there is disparity in FDI distribution in terms of origin, entry mode, location preference and industry concentration.

This chapter contains four sections. Section 2.2 analyses the pattern of economic growth in China, including its unstable growth rate, its structural changes over time, and widening regional inequality. This section focuses on background information to FDI. Sections 2.3 and 2.4 provide a broad overview of the trends and patterns of FDI and especially its unbalanced distribution. Section 2.5 provides a conclusion.

2.2 Patterns of economic growth in China

China's GDP has continued to grow for more than 30 years, but the growth rate has been unstable. Figure 2.1 shows that there have been four rapid growth cycles since 1978: 1978–1981, 1982–1990, 1991–1999, and 2000–2009. Each cycle peaks with a growth rate of more than ten per cent. These peaks are usually associated with significant reform policies but they are also accompanied by strains on the economy, such as inflation, economic bottlenecks, social instability, or external financial crises. Therefore, each peak is followed by a period of slower growth (Naughton, 2007).

China's rapid growth has been driven by investment. In the late 1970s, capital formation contributed about 30 per cent to GDP growth and this share climbed to 54.8 per cent in 2010. Final consumption, as another driver of economic growth, only contributed 37.3 per cent to GDP growth. The other 7.9 per cent was contributed to by net exports of goods and services. Such a growth model has been seen as unsustainable global recession during 2008–2012. The Chinese government declared a change to the structure of the economy by boosting domestic consumption while reducing its dependency on investment and exports. However, China's domestic consumption accounts for only 47.9 per cent

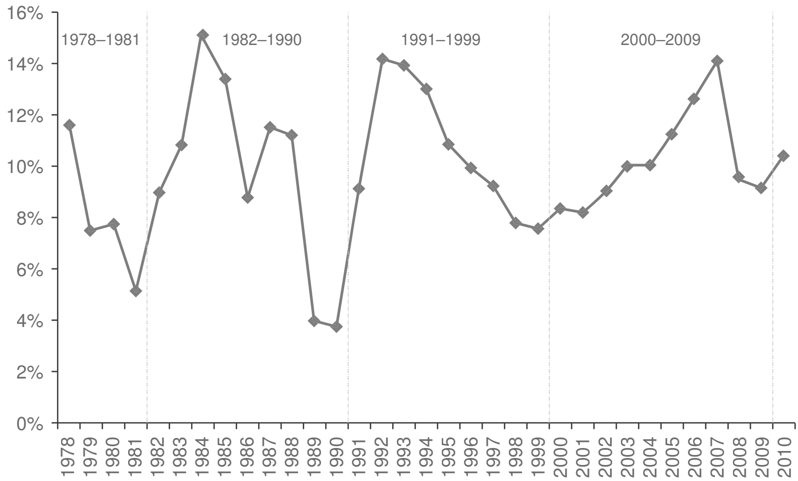

Figure 2.1 Annual GDP growth in China, 1978–2010

Source: China Statistical Yearbook (2011).

of GDP, compared to 88.6 per cent in the US. This low consumption was mainly due to low wages and high savings (52.1 per cent of GDP in 2009) caused by uncertainty and the imperfection of social services, for example, healthcare, education, pension, housing and so on.

Like many other countries, China categorizes its economic activities into three industry sectors. Primary industry includes agriculture, forestry, animal husbandry, and fisheries. Secondary industry refers to mining and quarrying, manufacturing, construction, and utilities. Tertiary industry contains the other economic activities (mainly services) not included in the primary or secondary sectors, for example, transportation, communication, household and business services, social services, education, and so on. GDP in any year is the total value of all goods and services produced by these three sectors during that year minus the total input value of goods and services, that is to say, the sum of the value-added.[3]

The relative importance of these three industry sectors to China's GDP has changed over time. Figure 2.2 shows the structural change in the Chinese economy from 1978–2010. The share of the primary sector declined from over 30 per cent to 10 per cent, correspondingly, the share of the tertiary sector doubled from about 20 per cent to more than 40

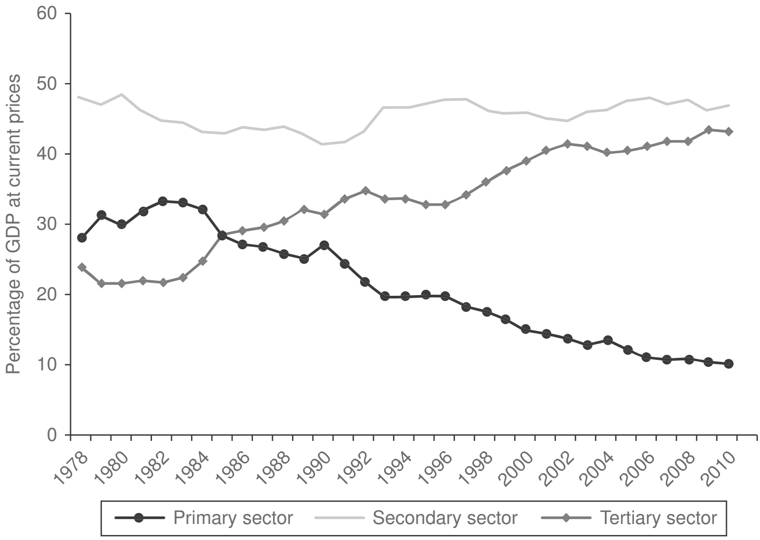

Figure 2.2 Composition of GDP, 1978–2010
Source: China Statistical Yearbook (2011).

per cent. The secondary sector share remained relatively stable at around 45 per cent.

Figure 2.3 presents the contribution these three industry strata made to GDP growth. In 1990, primary and secondary industries had the same importance to GDP growth, both contributing 41 per cent, in another words, both driving 1.6 percentage points of GDP growth. Interestingly, the importance of primary industry to increased GDP dropped to less than ten per cent in 1991, whereas the share of secondary industry jumped to over 60 per cent and stayed at this level until 2000. A main reason behind this is the reform towards a market-based economy which started in the early 1990s. However, the importance of secondary industry slightly declined after 2001, while the driving force of tertiary industry maintained its growth, reaching to 40–45 per cent of increased GDP.

It is noted that, although the importance of agriculture to GDP declined, grain output continued to grow, reaching 546.4 million tonnes in 2010. Because of increased productivity in agriculture a great number of labourers in the rural area moved to the cities. These migrant workers have made a great contribution to industrialization and providing services. Secondary industries grew quickly at the initial stage, increasing the number of workers, productivity and its share od

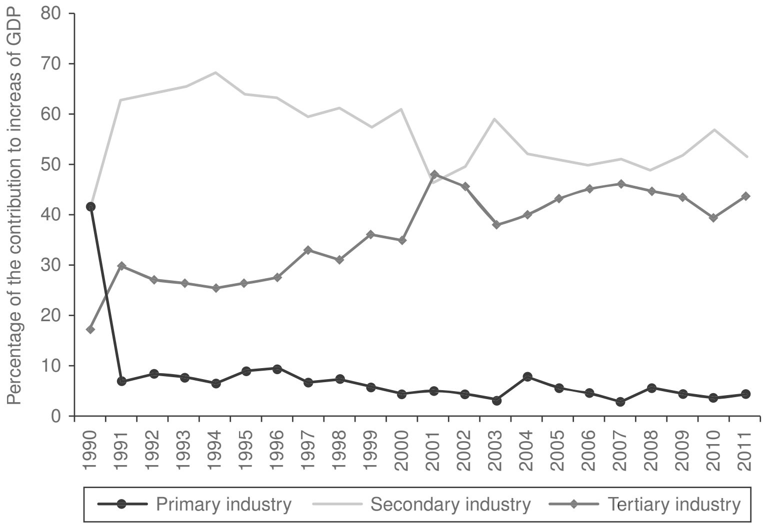

Figure 2.3 Contributions of the three strata of industry to GDP growth
Source: China Statistical Yearbook (2011).

GDP growth. Secondary industry could not maintain this fast growth forever; it levelled off, sending some capital and employment to tertiary industries, where there have been more medium- and high-skilled labourers providing higher value-added services. Inevitably, the services sector has a growing importance to the national economy. However, China's service sector is still lagging behind that of most developed countries where the service sector accounts for more than 70 per cent of national GDP.

After 30 years of economic reform, all Chinese are richer but some are richer than others. Income gaps are large. Geographically, coastal regions are generally richer than inland regions, while south China is wealthier than the north. Figure 2.4 is a map of China with the names of the administrative areas. It shows the traditional division into three regions. Coastal regions have geographical advantages and a proximity to exports and imports. Provinces in the south east, such as Guangdong and Fujian, are close to Hong Kong and Taiwan, and are the home regions of many overseas Chinese. Many eastern provinces were industrial centres before 1949 but were held back during the planned economy period. In addition to the natural and historical advantages of the eastern regions, the government's favourable policies towards international trade and FDI also offer a better

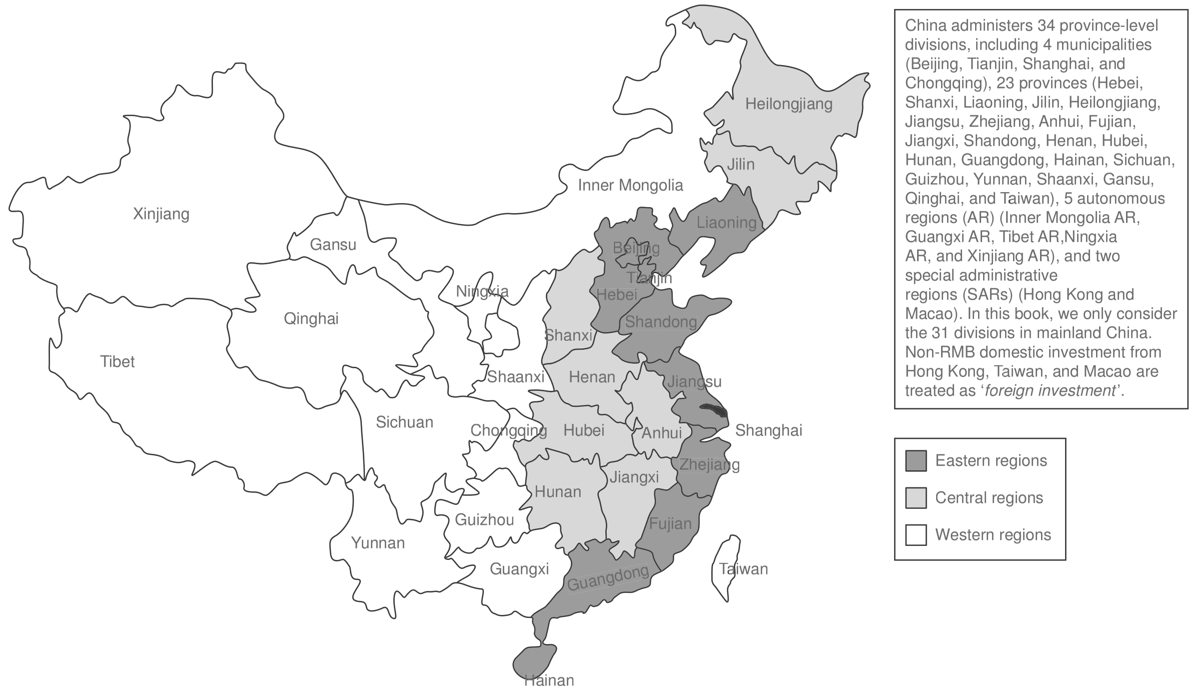

Figure 2.4 Map of China

business environment in this region than in others. Therefore, the coastal regions become prosperous first. Although the central government paid more attention to the development of central and western China in 2000 and a Western Development Programme was implemented, the economic development gap between coastal and inner regions is still wide.

Table 2.1 shows the income and population of all the provinces ranked according to their regional GDP in 2010. The sum of the GDP of

Table 2.1 Income and population by province in 2010

	GDP (billion yuan)	GDP growth (%)	Per capita GDP (yuan)	Population (million persons)
National	**40,120.2**	**10.4**	**29,992**	**1,340.9**
Guangdong	4,601.3	12.4	44,736	104.4
Jiangsu	4,142.5	12.7	52,840	78.7
Shandong	3,917.0	12.3	41,106	95.9
Zhejiang	2,772.2	11.9	51,711	54.5
Henan	2,309.2	12.5	24,446	94.1
Hebei	2,039.4	12.2	28,668	71.9
Liaoning	1,845.7	14.2	42,355	43.7
Sichuan	1,718.5	15.1	21,182	80.4
Shanghai	1,716.6	10.3	76,074	23.0
Hunan	1,603.8	14.6	24,719	65.7
Hubei	1,596.8	14.8	27,906	57.3
Fujian	1,473.7	13.9	40,025	36.9
Beijing	1,411.4	10.3	75,943	19.6
Anhui	1,235.9	14.6	20,888	59.6
Inner Mongolia	1,167.2	15.0	47,347	24.7
Heilongjiang	1,036.9	12.7	27,076	38.3
Shaanxi	1,012.3	14.6	27,133	37.4
Guangxi	957.0	14.2	20,219	46.1
Jiangxi	945.1	14.0	21,253	44.6
Tianjin	922.4	17.4	72,994	13.0
Shanxi	920.1	13.9	26,283	35.7
Jilin	866.8	13.8	31,599	27.5
Chongqing	792.6	17.1	27,596	28.8
Yunnan	722.4	12.3	15,752	46.0
Xinjiang	543.7	10.6	25,034	21.9
Guizhou	460.2	12.8	13,119	34.8
Gansu	412.1	11.8	16,113	25.6
Hainan	206.5	16.0	23,831	8.7
Ningxia	169.0	13.5	26,860	6.3
Qinghai	135.0	15.3	24,115	5.6
Tibet	50.7	12.3	17,319	3.0

Source: China Statistical Yearbook (2011).

the four biggest economic provinces, Guangdong, Jiangsu, Shandong, and Zhejiang, accounted for over 35 per cent of the national total. Guangdong's GDP was greater than the sum of that from the ten inland provinces ranked at the bottom (Tibet, Qinghai, Ningxia, Hainan, Gansu, Guizhou, Xinjiang, Yunnan, Chongqing, and Jilin). In terms of per capita income, three municipalities like Shanghai, Beijing, and Tianjin were on the top. Their per capita GDP was over 5.5 times as large as that of the poorest province of Guizhou. Provinces in south east China seem to be better off than the rest of the country.

When looking at the GDP growth rate, the data shows that central and western regions generally had higher growth rates than eastern regions, indicating a trend of convergence in economic development. However, because the gap was so large, there is still a long way to go before the inland regions catch up with those in the east.

In summary, China has become a big economy thanks to its 30 years of economic reform. Secondary industry has been the biggest contributor to its economy and economic growth but services sector seems to be increasing in importance. Income disparity exists in many places in China, and it is obvious across the regions.

2.3 Trends and patterns of FDI in China

The trends and characteristics of FDI in China have been reviewed in previous studies by Wu (1999), OECD (2000), Wei and Liu (2001), Wei (2002). Figure 2.5 shows the utilized FDI inflows in China from 1979 to 2010. The general trend is positively associated with economic growth in China and can be distinguished by five phases: the experimental stage (1979–1984), the growth stage (1985–1991), the peak stage (1992–1994), the adjustment stage (1995–2001), and the post-WTO surge stage (2002 onwards). GDP per capita increases quickly in the stages when FDI is booming, and slowly when FDI inflows decrease.

In 1979 China issued the Law on Sino-Foreign Equity Joint Ventures, meaning that foreign investors were allowed to enter China in the form of equity joint ventures (EJVs). During the first stage, FDI was mainly concentrated in the four Special Economic Zones (SEZs) established in Guangdong and Fujian provinces, which provided special incentive policies to foreign firms, including lower taxes and exemption on export duties.[4] However, the total amount was rather low.

With the success of the first stage experiment and a satisfactory economic situation nationwide, China formulated a series of laws and regulations to improve the business environment (for example Law

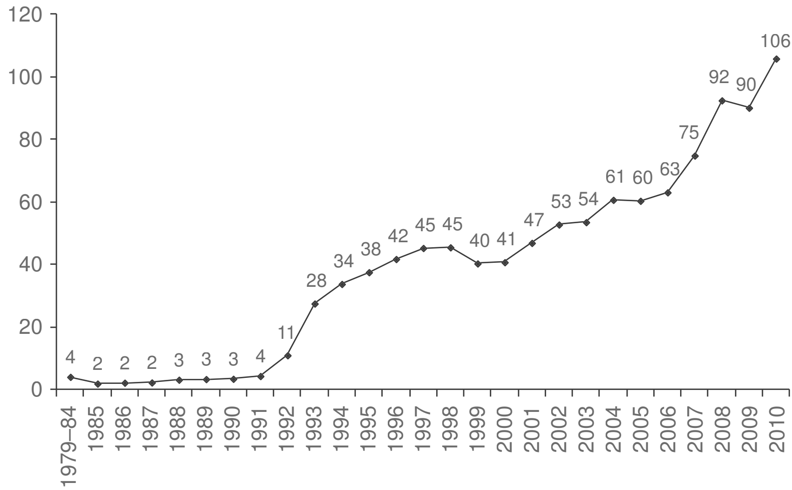

Figure 2.5 Actually utilized FDI, 1979–2010 ($ billion at current prices)
Source: China Statistical Yearbook (2011).

on Wholly Foreign-Owned Enterprises in 1986, Law on Sino-Foreign Cooperative Joint Ventures in 1988, Patent Law in 1984, and the gradual and moderate depreciation of Chinese currency). From 1984, SEZs were expanded in various ways to other areas in the country. China established Hainan Island (which became a province in 1988) as the fifth SEZ, opened fourteen coastal cities, created economic and technology development zones in selected major cities, and opened a number of border cities and all the capital cities of the inland provinces. There was a steady and gradual growth of FDI from 1984, which slowed down immediately after the Tiananmen incident in 1989. During the first two phases of FDI, cooperative joint ventures, equity joint ventures, and cooperative development were the main forms of FDI, with cooperative joint ventures being favoured by Hong Kong and overseas Chinese investors.

In the early 1990s, FDI increased quickly and reached a peak level of $28 billion in 1993, which exceeded the figures for the previous years. This situation was closely associated with a number of events, including Deng Xiaoping's visit to the southern coastal areas and SEZs, nationwide implementation of opening up policies for FDI and the worldwide rise in FDI flows.[5] During this period, the Equity Joint Venture Law was amended, followed by the Foreign Investment Enterprise and Foreign

Enterprise Income Tax Law, Trademark Law and the promulgation of the Copyright Law, Software Protection regulations, and proposals for amending Patent Protection Law (Tian, 2007). These all made the business environment more transparent and more accommodating to FDI. Wholly foreign owned enterprises were allowed to enter some industrial sectors.

From 1994, the growth rate of actually used FDI slowed down and became negative in 1999. This was mainly due to the impact of the Asian financial crisis and the rise of acquisition transactions in both OECD and non-OECD countries. In terms of the legal structure for FDI, in 1995 the Chinese government issued *Provisional Regulations on Direction Guide to Foreign Investment* and the *Catalogue for the Guidance of Foreign Investment Industries*. In these two documents, foreign investors could clearly find which industries were 'encouraged', 'restricted' and 'prohibited' by the Chinese government (Tian, 2007). The industries that were not included in these three categories were 'permitted'. In addition, the new Companies Law was issued in 1999, aimed at eliminating the special treatment for foreign invested firms and local state owned firms, and creating a uniform company code, which is required for entry to the WTO. During this period, there was an increase in the number of wholly foreign owned enterprises, which became one of the major forms of FDI along with equity joint ventures.

After entry to the WTO in November 2001, inflows of FDI into China surged again. China further adjusted the institutional and legal environment to comply with WTO rules. It gradually opened up its service industries to foreign investors, such as telecommunications, banking, insurance, tourism, retail and distribution. In terms of the form of FDI, wholly foreign owned enterprises became the most popular mode, correspondingly the share of joint ventures declined. In addition, new forms of FDI, such as mergers and acquisitions (M&As) activities increased but official data is not available. Therefore, FDI inflows increased dramatically although there was slightly negative growth in 2009 due to the world financial crisis.

2.4 Unbalanced distribution of FDI in China

Although the total amount of FDI inflows into China is extremely high, there are significant imbalances in both FDI stocks and inflows across China in terms of its source, form, geographical and sectoral distributions.

2.4.1 Main sources of FDI

According to a report from China's Ministry of Commerce (Tables 2.2 and 2.3), Hong Kong is the major source of FDI, continuously contributing more than 43 per cent of total FDI inflows to China between 1979 and 2010. If also considering investment via offshore financial centres

Table 2.2 FDI stock in China by major countries/regions, 1979–2010 (USD billion)

Country/Region	FDI	%
Total	**1048.4**	**100**
Asia: Ten economies	**697.7**	**66.5**
Hong Kong	455.1	43.4
Indonesia	2.1	0.2
Japan	73.4	7.0
Macao	9.6	0.9
Malaysia	5.6	0.5
The Philippines	2.8	0.3
Singapore	46.7	4.5
Korea	47.2	4.5
Thailand	3.3	0.3
Taiwan	51.9	5.0
EU: 15 countries	**72.0**	**6.9**
Belgium	1.1	0.1
Denmark	2.0	0.2
UK	17.1	1.6
Germany	17.2	1.6
France	10.7	1.0
Ireland	0.5	0.0
Italy	5.1	0.5
Luxembourg	1.2	0.1
Netherlands	10.9	1.0
Greece	0.1	0.0
Portugal	0.2	0.0
Spain	2.0	0.2
Austria	1.2	0.1
Finland	0.7	0.1
Sweden	2.1	0.2
North America	**72.9**	**7.0**
Canada	7.8	0.7
US	65.1	6.2
Some Free Ports	**148.8**	**14.2**
Cayman Islands	21.6	2.1
Virgin Islands	111.4	10.6
Samoa	15.8	1.5
Others	**56.9**	**5.4**

Source: Constructed by the author based on China Statistical Yearbook (various years).

Table 2.3 Share of major sources of FDI inflows in China, 1986–2010 (%)

Year	Hong Kong	Taiwan	US	Japan	EU 15*
1986	59.22		14.54	11.74	7.96
1987	69.08		11.36	9.50	2.28
1988	65.60		7.39	16.11	4.92
1989	61.24	4.56	8.38	10.50	5.53
1990	54.87	6.38	13.08	14.44	4.23
1991	59.96	10.68	7.40	12.20	5.63
1992	70.03	9.54	4.64	6.45	2.21
1993	64.91	11.41	7.50	4.81	2.44
1994	59.75	10.04	7.38	6.15	4.55
1995	54.64	8.43	8.22	8.28	5.68
1996	50.95	8.33	8.25	8.82	6.56
1997	46.46	7.27	7.16	9.56	9.22
1998	41.64	6.41	8.58	7.48	8.75
1999	41.35	6.45	10.46	7.37	11.11
2000	38.92	5.64	10.77	7.16	11.00
2001	36.35	6.36	9.46	9.28	8.92
2002	34.75	7.53	10.28	7.94	7.03
2003	33.86	7.35	7.85	9.45	7.35
2004	31.33	5.14	6.50	8.99	6.99
2005	24.79	2.97	5.07	10.82	8.61
2006	29.30	3.07	4.55	7.30	8.45
2007	33.17	2.12	3.50	4.80	5.13
2008	37.89	1.75	3.19	3.95	5.41
2009	48.98	2.00	2.84	4.56	5.63
2010	58.79	2.16	2.85	3.86	5.19

Note: * EU 15 refers to the countries listed in Table 2.1.

Source: Constructed by the author based on China Statistical Yearbook (various years).

or free ports, such as British Virgin Islands, Cayman Islands, Samoa, Mauritius, Barbados, and so on, Hong Kong's share may exceed 60 per cent. Japan, the US, Europe and some Asian countries and economies, such as Taiwan, Singapore, and South Korea, are the top sources of FDI. Some FDI inflows to China are 'round-tripping', which means they are the return of Chinese capital that has gone abroad in order to seek, for example, tax advantages and property rights protection, and to escape foreign exchange controls.

The share of FDI from Hong Kong declined from the 1990s and reached its lowest point in 2006 (29.3 per cent). However, it has shown a big rise in recent years. The share of FDI from Taiwan, US and Japan have decreased, while that of the EU slightly fluctuated but remained at a relatively stable level.

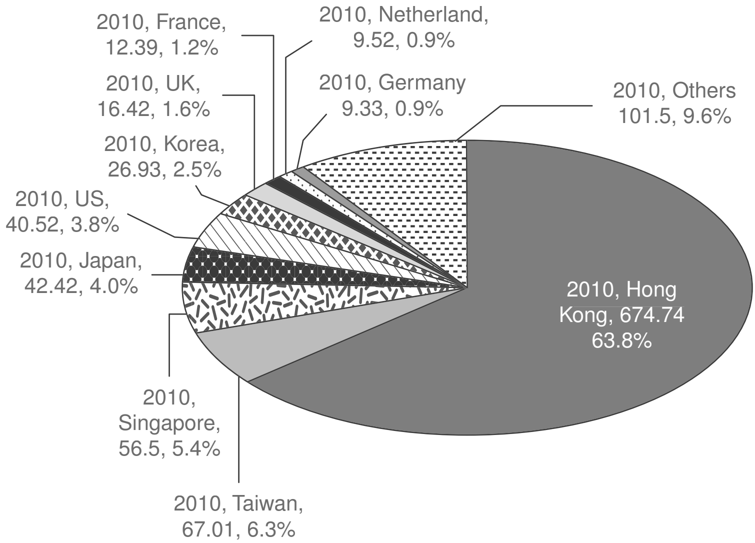

Figure 2.6 Sources of FDI inflows into China, 2010

Source: 'Statistics of China's Absorption of FDI from January to December 2010', Ministry of Commerce of China.

Considering their FDI inflows via offshore financial centres or free ports, the top ten originating countries/regions of 2010 are shown in Figure 2.6. The capital flows from these ten economies accounted for more than 90 per cent of the total FDI inflows in 2010.

2.4.2 Forms of FDI

The establishment of new enterprises like equity joint ventures and contractual joint ventures were the main types of FDI into China in the 1980s. Wholly foreign-owned enterprises were popular from the early 1990s and were the most popular type after 2000. From late 1990s, equity joint ventures and wholly foreign-owned enterprises were the main types of FDI into China. From Table 2.4, it is clear that up until 2010, equity joint ventures accounted for 31 per cent of the cumulative inward FDI and wholly foreign-owned enterprises accounted for approximately 58 per cent. Contractual joint ventures have been the third important type, which took ten per cent in terms of actually used FDI from 1979–2010.

Different from developed countries, where cross border M&As have been the major form of FDI, the value of inward M&As is not captured in

Table 2.4 FDI stock in China by type, 1979–2010

Form	# of projects	%	Actually used value	%
Total	**710,641**	**100**	**1048.4**	**100**
Equity joint venture	292,154	41.11	324.1	30.91
Contractual joint venture	59,856	8.42	100.5	9.58
Wholly foreign-owned enterprise	358,053	50.38	607.7	57.97
Fdi shareholding inc.	355	0.05	7.7	0.74
Joint exploration	191	0.03	7.5	0.72
Others	32	0.005	0.9	0.09

Source: Constructed by the author based on China Statistical Yearbook (various years).

Table 2.5 Inward mergers and acquisitions in China, 1999–2010

Year	Value ($ billion)	Deals
1999	2.4	
2000	2.2	
2001	2.3	
2002	2.1	
2003	3.8	
2004	6.8	
2005	7.2	217
2006	11.3	224
2007	9.3	232
2008	5.4	236
2009	10.9	142
2010	6.0	146

Source: UNCTAD (2011), World Investment Report 2011: Non-Equity Modes of International Production and Development.

China's official FDI data. Cross border M&As started in the early 1990s in China, but the first major foreign acquisition occurred in 1995 when two Japanese firms, Itochu Corp. and Isuzu Motors Ltd., acquired 25 per cent equity of Beijing Tourist Coach Co. In 1999, the total value of inward M&As increased from below $1 billion to over $2 billion and remained at similar transaction values until 2002 (see Table 2.5). In recent years,

Table 2.6 FDI in different regions in China, up to 2003 (USD billion)

Region	# of projects	per cent	Actually used value	per cent
Total	**465277**	**100**	**501.47**	**100**
Eastern region	381527	82.00	432.61	86.27
Central region	52424	11.27	44.79	8.93
Western region	31326	6.73	24.07	4.80

Source: http://www.chinafdi.org.cn [Accessed 20 March 2005]

China has seen more or less 200 foreign acquisition deals a year, with the total value varying between $5.4 and $11.3 billion. As M&As have become popular forms of global FDI, they may also have potential for further expansion in China. However, the Chinese government is very cautious about the approval of M&A deals, particularly when the deal involves a big amount of money, the target is in strategic sectors and/or market competition will be affected after the takeover. In addition, official data is not available from the Chinese authorities.

2.4.3 Geographical distribution

The geographical distribution of FDI in China is very unbalanced. Eastern regions have been the most developed area and also have received most of the FDI inflow. Table 2.6 demonstrates that, between 1979 and 2003, 86.27 per cent of cumulative FDI was located in the eastern regions, 8.93 per cent in the central regions and only 4.80 per cent in the western regions.[6] Among the eastern provinces, Guangdong has attracted more than a quarter of the total cumulative FDI (Figure 2.7). Jiangsu and Fujian, which have respectively received 14.24 per cent and 8.75 per cent of the total FDI, ranked second and third among thirty-one provinces in mainland China. Other eastern provinces, Shanghai, Shandong, Liaoning, Zhejiang, Beijing, Tianjin and Hebei also ranked in the top group.

If we look at the registration status of enterprises, we find that there were 445,004 foreign funded enterprises registered in China by the end of 2010, excluding 240 enterprises registered by various central government departments (China Statistical Yearbook, 2011). About 80 per cent of these firms were located in the eastern regions. The total investment of these enterprises exceeded $2,595 billion and the registered capital above $1,498 billion, with $1,212 billion from foreign investors. Figure 2.8 shows more detail for the distribution of registered capital from foreign investors. About 39.5 per cent of the foreign capital went to enterprises in lower Yangzi provinces (like Jiangsu, Shanghai and Zhejiang), 23.0

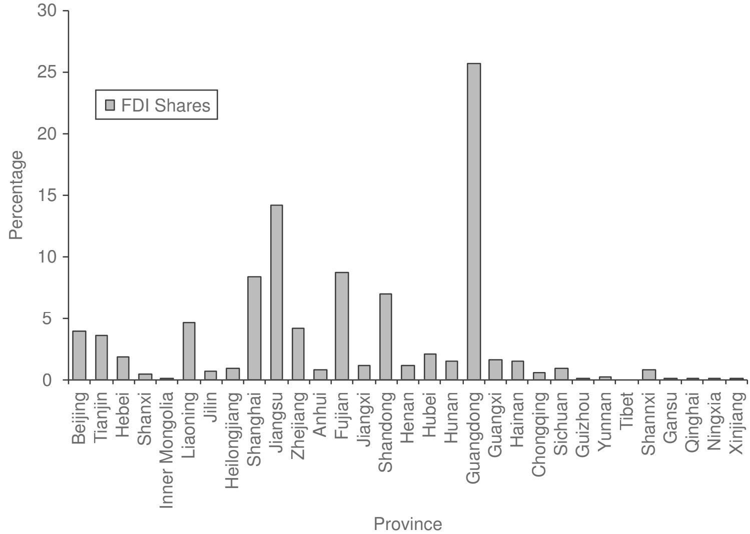

Figure 2.7 FDI shares by province, 1979–2003

Source: http://www.chinafdi.org.cn [Accessed 20 March 2005].

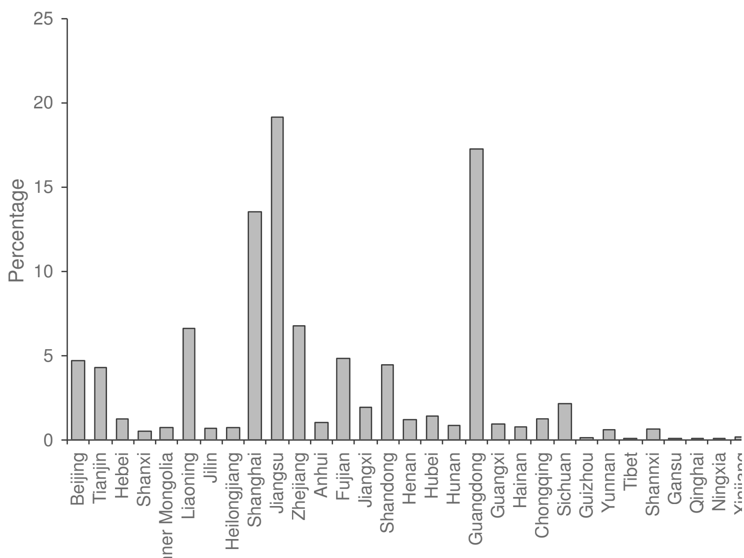

Figure 2.8 Shares of registered foreign capital in FIEs by province at the end of 2010

Source: China Statistical Yearbook (2011).

per cent to south eastern provinces (for example Guangdong, Fujian and Hainan), and 21.5 per cent to northern (around Bohai Gulf) provinces (for example Beijing, Tianjin, Shandong, Liaoning and Hebei). The other 16 per cent were scattered among the other 20 inland provinces with large territories.

2.4.4 Sectoral distribution of FDI

Thus far, the majority of FDI has flowed into the secondary sector. Table 2.7 shows that among secondary industry sectors, manufacturing has taken 57.17 per cent of the total cumulative contracted FDI between 2004 and 2010.[7] The tertiary sector comes second with the proportion of real estate (the leading industry) accounting for about 17.56 per cent. The primary sector attracted 1.44 per cent of total FDI inflows.

Table 2.8 reports some indicators of foreign funded enterprises by industrial sector in 2010. FDI has been concentrated in electronic equipment, textiles, different kinds of machinery and equipment, chemical products, plastics, food processing and metal products. The analysis of OECD (2002) and Wei (2002) also confirm that much of FDI in the manufacturing sector was concentrated in labour intensive industries such as textiles, clothing and assembly lines for mechanical, electronic and electric products. Although there have been a large number of enterprises and outputs from high-tech industry, such as electronics and automotive factories, many of them are still using low-skilled and semi-skilled workers. For example, the well-known Foxconn, a Taiwanese company, involved in the assembly of consumer electronics products for famous multinational companies such as Apple and Acer, employed a huge number of low-skilled workers in its workshops, with only a small number of workers who needed to be trained for high level technical jobs. In recent years, there is a significant increase of FDI inflow into capital- and technology-intensive sectors. But foreign investors are still cautious about moving some of their core competencies to China, particularly advanced technologies, due to the weak protection of intellectual property rights.

In recent years, a dramatic increase of FDI has been found in some service sectors, including leasing and business services; wholesale and retail trades; transport, storage and post; information transmission, computer services and software; scientific research, technical services and geological prospecting; and households services and others. The investment in manufacturing tended to increase in general but appeared to have negative growth in some years. Real estate sector seemed to be profitable in China in the most recent decades and therefore attracted a huge amount of foreign (as well as domestic) capital into this business area.

Table 2.7 FDI stock in the three strata of industry, 2004–2010 (USD billion)

Sector	**# of projects**	**%**	**Actually used value**	**%**
Total	**245,363**	**100**	**546.91**	**100**
Primary Industry	**6,929**	**2.82**	**7.89**	**1.44**
Agriculture, forestry, animal husbandry, and fishery	6,929	2.82	7.89	1.44
Secondary Industry	**141,618**	**57.72**	**332.72**	**60.84**
Mining	1,313	0.54	3.60	0.66
Manufacturing	135,679	55.30	312.67	57.17
Production and supply of electricity, gas, and water	2,340	0.95	10.82	1.98
Construction	2,286	0.93	5.63	1.03
Tertiary Industry	**96,816**	**39.46**	**206.30**	**37.72**
Transport, storage and post	4,009	1.63	14.70	2.69
Information transmission, computer services, and software	9,298	3.79	11.99	2.19
Wholesale and retail trades	33,044	13.47	22.66	4.14
Hotels and catering services	6,093	2.48	5.99	1.09
Financial intermediation	348	0.14	3.18	0.58
Real estate	9,439	3.85	96.06	17.56
Leasing and business services	21,486	8.76	33.08	6.05
Scientific research, technical service, and geologic prospecting	8,510	3.47	7.20	1.32
Management of water conservancy, environment, and public facilities	1,053	0.43	2.64	0.48
Services to households and other services	1,715	0.70	5.85	1.07
Education	208	0.08	0.18	0.03
Health, social security, and social welfare	116	0.05	0.31	0.06
Culture, sports, and entertainment	1,488	0.61	2.46	0.45
Public management and social organizations	9	0.004	0.01	0.002

Source: Constructed by the author based on China Statistical Yearbook (various years)

Table 2.8 Indicators of foreign funded industrial enterprise by industrial sector, 2010

	No. of enterprises	Gross industrial output	Total profits
National total	**74,045**	**18,991.7**	**1,502.0**
Mining and washing of coal	36	79.0	17.2
Extraction of petroleum and natural gas	18	67.5	37.1
Mining and processing of ferrous metal ores	43	14.1	2.9
Mining and processing of non-ferrous metal ores	63	16.6	3.1
Mining and processing of non-metal ores	133	13.9	1.4
Mining of other ores	0	0.0	0.0
Processing of food from agricultural products	2,453	785.5	50.6
Manufacture of foods	1,558	361.5	36.1
Manufacture of beverages	842	287.8	25.9
Manufacture of tobacco	3	0.4	0.1
Manufacture of textile	5,663	607.3	36.5
Manufacture of textile wearing apparel, footwear, and caps	5,906	462.6	34.1
Manufacture of leather, fur, feather, and related products	2,575	355.1	26.2
Processing of timber, manufacture of wood, bamboo, rattan, palm, and straw products	930	87.2	5.0
Manufacture of furniture	1,359	144.2	9.0
Manufacture of paper and paper products	1,492	318.2	26.1
Printing, reproduction of recording media	744	82.8	9.1
Manufacture of articles for culture, education, and sport activities	1,830	163.9	7.0
Processing of petroleum, coking, processing of nuclear fuel	220	394.2	21.4
Manufacture of raw chemical materials and chemical products	4,302	1,258.7	128.5
Manufacture of medicines	1,140	317.1	41.1
Manufacture of chemical fibres	321	156.7	14.4
Manufacture of rubber	931	191.0	12.7
Manufacture of plastics	4,231	436.9	29.3

Continued

Table 2.8 Continued

	No. of enterprises	Gross industrial output	Total profits
Manufacture of non-metallic mineral products	3,072	456.7	49.0
Smelting and pressing of ferrous metals	574	684.2	32.2
Smelting and pressing of non-ferrous metals	857	405.8	26.9
Manufacture of metal products	3,941	510.1	37.8
Manufacture of general purpose machinery	4,884	798.0	79.0
Manufacture of special purpose machinery	3,564	537.9	55.3
Manufacture of transport equipment	3,677	2,460.9	285.3
Manufacture of electrical machinery and equipment	5,347	1,361.3	106.3
Manufacture of communication equipment, computers, and other electronic equipment	6,695	4,253.9	172.6
Manufacture of measuring instruments and machinery for cultural activity and office work	1,498	309.4	23.7
Manufacture of artwork and other manufacturing	2,064	193.2	13.3
Recycling and disposal of waste	173	42.4	1.9
Production and supply of electric power and heat power	496	269.6	27.8
Production and supply of gas	250	87.3	12.6
Production and supply of water	160	18.9	3.5

Source: China Statistical Yearbook (2011)

2.5 Conclusions

Foreign invested enterprises have contributed to China's rapid economic growth. However, their distribution has been unbalanced. They have concentrated mainly in coastal regions and in labour intensive industries. Some of these industries are highly pollution intensive, for example, factories in textiles, chemical products and processing of food are the main emitters of waste water. Therefore, such unbalanced distributions may have significant implications for China's environment. Recently, rising labour costs in the east have driven many low-end, labour intensive and low-tech factories to relocate to inland regions where labour is relatively cheaper. For example, Foxconn has established new factory sites in Chengdu and Wuhan.[8] The less developed inland regions are happy about the entry of these firms in order to boost local economy, even though they may be vulnerable in terms of the natural environment and the ecological system. The relocation may have a significant impact on China's growth as well as on the environment.

3
Environmental Quality in China

3.1 Introduction

China has limited natural resources even though it has a large territory and is the most populous country in the world. Rapid economic growth in the last three decades sped up the exploration of natural resources and led to severe environmental degradation. China has been a heavily polluting country with rapidly increasing and unsustainable industrial production, domestic and foreign trade and investment.

Environmental Protection Minister, Zhou Shengxian, published an article on 28 February 2011 saying, 'in China's thousands years of civilization, the conflicts between humanity and natural has never been as serious as it is today. The depletion, deterioration and exhaustion of nature resources and the deterioration of the environment have been serious bottlenecks constraining economic and social development' (Zhou, 2011).

The State Environmental Protection Administration (SEPA, now Ministry of Environmental Protection, MEP) reported in 2006 that five of the ten most polluted cities worldwide are in China; acid rain is falling on one-third of the country; half the water in the seven largest rivers is 'completely useless'; a quarter of China's citizens lack access to clean drinking water; one-third of the urban population is breathing polluted air; and less than a fifth of the rubbish in cities is treated and processed in an environmentally sustainable way (Reuters, 16 August 2006).

Due to a heavy reliance on burning fossil fuels and other human activities, China has been the world's biggest emitter of greenhouse gases. China is also the biggest emitter of acid rain causing sulphur dioxide (SO_2) and the biggest energy consumer. Figure 3.1 presents China's emissions of carbon dioxide (CO_2) from fossil fuel burning between 1950 and

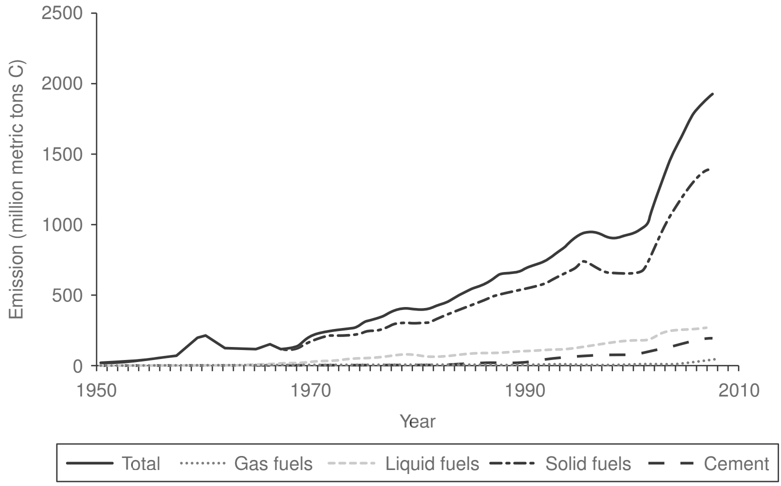

Figure 3.1 Carbon dioxide emissions in China, 1899–2008

Source: Carbon Dioxide Information Analysis Centre, http://cdiac.ornl.gov/trends/emis/meth_reg.html [Accessed 02 February 2012].

2008. The emissions grew rapidly after 2002, with over 73 per cent from the burning of solid fuels such as coal. Although China has improved its energy efficiency and developed a substantial amount of renewable energy, it will continuously require more low-cost coal to fuel its rapidly growing economy, which will produce more pollution and greenhouse gases.[1]

This chapter consists of seven sections. Following the introduction, Section 3.2 provides a brief overview of the natural environment in China. Although China's natural resources are large in volume, they are scarce when divided by the large population. Water shortages combined with pollution and natural disasters are at a crisis point and have become an obstacle to development. The following three sections analyse the major pollution problems in China – water, air and solid waste – and explore environmental quality, the origins of pollutants and their geographical and industrial distribution. Section 3.6 investigates and compares the estimates of the costs of pollution in China, followed by conclusions in the final section.

3.2 Overview of the natural environment in China

The total area of China is about 9.6 million km^2. China's Ministry of Land and Resources reports that by the end of 2008 the area of cultivated land was 1.826 billion *mu*, equivalent to 121.1 million hectares, only 12.7 per cent of the national area.[2] But the per capita cultivated land area is about 0.094 hectares, which is less than half of the average world level. Both the total and the per capita area of cultivated land decreases year on year. Over the 12 years from 1996 to 2008, the arable area declined by 125.26 million *mu* (or 8.35 million hectares). Additionally, the quality of cultivated land is relatively low in China. China has set a red line goal to maintain at least 1.8 billion mu (equivalent to 120 million hectares) in cultivation to feed its large population.

The eroded land area is 3.56 million km^2, which takes up 37.2 per cent of the country area.[3] About 1.14 million km^2 area suffers a serious erosion level. Erosion is an intrinsic natural process, but in many places in China it is caused by human activities, such as deforestation, overgrazing, over cultivation, and unmanaged construction. The erosion has resulted in soil texture degeneration, river deposit, and natural calamities, hence the deterioration of the environment.

According to a survey by the State Forestry Administration covering 2004–2008, China's forested area is 195.45 million hectares, ranked fifth in the world (4.5 per cent of the world's forested area).[4] The forest coverage rate is 20.36 per cent, which is only two-thirds of the world average and is ranked 139th in the world. The stock volume of forest is 13.72 billion cubic metres, and is ranked sixth in the world. China also has the largest area of plantation forests in the world, 61.69 million hectares. The total afforested land area in mainland China, excluding Hong Kong, Taiwan and Macao, is 303.78 million hectares, with total standing forest stock of 14.91 billion cubic metres. However, the per capita forest area is 0.145 hectares, which is only one-fourth of the average world level; and the per capita stock volume is 10.151 cubic metres, which is one-seventh of the average world level. In addition, the quality of the forest resource is not good and the ecological function of some forested areas is vulnerable.

China is ranked in second place in terms of the area of grassland, with 3.93 million km^2 (which accounts for 41.7 per cent of the national surface). But the per capita level (3,300 m^2) is only half of the average world level. Moreover, the natural grassland is mainly located in arid and semi-arid areas, where the rainfall is less than 400 mm annually. About 90 per cent of the usable grassland has different extents of degradation, among which 1.8 million km^2 has been seriously degraded and the degradation rate is two million hectares per year. The annually decrease in natural grassland is about 65–70 hectares a year. The quality of the grassland also falls every year. The main reasons for grassland degradation are overgrazing, inappropriate reclamation, industrial pollution, mice and pests, and excessive excavation.

Therefore, China has a relative shortage of cultivated land, forested area and grassland. Fortunately, China has adopted several polices and carried out many activities for the protection of cultivated land and treatment for solid erosion. It has also taken effective measures to protect and enlarge the forested area, such as the preserving natural forests project, the Grain for Green project, and protecting forests in north China and the Yangtze river basin, which have stopped the forest from shrinking any further. Among the environmental protection projects, the projects on converting cultivated land to forests and grassland (Grain for Green Projects), and Grain for Lakes projects, have been the major reason for cultivated land reduction (SEPA Environment Bulletin, various years).

Water shortage is another serious problem in China, which has one-fifth of the world's population but only seven per cent of its water resources. The water per capita is only a quarter of the world average.[5] The distribution of water resources is very uneven in space and time. For example, there are wet seasons and dry seasons in turn; there are lush natural water resources in southern China but drought and scarce water in northern China.

China has also suffered from a high frequency of floods and droughts for thousands of years. Since 1949, China has been hit by more than 50 extraordinary floods and 17 widespread severe droughts, according to China's Ministry of Water Resources (MWR).[6] Although the government has taken a series of measures for flood control and drought relief, and won a victory in many areas, natural disasters have resulted in huge losses. MWR, in its Bulletin of Flood and Drought Disasters in China, reported that 30 provinces suffered from floods in 2010, which resulted in the death of 3,222 people and 1,003 missing, and affected crops over 17.87 million hectares.[7] The direct economic loss was RMB 374.5 billion, the highest since 1990 due to floods. There had been droughts in 27 provinces, which affected 13.26 million hectares of crops, and caused 33.34 million people and 24.40 million large domestic animals to have temporary difficulties in access to drinking water, with a direct economic loss of RMB 150.92 billion. The economic loss in Yunnan and Guizhou provinces, which were hit severely by the drought, was equivalent to 9.27 per cent and 3.34 per cent respectively of their provincial GDP in 2010.

Combined with the uneven distribution of water resources and natural disasters, there has been an increase in the demand for water due to a large population base and growth, and rapid economic development. The water shortage is caused by the insufficient water supply, uneven distribution of water resources, increasing water demand, inadequate urban infrastructure, poor management, wasteful and inefficient use, lax environmental regulations as well as the reduction of water quality. Many cities turned to extracting groundwater to meet their increasing needs, particularly those in north China, which are large. In 2010 groundwater supplied more than half the water to Hebei, Beijing, Henan, and Shanxi. Due to overextraction of groundwater, ground surfaces have sunk in some areas and seawater flowing inland is also a serious problem in some coastal regions.

Hu Siyi, Vice Minister of Water Resources, told Xinhua on 5 November 2006 that 'China's total water consumption would reach the top usable volume of its water resource by 2030, if without effective water saving measures. [...] China will take legislative, engineering, economic and administrative measures to further save water in future.'

3.3 Water pollution

The wastewater discharged by manufacturing and from the growing number of urban households, as well as the extensive use of agricultural fertilizers and pesticides, have contributed to lower water quality. MEP'sEnvironment Annual Report shows that the total amount of wastewater discharge has kept on growing since 2001, although industrial discharge has declined and the proportion of industrial wastewater meeting discharge standards has improved.

China classifies its water quality in six levels (see Table 3.1). Grade I is the cleanest. Water down to Grade III can be used for drinking, usually

Table 3.1 Water quality of seven river systems, 2010

		Percentage of total length in each grade					
River	**Evaluated length (km)**	**Grade I**	**Grade II**	**Grade III**	**Grade IV**	**Grade V**	**Worse than Grade V**
National	175,713	4.8	30.0	26.6	13.1	7.8	17.7
Songhua	13,347	0.5	8.4	41.9	21.2	8.8	19.2
Liao	5,316	1.4	31.1	9.2	7.3	17.0	34.0
Hai	12,680	1.8	21.2	14.2	8.4	6.2	48.2
Yellow	14,295	4.7	20.1	17.7	13.3	10.3	33.9
Huai	24,072	1.2	12.0	25.7	25.7	13.2	22.2
Yangtze	53,489	5.3	34.7	27.4	11.2	8.0	13.4
Pearl	19,805	1.5	34.0	35.3	14.4	4.9	9.9

Source: China Environment Yearbook (2011).

after treatment. Grade IV water is for industrial use and entertainment without human direct contact and Grade V is mainly for irrigation. Water worse than Grade V means it is most polluted and unsafe, and cannot even be used for agriculture. The seven river systems have been polluted to different extents according to the data from evaluated length and monitoring sections. In 2010, 17.7 per cent of the 175,713 km evaluated length was seriously polluted. Among the seven river systems, the water quality in Hai River is the poorest, after Liao River, Yellow River, Huai River, and Songhua River. Consistent results were found using the quality data from 409 monitoring sections on the 204 rivers of the seven river systems.[8] The more polluted rivers are all in northern China, where water shortage is a serious problem. This data only reflects the water quality of the entire water system; however, water quality is much worse downstream, where more people are concentrated in the urban areas. The seven river systems altogether absorbed 51.46 billion tons of wastewater in 2010, accounting for 83.4 per cent of the national total. The seven river systems mainly appeared as organic pollution. Main pollutants include chemical oxygen demand (COD), ammonia and nitrogen, permanganate, and petroleum.

Water in the lakes is also polluted to different extents. Twenty of the 26 big lakes and reservoirs were graded IV and above in 2010, for example the water quality of the largest lake, Poyanghu, was Grade IV, and those of another two big lakes, Taihu and Dianchi, were both worse than Grade V. Enclosed lakes in cities are more polluted than other freshwater lakes. Lake eutrophication is another serious problem due to the high level of pollutants such as nitrogen and phosphorus.

River and lake pollution has resulted in sea water quality problems. According to the data from 1,426 measuring stations in 2010, 60 per cent of the total sea area was polluted to some extent, with 27 per cent heavily polluted. In addition, about 70 per cent of the offshore marine area was polluted, with one third heavily polluted. Of the four marine areas, East China Sea and South China Sea were more polluted than Bohai Sea and Yellow Sea by the end of 2010. However, this conclusion may change after a series of spills from oil fields in the Bohai Sea in 2011 that polluted an area six times the size of Singapore. The oil fields are owned by the China National Offshore Oil Corporation and the US company ConocoPhillips. The latter was responsibile for the leak but the maximum penalty for such accidents is only RMB 200,000 (about $31,000) according to the law. The oil spills raised a nationwide debate about the out of date environmental laws, the lack of supervision, and the environmental impact of foreign invested firms.

Table 3.2 Wastewater and main pollutants discharge in China, 2000–2010

	Wastewater (billion tons)			COD (million tons)			Ammonia nitrogen (million tons)		
Year	**Total**	**Industry**	**Household**	**Total**	**Industry**	**Household**	**Total**	**Industry**	**Household**
2000	41.52	19.42	22.09	14.45	7.05	7.41			
2001	43.29	20.26	23.02	14.05	6.08	7.97	1.25	0.41	0.84
2002	43.95	20.72	23.23	13.67	5.84	7.83	1.29	0.42	0.87
2003	45.93	21.23	24.70	13.34	5.12	8.21	1.30	0.40	0.89
2004	48.24	22.11	26.13	13.39	5.10	8.30	1.33	0.42	0.91
2005	52.45	24.31	28.14	14.14	5.55	8.59	1.50	0.53	0.97
2006	53.68	24.02	29.66	14.28	5.42	8.87	1.41	0.43	0.99
2007	55.68	24.66	31.02	13.82	5.11	8.71	1.32	0.34	0.98
2008	57.17	24.17	33.00	13.21	4.58	8.63	1.27	0.30	0.97
2009	58.91	23.44	35.47	12.78	4.40	8.38	1.23	0.27	0.95
2010	61.73	23.75	37.98	12.38	4.35	8.03	1.20	0.27	0.93

Source: Environment Annual Report (2010), Ministry of Environmental Protection of China.

In terms of groundwater quality, MEP has monitored the groundwater quality of 4,110 stations in 182 cities. The results showed that quality at 2,351 monitoring stations was poor or very poor, accounting for 57.2 per cent.[9]

The origins of wastewater are industrial production and household usage in urban and rural areas. Table 3.2 shows that in 2010 the total amount of wastewater discharge was 61.7 billion tons, with 38.5 per cent from industrial sectors and 61.5 per cent from households and services. Household and service discharge has been the main sources of COD, ammonia and nitrogen. Other pollutants, including petroleum-like matter, volatile hydroxyl-benzene, cyanide, and heavy metals (such as mercury, cadmium, chromium, lead, and arsenic) were mainly from industrial waste. Their levels in industrial wastewater have declined in the last decade due to increasing treatment, particularly in the more regulated and larger factories. Detailed explanations of major pollutants can be found in Chapter 5.

The geographical distribution of water pollution is uneven. Figure 3.2 shows the wastewater discharge in 13 provinces with total discharge above two billion tons in 2010. Of the 45.4 billion tons of discharged wastewater, these 13 provinces were responsible for 73.6 per cent. Henan, Hubei, Hunan, Guangxi and Sichuan are inland regions, the others are coastal provinces where population density is high and more industries are concentrated.

Industrial wastewater was mainly produced by seven sectors: paper-making and paper products, raw chemical materials and chemical

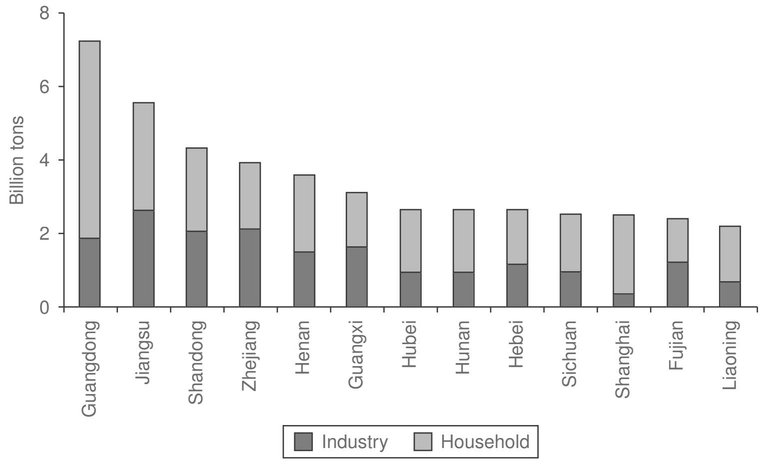

Figure 3.2 Wastewater discharge in the top 13 provinces, 2010
Source: China Environment Yearbook (2011).

products, textile, processing of food from agricultural products, production and distribution of electric power and heat, smelting and pressing of ferrous metals, and mining and washing of coal. Wastewater from these sectors accounted for 68.1 per cent of the national total in 2010.

3.4 Air pollution

The World Bank reported that 20 of the world's 30 most polluted cities are located in China, largely due to high coal use and motorization. As shown in Figure 3.3 China's total energy consumption continues to grow year on year. Of the total energy consumption (equivalent to about 3.25 billion tons of standard coal) in 2010, around 68 per cent was from coal, 19 per cent from oil, 4.4 per cent from natural gas, and 8.6 per cent from hydropower and others. Although the percentage of consumption of oil, hydropower, nuclear and wind power increased quickly in recent years, coal is still widely used as the major source of energy.[10] The combustion of coal generates several air pollutants, such as sulphur dioxide (SO_2), nitrogen oxide (NO_x) and dust, which are harmful to human health, especially to the respiratory system.

China has invested greatly in tackling air pollution in recent years. Air quality in urban areas has improved as a whole. Main sources of this improvement have been the reduction of burning coal in households for heating and cooking, as well as improved emission control in industrial sectors. In 2004, among the observed 342 cities, 132 of them (only 38.6 per cent of total) arrived at the national ambient air quality standard II (living standard), 141 (41.2 per cent) at standard III, and 69 (20.2 per cent) lower than standard III. By comparison, in 2010, 82.8 per cent of the observed 471 cities arrived at standard II (3.6 per cent at standard I), 15.5 per cent at standard III, and 1.7 per cent lower than standard III, indicating a general improvement of ambient air quality.

It is also noted that transportation has been a critical source of air pollution problems in big cities, such as smog and acid rain, due to a large and increasing number of motor vehicles. In 2010, the number of motor vehicles was 190 million, more than 27 times as many as in 1980. The total number of civil vehicles (automobiles) in China was 78.01 million, compared to 5.5 million in 1990 and 16.08 million in 2000 (China Statistical Yearbook, 2011). Of the pollution emissions of all motor vehicles (52.27 million tons in 2010), automobiles have contributed more than 70 per cent of carbon monoxide (CO) and hydrocarbons (HC), and more than 90 per cent of NO_x and particulate matters (PM) (China Vehicle Emission Control Annual Report, 2010).[11] The emissions of vehicles have been positively associated with the volume of

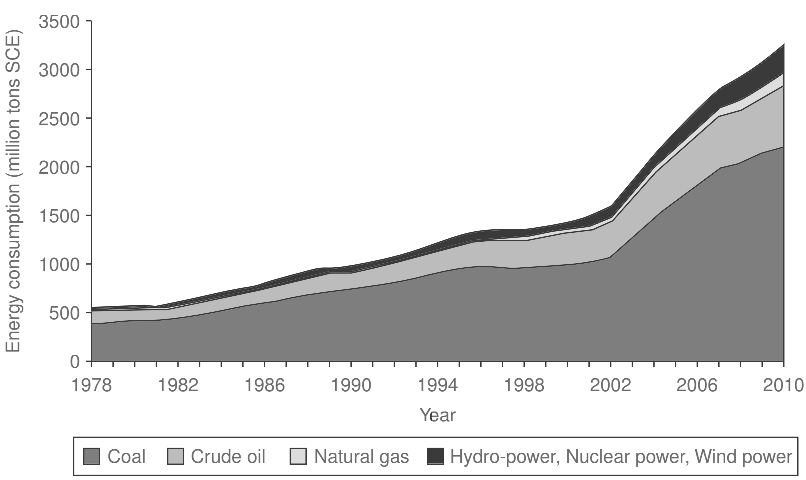

Figure 3.3 Energy consumption composition in China, 1978–2010

Note: The coefficient for conversion of electric power into SCE (standard coal equivalent) is calculated from the basic data on the average coal consumption in generating electric power in the same year.

Source: China Statistical Yearbook (2011).

possession from 1980 to 2000. In recent years, along with strengthened vehicle emission standards, vehicle emissions continued to grow but the growth rate has slowed down.

The major pollutants in air are suspended particulates, SO_2 and nitrogen dioxide (NO_2). The most particulate polluted cities are mainly concentrated in the north west, central plains and east of Sichuan province. About five per cent of observed cities have serious SO_2 pollution in 2010, compared with 25.7 per cent in 2004.[12] Furthermore, big cities, such as Beijing, Shanghai, Nanjing, Wuhan and Guangzhou had severe NO_2 pollution.

SO_2 is the major source of acid rain. 50.4 per cent of the observed cities (249 out of 494) have suffered from acid rain. Among these cities, 32.4 per cent (160 cities) had an acid rain frequency of more than a 25 per cent of rainfalls over a year, and 11.0 per cent (54 cities) had an acid rain frequency of more than 75 per cent. South China suffers the most from serious acid rain due to the presence of many low hills, abundant rainfall and a wet climate, mixed with increasing waste gas emissions. Some northern cities in Liaoning, Hebei and Shaanxi provinces also suffered from acid rain because of heavy industrial air pollution.

Unlike water pollution, the major sources of air pollution have been industrial production and processes, rather than households and services. Data from the MEP (Table 3.3) shows that the total volume of industrial waste gas emissions more than tripled during the first decade of the twenty-first century. However, the volume of major air pollutants,

Table 3.3 Emissions of major air pollutants in China, 2000–2010

		SO2 (million tons)			Soot (million tons)			
Year	**Industrial waste gas (billion cubic metres)**	**Total**	**Industry**	**Household**	**Total**	**Industry**	**Household**	**Industrial dust (million tons)**
2000	13,814.5	20.0	16.1	3.8	11.7	9.5	2.1	10.9
2001	16,086.3	19.5	15.7	3.8	10.7	8.5	2.2	9.9
2002	17,525.7	19.3	15.6	3.6	10.1	8.0	2.1	9.4
2003	19,890.6	21.6	17.9	3.7	10.5	8.5	2.0	10.2
2004	23,769.6	22.5	18.9	3.6	11.0	8.9	2.1	9.0
2005	26,898.8	25.5	21.7	3.8	11.8	9.5	2.3	9.1
2006	33,099.0	25.9	22.3	3.5	10.9	8.6	2.2	8.1
2007	38,816.9	24.7	21.4	3.3	9.9	7.7	2.2	7.0
2008	40,386.6	23.2	19.9	3.3	9.0	6.7	2.3	5.8
2009	43,606.4	22.1	18.7	3.5	8.5	6.0	2.4	5.2
2010	51,916.8	21.9	18.6	3.2	8.3	6.0	2.3	4.5

Source: China Environment Yearbook (2011).

SO_2, soot and dust, remained relatively stable, thanks to the improved technology used in production, as well as the treatment facilities which removed a large amount of pollutants before the emission of waste gas.

For industrial waste gas emissions, ten provinces (Hebei, Shandong, Shanxi, Jiangsu, Inner Mongolia, Liaoning, Guangdong, Henan, Zhejiang, and Sichuan) accounted for about 60 per cent of national total emissions (51,916.8 billion cubic metres) in 2010. From a regional perspective, of the 21.9 million tons of SO_2 emissions, Shandong, Inner Mongolia, Henan, Shanxi, Hebei, Guizhou, Sichuan, Guangdong, Jiangsu, and Liaoning were responsible for 55.6 per cent, and Shandong itself for 7.0 per cent. Seven provinces (Inner Mongolia, Liaoning, Shanxi, Henan, Hebei, Heilongjiang, and Shandong) took up 45.4 per cent of the total industrial soot emissions (8.3 million tons). Of the total 4.5 million tons of industrial dust emissions, Hunan, Shanxi, Hebei, Guangxi, Anhui, Henan, and Jiangxi were responsible for 47.1 per cent. Therefore, provinces in north China, such as Hebei, Shandong, Shanxi, Inner Mongolia, Henan, and Liaoning, seem to be bigger emitters of air pollutants than many others.

The top five air pollution industrial sectors are: production and distribution of electric power and heat, smelting and pressing of ferrous metals, non-metallic mineral products, raw chemical materials and chemical products, and smelting and pressing of nonferrous metals. They account for 85.3 per cent of China's total volume of industrial waste gas emissions in 2010. Industrial waste gas is mainly generated from the processes of burning fuel and production. About 58.5 per cent of the waste gas originated from the process of burning fuel. For the sector of production and distribution of electric power and heat, 99.9 per cent of their total emissions are from burning fuel. However, for sectors such as non-metallic mineral production, smelting and pressing of ferrous metals and smelting and pressing of nonferrous metals, waste gas was mostly from the production process, about 66.4 per cent, 75.7 per cent and 74.8 per cent respectively. In general, industrial waste gas pollution shows relatively similar regional and sectoral features of high concentration as industrial wastewater.

3.5 Solid waste pollution

The production of industrial solid waste has increased year after year, however, the discharge volume has declined rapidly due to increasing levels of utilization and treatment (Table 3.4). In 2010, the production of solid waste increased by 18.1 per cent but the discharge rate declined by 29.9 per cent compared with 2009, making the volume of discharged solid waste account for only 0.2 per cent of total solid waste generated.

The pattern of regional concentration for industrial solid waste is quite different from the patterns for industrial wastewater and industrial waste gas. Table 3.5 provides a regional perspective. Observe that the eastern region, which covers only 11.1 per cent of the country's area, had about half of the wastewater and waste gas emissions in 2010. However, in terms of solid waste, the western region, which covers 70.1 per cent of the country's surface, discharged about 70 per cent of the total volume; while the eastern region only discharged about five per cent.[13] Western and central regions have been the main emitters

Table 3.4 Industrial solid waste generated, discharged, and utilized

Year	Generated (million tons)	Discharged %	Utilized %	Stock %	Disposed %
2000	816.08	3.9	45.9	35.4	11.2
2001	888.40	3.3	53.2	34.0	16.3
2002	945.09	2.8	53.0	31.8	17.6
2003	1,004.28	1.9	55.8	27.5	17.7
2004	1,200.30	1.5	56.5	21.7	22.2
2005	1,344.49	1.2	57.3	20.7	23.2
2006	1,515.41	0.9	61.1	14.8	28.3
2007	1,756.32	0.7	62.8	13.7	23.5
2008	1,901.27	0.4	64.9	11.5	25.4
2009	2,039.43	0.3	67.8	10.3	23.3
2010	2,409.44	0.2	67.1	9.9	23.8

Note: Since the volume of industrial solid waste 'utilized' includes the utilization of 'stock' from previous years, the sum of the percentages in each year may exceed 100 per cent.

Source: China Environment Yearbook (2011).

Table 3.5 Regional comparison of industrial pollutions, 2010 (percentages of total in brackets)

Region	Area (million km2)	Wastewater (billion tons)	Waste gas (trillion cubic metres)	Solid wastes (million tons)
Eastern regions	1.07 (11.1%)	12.57 (52.9%)	24.31 (46.8%)	0.26 (5.1%)
Central regions	1.68 (17.5%)	6.12 (25.8%)	13.24 (25.5%)	1.31 (26.3%)
Western regions	6.73 (70.1%)	5.06 (21.3%)	14.36 (27.7%)	3.41 (68.5%)

Source: China Environment Yearbook (2010), and http://www.usacn.com/china/brief/population.htm [Accessed 23 March 2012].

of solid waste. Five provinces (Chongqing, Shanxi, Xinjiang, Guizhou, and Yunnan) discharged 77.9 per cent of the country's industrial solid waste (Chongqing alone contributing 26.8 per cent). In terms of sectoral concentration, 70.9 per cent was discharged from three sectors: mining and washing of coal, mining and processing of non-ferrous metal ores, and production and distribution of electric power and heat.

Solid waste imports

In addition to the solid waste generated within the country, vast quantities of solid waste have been imported into China. Some developed countries, for example the UK, have been shipping their recycling waste to China for processing for many years. In 2010, 2,942 organizations gained 14,413 import licences for solid waste and imported 48 million tons of solid waste and 242 scrap ships. Over 90 per cent of imported waste has been scrap paper, scrap plastics, scrap motor and electric appliances, and scrap iron and steel.

In 2010, 47 batches of illegal imports of solid waste were prevented from entering or were sent back to the originating country. Some countries shipped solid waste to China for disposal and dumping rather than recycling. Some imported solid waste cannot be used for raw materials or used in an environmentally sound manner. Some imported waste, such as electric appliances, are highly hazardous. For example, two UK firms disguised ten containers (259 tons) of mixed waste as scrap metal and tried to ship them to China but were discovered at a British port during a routine inspection by the British Environment Agency.[14]

These imported solid wastes are usually dismantled and processed in very primitive ways, for instance using hammers and stoves, in legal or illegal small-scale workshops. These workshops are concentrated in villages and towns in Guangdong and Fujian. They recruit migrant and local workers, including women and even children, to dismantle the waste without any safeguarding measures. After processing, toxic chemicals are discharged through wastewater, waste gas and secondary solid wastes. The toxic chemicals pollute the local environment and result in negative health impacts on workers and residents, including fester, respiratory diseases, kidney stones, neonatal death and stillbirths. However, driven by the high profits in this sector, many companies have imported a great amount of solid waste via smuggling or by disguising it as solid waste that can be used for raw materials.

The harms from solid waste imports come to the attention of both the government and the public. For this reason solid waste imports are called *yang la ji* or foreign rubbish and are regarded with repugnance. In 2011 the Chinese government introduced stricter regulations to tighten the supervision of imports of solid wastes in order to ban their dumping and treatment, as well as the transfer of hazardous wastes from other countries.

3.6 Costs of pollution

The cost of pollution covers a wide range of damage to natural resources, people's health, the productivity of workers, damage to agriculture and industry, and other negative impacts on the economy and society. The costs include:

- Costs of resource depletion, environmental degradation, ecological damage and loss of biological diversity;
- Costs of environmental conservation and disaster relief;
- Health losses due to air pollution, particularly lung cancer, chronic bronchitis and other respiratory diseases; death, chronic disease and reduced intelligence due to water pollution, especially heavy metals and toxins (for example lead, cadmium, and mercury);
- Medical costs, lost work from illness, absenteeism due to looking after patients, and loss of life quality;
- Reduction of agricultural yields and quality because of air pollution (for example acid rain), water pollution (for example associated with wastewater for irrigation of crops), and water scarcity caused by pollution;
- Negative impact on fisheries due to pollution, particularly acute pollution incidents;
- Forestry damage and impacts on timber from air pollution, including SO_2 and acid rain;
- SO_2 and acid rain damage to building and materials;
- Additional cost of treating polluted water prior to industrial production and industrial losses due to water scarcity;
- Increased cost of polluted water purification and treatment prior to household usage.

Cases related to pollution are too numerous to detail. For example, in April 2009 Phoenix Weekly reported a horrific story of cancer villages in 17 provinces in China. The journalist, Deng Fei, revealed a list of about 100 villages where a large number of villagers died from various cancers. For the majority of villages, the cancers were as a result of serious air and water pollution caused by heavily polluting factories nearby. Many of these villages are located in eastern and central China, such as Jiangsu, Henan, Guangdong, and Hebei.[15] More recent reports, officially and unofficially, suggest there are over 450 cancer villages.

A World Bank report from 2004 estimated that 300,000 people a year died prematurely from respiratory diseases and that pollution is costing China an annual 8–12 per cent of GDP (about $110–$170 billion) in direct damage, such as the impact on crops of acid rain, medical bills, lost work from illness, money spent on disaster relief following floods and the implied costs of resource depletion (The Economist, 19/08/2004).[16] In a joint report by the World Bank and the Government of China, health and non-health costs of outdoor air and water pollution in China were estimated using economic models and based on surveys about the willingness to pay for reducing health risks from pollution among households in Shanghai and Chongqing in 2003.[17] The results suggest that health costs of air and water pollution account for 4.3 per cent of China's national GDP and the total cost of pollution is about 5.8 per cent of GDP. Air pollution in large cities is associated with higher incidences of lung diseases, respiratory problems and hence higher levels of absence from work and school. Water pollution causes cancer and diarrhoea, particularly in children under five. Surface water pollution has increased the use of groundwater and the depletion of non-rechargeable groundwater will lead to seawater intrusion and land subsidence, as well as increased future costs of pumping groundwater. The overall estimated costs of groundwater depletion and the using of polluted water to industry are about one per cent of China's GDP.

From 2004, China's MEP and NBS started to account for the environmental cost of economic development and published a six-year (2004– 2009) Chinese Environmental and Economic Accounting Report.[18] The report concludes that the cost of environmental pollution continued to grow during the six years, even though China has achieved great progress in pollution emission reduction. China is facing more and more pressure to tackle its environmental pollution problems. The findings show that the cost of environmental degradation increased from RMB 511.82 billion (about $62 billion) in 2004 to RMB 970.11 billion (about $142 billion) in 2009.[19] By adding the losses from ecological destruction, the total environmental cost in 2009 was about RMB 1,391.62 billion (about $204 billion), which is estimated to be about 3.8 per cent of that year's GDP. China's average resource productivity over the six years was about $320–$350 per ton, much lower than the average level in developed countries which is $2,500–$3,500 per ton. There is a negative correlation between the share of environmental cost in GDP and per capita GDP in less developed regions, indicating that China's poor regions are disproportionately affected by pollution and environmental degradation.

There have been a few Chinese researchers estimating pollution related costs at province or city level. For example, Yang and Li (2010) estimated the loss accounted for by environmental pollution in Shandong Province from 2000 to 2005. Their evaluation considered the damage of air and water pollution as reflected in: pollution related health impact: loss of crops, forest, and fisheries; material damage; losses due to wastewater used in irrigation, industrial production and household usage. The total loss from damages was much higher than the total cost of pollution treatment, and even higher than the investment in environmental pollution treatment in each year. The loss from air and water pollution has accounted at 1.77 per cent, which was 2.94 per cent of GDP in Shandong from 2000–2005. According to current prices, the average annual growth rate of pollution related loss was 30.2 per cent, which is evidently higher than the annual growth rate of provincial GDP (17.5 per cent) over the same period.

No matter which data or method has been used in for estimating, the cost of pollution in China has been huge and, to certain extent, has offset the achievements of economic development. Recently, China's annual GDP growth rate remained at about eight per cent. If pollution costs were at eight per cent or more, any economic growth is meaningless. In order to achieve sustainable development there must be no delay in carrying out environmental protection and pollution treatments.

3.7 Conclusions

With rapid expansion in economic activities, China has been a heavily polluting country and the emissions of most of the pollutants seem to be increasing overall. Will pollution increase forever? Is there a turning point at a certain income level after which pollution declines, or in another words, does the EKC exist in China? Given the great differences in economic development and pollution levels across regions, if the hypothesis of EKC holds, is it possible that some regions have arrived or passed the turning point?

Regarding to the impact of FDI on the environment, an argument for pollution haven hypothesis is that foreign firms are moving pollution intensive production to developing countries to take advantage of their weak environmental regulations and therefore they are harmful to the local environment. An opposite point of view is that foreign firms in developing countries are usually cleaner than the indigenous counterparts and bring advanced technologies and environmental management systems to the host country, thus FDI benefits the environment in these countries. What are the environmental impacts of foreign investment enterprises in China?

Answering these questions has important policy implications for current development in China. The following chapters review the theory and empirical studies and investigate these questions using data about Chinese cities from 2001 to 2004.

4
Literature Review on EKC and the Effects of FDI on the Environment

4.1 Introduction

The relationship between economic growth and the environment was first observed by Grossman and Krueger (1991) in their investigation of the environmental impacts of a North American Free Trade Agreement. They found that the relationship between economic growth and environmental quality 'may change sign from positive to negative when a country reaches a level of income at which people demand and afford more efficient infrastructure and a cleaner environment'.[1] Such an inverted-U relationship between environmental degradation and economic growth is known as the Environmental Kuznets Curve (EKC), analogous to the income–inequality relationship hypothesised by Kuznets (1955).

Since 1992 a considerable amount of empirical and theoretical research has examined the relationship between economic growth and various indicators of environmental degradation, with mixed results. Generally, there are two different schools of thought in the EKC literature: optimists, who support the EKC implication that economic growth is ultimately good for the environment (for example Beckerman, 1992; Shafik and Bandyopadhyay, 1992, Grossman and Krueger, 1995; Lomborg, 2001); and critics, who point out a number of methodological flaws in deriving the EKC or who advocate caution in interpreting its causes and implications (for example Arrow *et al.*, 1995; Stern *et al.*, 1996; Ekins, 1997; Stern, 1998; Suri and Chapman, 1998; Rothman, 1998; Stern and Common, 2001; Cole, 2003, 2004).

One of the most damaging criticisms is related to the occurrence of FDI and international trade. 'The argument asserts that the downturn in emissions at higher levels of PCI (per capita income) can be explained, at least to some extent, by the relocation of 'dirty' industries from developed to developing countries, and the tendency among developed countries to import pollution intensive goods from developing countries rather than produce them at home.'[2]

The past approach of empirical work on trade/FDI patterns and the EKC was to test the pollution haven hypothesis (Tobey, 1990; Birdsall and Wheeler, 1993; Jaffe *et al.*, 1995; Rothman, 1998; Antweiler *et al.*, 2001; Levinson, 1996a, 1996b; Xing and Kolstad, 2002; Eskeland and Harrison, 2003; Smarzynska-Javorcik and Wei, 2005). These studies found little evidence that environmental stringency impacts on trade/ investment flows. However, it does not mean that trade and FDI flows do not explain the EKC.

Grossman and Krueger (1991) described three possible sources of environmental impact from a greater openness to trade and foreign investment: a scale effect, a technique effect and a composition effect. These three effects are examined in the following studies on FDI and the environment.

The scale effect relates to the impact on the environment as a result of an increase in economic output due to the expansion of investment. The composition effect refers to investment that will change the industrial structure of an economy. The technique effect states that investment either drives a more rapid rate of technology development, diffusion and transfer, or it increases income and hence the demand for a cleaner environment. Each change can influence pollution levels in different ways. In general, the scale effect is expected to be negative, the technique effect is expected to be positive, while the composition effect cab be ambiguous. Therefore, the real relationship between FDI and the environment cannot be explained simply as positive or negative. Previous studies (for example Jha, 1999; Zarsky, 1999) showed that the effects of FDI on a host country's environment can be positive, negative or neutral.

Although many empirical studies have been devoted to the impact of environmental stringency on FDI inflows, studies on the net effect of FDI on the environment are scarce. One reason for the scarcity is that it is difficult to separate clearly the environmental effects of domestic economic activity from the effects of the activities of foreign affiliates.

This chapter is organized as follows: Section 4.2 commences with the theoretical and empirical studies on economic growth and the environment, then Section 4.3 introduces the literature on the environmental effects of FDI, and Section 4.4 provides a brief summary.

4.2 Economic growth and the environment

4.2.1 Theoretical principles

The basic Environmental Kuznets Curve (EKC) is the hypothesis that as an economy's per capita income increases, the total amount of environmental impact of economic activities initially grows, reaches a maximum and then falls. Grossman and Krueger (1991) explained that the improvement in environmental quality at higher levels of per capita income are due to factors such as changes in the composition of output, the introduction of cleaner production technology, and the greater demand for improved environmental quality, leading to more stringent environmental regulations. Grossman and Krueger (1995) added another possible explanation for the downward sloping part of the EKC: as countries develop, they stop producing pollution intensive goods and instead import them from developing countries with weaker environmental standards. However, they argued that it does not mean the differences in environmental stringency are an important determinant of the pattern of international trade, because 'the volume of such trade is probably too small to account for the reduced pollution that has been observed to accompany episodes of economic growth'.[3]

Numerous theoretical and empirical papers have considered the relationship between economic growth and environmental quality. Theoretical studies have concentrated on tracing the path of environmental quality and development using alternative assumptions about social welfare functions, pollution damage, the cost of abatement, and the productivity of capital (Dasgupta *et al.,* 2002).

Lopez (1994) used a model to show that if producers pay the social marginal cost of pollution, the relationship between pollution and income depends on the properties of both technology and preferences. If the preferences are homothetic, pollution levels will increase with economic growth. If the preferences are non-homothetic, the relationship between income and pollution depends on the elasticity of substitution between pollution and other inputs and on the marginal utility of income. The higher the elasticity of substitution and marginal utility, the less pollution will increase with income. Then the inverted-U relationship between pollution and income is obtained.

Selden and Song (1995) used the neoclassical environmental growth model of Forster (1973) to derive an inverted-U curve for optimal pollution, assuming the optimal abatement is zero until a critical level of development, but then grows at an increasing rate thereafter.

McConnell (1997) focused on the role of preferences and, in particular, the income elasticity of demand for environmental quality using a simple static model. He found that higher income elasticity results in slower increases or faster declines in pollution, and there is no special role of income elasticity equal to one. Pollution can decline even with zero or negative income elasticity when pollution causes a reduction in output (for example, forestry reduction, material damage due to acid rain, and health effects on the labour force due to air and water pollution). He also provided microeconomic evidence to support a major role for the income responsiveness of preferences in the EKC model.

Lopez and Mitra (2000) suggested that corruption may not preclude the existence of an inverted-U shaped EKC. The results show that for any level of per capita income the pollution levels corresponding to corruption behaviour are always above the social optimal level. In addition, the turning point of the EKC takes place at income and pollution levels above those corresponding to the social optimum.

4.2.2 Empirical studies

A great number of empirical studies have been devoted to the relationship between economic growth and the environment. The empirical models are usually reduced form single equation specifications relating an environmental quality indicator to a measure of income per capita. The indicators of environmental quality include certain water and air pollutants (for example oxygen, heavy metals, SO_2, CO_2, and particulates), deforestation rate, energy consumption, solid wastes, traffic volume, and environmental R&D. Recent analysis considers a far wider range of environmental problems, for example, hazardous wastes, greenhouse gas emissions and biodiversity loss. Water and air pollutants are widely used in empirical studies, in the form of emissions per capita and concentration of pollutants as recorded by monitoring stations.

The common dependant variable is income per capita, but some studies use income data converted into purchasing power parity (PPP), while others use incomes at market exchange rates. Different studies use different control variables, such as openness to trade, population density, income distribution, geographical variables, and political freedom. The functional specification is usually quadratic, log quadratic, or cubic in income. They are estimated econometrically using cross section or panel data. Some test for country and time fixed effects and some test for random effects.

The first set of empirical studies appeared independently in three working papers: Grossman and Krueger (1991), Shafik and Bandyopadhya

(1992), and Panayotou (1993). They found turning points for several pollutants (the concentrations of SO_2, NO_x, and suspended particulate matter (SPM)) in a similar income range of $3,000–$5,000 per capita. The results of some studies before the mid-1990s also confirmed the basic EKC pattern for certain pollutants (for example Selden and Song, 1994; Grossman and Krueger, 1995). However, the turning points for the emissions of SO_2, NO_x, SPM, and CO in Selden and Song (1994) are much higher than those found by Grossman and Krueger (1995). The difference is explained by the reduction of emissions lagging behind the reduction in ambient concentrations. Additionally, the results from Shafik (1994) are ambiguous, suggesting that the EKC does not hold at all times and for all pollutants (for example the linear downward relationship between income and some pollution indicators such as lack of safe water, dissolved oxygen in water, municipal waste, and carbon emission).

Since the mid-1990s, the EKC has been attacked on both empirical and methodological grounds, a trend that has continued in recent years, and the results have been far more ambiguous (Nahman and Antrobus, 2005).

Cole *et al.* (1997) estimated the EKC for many environmental indicators, including total energy use, transport emissions of SO_2, SPM, and NO_2, nitrates in water, traffic volumes, chlorofluorocarbon emissions, and methane. They found that a meaningful EKC exists only for local air pollutants, whereas indicators with a more global, indirect, environmental impact either increase monotonically with income or else have turning points at high income levels with large standard errors. They also confirmed that the concentration of local pollutants peaks at a lower income level than total emissions per capita. Hilton and Levinson (1998) found the EKC for automotive lead emissions, but the peak of the curve is sensitive to both the functional form estimated and the time period considered. Kaufmann *et al.* (1998) found a U relationship between income and atmospheric concentrations of SO_2, and an inverted-U relationship between the spatial intensity of economic activity (GDP/Area) and SO_2 concentration. The trade-off between the effects of income gains and the spatial intensity of economic activity on the concentration of SO_2 is consistent with the notion that some environmental problems can be improved by slowing population growth and increasing income levels.

Hettige *et al.* (2000) rejected the EKC hypothesis for industrial water pollution: that industrial water pollution rises rapidly through middle-income status and remains roughly constant thereafter. Stern and Common (2001) estimated the EKC for sulphur emissions using a larger and more global sample than previous studies. They found the emissions–income relationship is monotonic for the global sample because the estimated turning point is far above all countries' income levels; while the relation is an inverted-U shape for the subsample of OECD countries. The results of first differences model suggest a monotonic income-emission relationship in both OECD and non-OECD subsamples. They conclude that reductions in emissions are time-related rather than income-related. Harbaugh *et al.* (2002) used the updated and revised panel data on ambient air pollution in cities worldwide to re-examine the robustness of the evidence for the existence of the EKC studied by Grossman and Krueger (1995). They tested the sensitivity of the pollution–income relationship to the function forms and econometric specifications used, including additional covariates and changes in the nations, cities and years sampled. They concluded that there is little evidence in the data to support an inverted-U shaped relationship between several important air pollutants and national income.

Some studies attempted to break down the EKC relationship into its constituent scale, composition and abatement effects (including Panayotou, 1997; De Bruyn *et al.*, 1998).

Panayotou (1997) argued that the determinants of environmental quality include: (1) the scale of economic activity (scale effects); (2) the composition of economic activity (composition effects); and (3) the effect of income on the demand and supply of pollution abatement efforts (pure income effects). The scale effect is expected to be a monotonically increasing function of income while the income effect is monotonically decreasing function of income, all else being equal. The composition effect is likely to be a non-monotonic (inverted-U) function of income. Panayotou (1997) specified a cubic function form for all decomposition effects, with other variables including population density, the rate of economic growth and the quality of institutions. The results on ambient SO_2 levels confirmed the expectation of the three effects, and also suggested that policies and institutions can help flatten the EKC and reduce the environmental price of economic growth.

De Bruyn *et al.* (1998) adopted a dynamic model and estimate for three types of emissions (CO_2, NO_x, and SO_2) in four developed countries (Netherlands, UK, US, and Western Germany). They found that these emissions correlated positively with economic growth and that emissions may decline over time, probably due to structural and technological changes.

There are a few studies focusing on individual countries. For example, Vincent *et al. (*1997) found that SPM and chemical oxygen demand (COD) increase with income, while biochemical oxygen demand (BOD) decreases with income in Malaysia; Carson *et al.* (1997) found that all major air pollutants declined with increasing levels of income across 50 US states.

In terms of empirical studies on China, Shen (2006) used a simultaneous equations model to examine the existence of the EKC relationship between per capita income and per capita pollution emissions. Shen (2006) tested two air pollutants (SO_2 and dust fall) and three water pollutants (COD, arsenic, and cadmium) from 1993 to 2002 in 31 Chinese provinces and municipalities. The results suggested an EKC relationship for all water pollutants. While SO_2 showed a U-shaped relationship with income levels and dust fall had no significant relationship with income levels. In addition, government expenditure on pollution abatement had a significant, and negative, effect on pollution; while the net effect of secondary industries on pollution emissions were all positive and significant. Therefore, environmental policy and industrial structure both play important roles in determining water and air pollution levels in China.

4.2.3 Critiques of the EKC

Nahman and Antrobus (2005) summarized that 'in some cases the data does give rise to an EKC-type relationship, in other cases it does not, while in many cases the emergence of an EKC-type relationship depends on the variables included in and the functional form attached to the statistical model, or on the type of model used'.[4] Therefore, there has been a decline in theoretical explanations of EKC patterns and a rise in empirical explanations, especially in studies that criticise previous empirical studies. Cole (2003) divided these critiques of the EKC into two categories, methodology and interpretation of results.

In terms of the EKC methodology, there are following five kinds of critiques. First, EKC is no more than a methodology artefact due to the omission of certain important variables, such as the price of energy, the distribution of income and the demand for and supply of environmental quality, or education (for example Chapman and Agras, 1999; Magnani, 2000; Heerink *et al.*, 2001; Lekakis and Kousis, 2001; Hill and Magnani, 2002). In addition, some argued that the basic EKC is determined by changing trade and investment patterns rather than growth-induced pollution abatement, and these trade/investment patterns have been omitted in EKC studies. EKC might arise by the relocation of 'dirty' industries from developed countries to developing countries to take advantage of less stringent environmental regulations (for example Stern *et al.*, 1996; Stern, 1998; Suri and Chapman, 1998; Rothman, 1998; Cole, 2003, 2004). This argument led to research on the well-known pollution haven hypothesis related to international trade and foreign direct investment, with mixed and relatively weak results.[5] However, weak evidence in support of the pollution haven hypothesis does not imply that trade/investment flows do not explain the environmental Kuznets curve. Pollution intensive industries might relocate to developing countries for reasons other than weaker environmental regulations. For example, the strong incentive of access to the source of raw materials leads many traditionally energy- and pollution-intensive activities to migrate to developing countries (Rothman, 1998).

Second, the EKC assumes unidirectional causality from income to emissions and does not allow for the impact of environmental degradation on income levels. Therefore, 'least square estimation in the presence of such simultaneity will provide biased and inconsistent estimates'.[6]

Third, Stern and Common (2001) and Perman and Stern (1999) postulated two econometric issues, that (1) the estimated turning points using data for the world are at higher income levels than using only OECD data because developing countries are experiencing increasing emissions of local air pollutants such as SO_2; and (2) the non-stationarity of income and emissions are usually neglected by EKC studies.

Fourth, there are some other econometric issues, for example Stern *et al.* (1996) were concerned that many EKC studies ignore the issue of heteroskedasticity that may be present in cross-section data. Other issues include: cubic relationships between income and pollution should be considered in case emissions begin to increase again at high income levels; the pattern of the EKC depends on the datasets, particular function forms used or covariates included in the model (for example Ekins, 1997; List and Gallet, 1999; Spangenberg, 2001; Harbaugh *et al.*, 2002; Perman and Stern, 2003; Millimet *et al.*, 2003).

Finally, Stern (1998) argued, 'EKC regressions that allow levels of pollution to become zero or negative as being incompatible with the laws of thermodynamics, since all resource use inevitably produces wastes'.

Regarding the interpretation of EKC results, first, an EKC relationship may not exist for all environmental indicators (Arrow *et al.*, 1995). Second, EKCs do not indicate that economic growth automatically solves environmental problems without giving any attention to the environment. Emissions could be reduced through investment and regulations, neither of which are automatic consequences of economic growth.

Finally, 'although many EKC estimate turning points around the current world mean per capita income level, this does not mean that, globally, emissions are about to decline. Global income distribution is skewed with far more people below the mean than above it'.[7] Therefore, median income levels are worth considering rather than mean income levels.

In this book we address many of these criticisms (see details in Chapter 5).

4.3 Effects of FDI on the environment

4.3.1 Theoretical analysis

Grossman and Krueger (1991) distinguished three separate mechanisms by which a change in trade and foreign investment policy can affect the level of pollution and the depletion rate of scarce environmental resources. The three mechanisms are scale effects, composition effects and technique effects. These have been the standard approaches to analysing the FDI environment nexus.

Scale effect

The scale effect refers to the expansion of economic activity as a result of an increase in foreign investment. If the nature of the economic activity remains unchanged, the total amount of pollution generated must increase, as well as the use of natural resources. 'Even if the foreign firms are relatively less polluting across all emissions and/or more concerned about sustainable resource harvesting, the overall quantity of pollution and level of resource degradation increases with a greater level of investment. In addition to pollution, a larger increase in the scale of investment without a larger 'sustainable development' land and resource use planning framework is likely to undermine biodiversity and degrade common access resources such as river and coastlines.'[8] *Ceteris paribus*, the scale effect on environmental quality is expected to be negative.

Composition effect

The composition effect (or structural effect) means that FDI may have an impact on the environment by changing the industrial structure. Traditional trade theory suggests that countries will specialize in those sectors in which they have competitive advantage. Foreign investment, to a greater extent, is attracted by such competitive advantage. 'If competitive advantage derives largely from differences in environmental regulation, then the composition effect…will be damaging to the environment. ... On the other hand, if the sources of international comparative advantage are more traditional ones, namely cross-country differences in factor abundance and technology, then the implications of the composition effect for the state of environment are ambiguous. ... The net effect of this on the level of pollution in each location will depend upon whether pollution-intensive activities expand or contract in the country that on average has the more stringent pollution controls.'[9]

However, some research (for example OECD, 2002) believes that structural effects are expected to be positive because trade and investment liberalization promote allocative efficiency among economies. A report from UNCTAD in 1999 showed that FDI destined for primary sectors declined from 8.6 per cent to 4.5 per cent between 1988 and 1997 in developed and developing countries, while the services sector had a corresponding increase in both categories of countries in the same period. Some analyses suggest that this structural shift towards service FDI generally has a positive effect on the environment (Gentry, 1998; UNCTAD, 1999; OECD, 2001).

Technique effect

Grossman and Krueger (1991) provided two reasons that pollution per unit of output might fall, especially in developing countries. First, foreign investors may bring newer and better technologies, which tend to be less polluting and use fewer resources. In addition to technology transfer, FDI may also create other positive technological spillovers to national firms through imitation, employment turnover, and supply chain requirements (OECD, 2002). Second, FDI may increase residents' income and then people may have more demand for environmental quality. Thus, there will be more pressure on the government to implement more stringent environmental regulations and stricter enforcement of existing laws. Some researchers extract the second point from the technique effect and call it an income effect (for example Zarsky, 1999).

However, the technology effect may be negative in some cases (OECD, 2002). Multinationals may apply relatively more damaging technologies in regions with weak environmental regulations. In addition, some evidence suggests that overseas multinational R&D is concentrated in only a few developed countries (Freeman and Hagedoorn, 1994; UNCTAD, 1999).

4.3.2 Empirical studies

From an analytical perspective, research on the net outcome of these three effects is relevant. However, identifying the net effect of FDI on the environment is complex. The OECD (2002) presented two limitations that might explain the difficulties in addressing the net environmental effect of FDI flows. First, it is difficult to separate clearly the environmental effects of domestic economic activity from the effects of foreign affiliate activity. Second, FDI does not occur in a vacuum so environmental effects cannot be analysed in isolation from other related factors, for example, trade influences the potential market opportunities in a country.

These limitations led to some pragmatic studies on foreign investment and the environment, for example, reports from UNCATD/CBS (Copenhagen Business School) on 'Cross Border Environmental Management in Transnational Corporations' which included case studies on China (Xian *et al.*, 1999), India (Jha, 1999) and Malaysia (Rasiah, 1999). These reports provide many examples of both positive and negative environmental effects of transnational corporations.

Wheeler (2001) provided a simple statistical test of the race to the bottom model using data on FDI and urban air quality (measured by concentrations of fine particulate matter less than ten microns in diameter, PM_{10}, or SPM) in three developing countries, China, Brazil, and Mexico. The race to the bottom model indicates that after decades of increasing capital and economic liberalization, pollution should increase everywhere; increasing in poor countries because they are pollution havens, and in rich countries because they relax environmental standards to remain cost competitive. The three developing countries received 60 per cent of the total FDI for developing countries in 1998. If the race to the bottom model is correct, then air pollution should increase in all three countries. At the same time, the air quality in US cities should decline because US industrial imports from these three countries have been expanding for decades. However, the figures showed that urban air quality in all four countries improved. The result strongly contradicts the race to the bottom model.

There has been scarce empirical evidence on cross-country studies of environmental effects from foreign investment in the 1990s. Recently, some studies have begun to investigate the extent to which different forms of environmental degradation within less developed countries are a function of transnational organization of production (for example Grimes and Kentor, 2003; Jorgenson, 2006, 2007a, 2007b, 2007c; Kentor and Grimes, 2006). These studies are based on the context of foreign investment dependence theory.[10]

Grimes and Kentor (2003) observed the impact of foreign investment dependence on carbon dioxide emissions between 1980 and 1996 using a cross-country panel data for 66 less developed countries. They found that foreign capital penetration in 1980 had a significant positive effect on the growth of CO_2 emissions between 1980 and 1996.

Jorgenson (2007c) investigated the extent to which the transnational organization of production affected the environment in 37 less developed countries from 1975 to 2000. He tested the hypotheses that foreign investment dependence in the manufacturing sector is positively associated with carbon dioxide emissions and organic water pollutants (BOD) in less developed countries. In addition to the key determinant variable, the secondary sector FDI stock as a percentage of total GDP, other control variables included population size, level of economic development (GDP per capita), domestic investment, relative size of manufacturing sector, urbanization, and export intensity. The findings from fixed effect estimations confirmed the hypotheses and provided support for the theory of foreign investment dependence. Jorgenson's other studies used a similar methodology and got consistent results showing that foreign investment increases pollution emissions in less developed countries.

4.3.3 Empirical studies related to China

Two papers have examined the environmental impact of FDI in China. Liang's (2006) working paper used city level data (for more than 260 cities) from the late 1990s to examine the relationship between local SO_2 emissions and the scale of foreign direct investment, industry composition and income. The paper tested two hypotheses: (1) that the pollution level in China's cities increases with per capita income, but decreases with the square of per capita GDP (a pollution–income nexus of an EKC-type); and (2) everything else being equal, the pollution intensity in China's cities decreases with the scale of foreign direct investment. The scale of FDI is measured by two variables, net assets and employment of foreign firms in each city. To tackle the endogeneity of FDI, these two variables are instrumented by geographic location, trade policy and local population. The major conclusion was that there is a negative correlation between FDI and SO_2 emissions, indicating that the overall effect of FDI is beneficial to the environment. The results also support the EKC hypothesis. A turning point of around $1,200 is found, suggesting that 30 per cent or more cities passed this level in 2000 and the proportion increases by about four per cent each year. This interpretation is optimistic and much lower than SEPA's official prediction in April 2006 ($3,000).

He (2006) constructed a five equation simultaneous system to study the FDI–emission nexus and got different results to Liang (2006). The system includes the FDI location decision with respect to the host country's environmental regulation stringency and the impact of FDI on pollution through the scale, composition and technique effects. The simultaneous system is estimated using a dynamic panel of SO_2 emissions in 29 Chinese provinces from 1994 to 2001. A Generalized Method of Moment (GMM) estimator is used to correct potential first-order serial correlation and heteroskedasticity. The results show that the total impact of FDI on industrial SO_2 emissions is very small. A one per cent increase in FDI capital stock contributes a 0.098 per cent increase in industrial SO_2 emissions, indicating that the emission increase caused by the impact of FDI on economic growth and composition transformation cancels out the emission reduction resulting from the impact of FDI on reinforcing environmental regulations. Furthermore, the FDI entry decision equation (that depends on the previous period's economic growth and environmental regulation stringency) in the simultaneous system provides convincing evidence for the pollution haven hypothesis. Although the overall effect of FDI on industrial SO_2 emission is relatively weak and foreign funded enterprises in China generally produce with higher efficiency, the increase in environmental stringency does have a modest deterrent effect on FDI inflows.

4.4 Conclusions

There have been numerous theoretical and empirical studies that examine the relationship between economic growth and the environment based on the theory of the Environmental Kuznets Curve from the early 1990s. The results of empirical evidence are mixed and show that the EKC does not hold all the time or for all pollutants. Among the empirical studies, only a few employ a cross-region analysis for an individual country. There are several critiques of the EKC, focusing on the methodology and the interpretation of results. We address many of these critiques in next chapter.

To consider the impact of FDI on the environment, most analytical studies are pragmatic and empirical evidence is rather limited. The most recent cross-country studies on the FDI–environment nexus all focus on less developed countries and are based on the foreign investment dependence theory. Of those empirical studies on the cross-region FDI–environment relationship in China, Liang (2006) and He (2006) both looked at the impact of FDI on SO_2 industrial emissions but got different results.

The lack of cross-regional evidence for the EKC for an individual country and the contradictory empirical results on the FDI–environment nexus in China provided the motivation to examine the net environmental effects of income as well as foreign investment in China. We believe that Chapter 5 in this book is the first study to examine these issues using city level data for a range of environmental indicators, in order to check the robustness of these two effects. Chapter 5 also represents the first attempt to examine the differences between the behaviour of firms from Hong Kong, Taiwan and Macao, and other foreign firms.

5

Growth, FDI, and the Environment: Evidence from Chinese Cities

5.1 Introduction

In this chapter, we investigate the relationship between economic growth and industrial pollution emissions in China using data for 112 major cities from 2001 to 2004. We also compare the environmental effects of domestic firms to those of foreign firms. Foreign firms are split into two groups: affiliates from Hong Kong, Macao, and Taiwan, and affiliates from other foreign economies. We chose four industrial water pollution indicators (wastewater, chemical oxygen demand, hexavalent chromium compounds, and petroleum-like matter) and four industrial air pollution indicators (waste gas, sulphur dioxide, soot, and dust).

Our results suggest that most air and water pollution emissions rise with an increase in economic growth at current income levels. Domestic firms have a strong and positive impact on most pollution emissions. The output of firms from Hong Kong, Macao, and Taiwan does increase all pollution emissions but their share is only statistically significant for some water pollution emissions; while the output of firms from other foreign economies significantly increases emissions of petroleum-like matter, waste gas, and SO_2.

We make three specific contributions to the growth-environment literature. First, we focus specifically on China given the undeniable strain such a large and rapidly growing economy is placing on the natural environment. Studies investigating these issues in China are relatively scarce. Second, since the majority of industrial emissions are released in urban areas, we concentrate our analysis on Chinese cities and examine the city-level characteristics that influence industrial emissions. We believe the use of city-level variables provides more potential explanatory power than the use of highly aggregated variables at national level. Third, given the vast FDI flows into China in recent years we analyse the contribution of FDI to China's industrial pollution emissions and also take the additional step of identifying the FDI by source country.

There are five sections in this chapter. Section 5.2 introduces the related background information, including economic development, FDI inflows and pollution levels in a large number of Chinese cities during the observed period. We also provide information about the environmental indicators that are considered in this chapter. Section 5.3 provides the model specification and data description. Section 5.4 describes the empirical results and the final section draws conclusions and looks at policy implications.

5.2 Background information on Chinese cities

5.2.1 Economic development and FDI in Chinese cities

In China cities are classified in three levels according to administrative division: county-level cities, prefecture-level cities (including sub-provincial cities) and municipalities.

County-level cities are usually governed by prefecture level divisions, but a few are governed directly by province-level divisions.[1] Prefecture-level cities are completely ruled by their provinces; sub-provincial cities are ruled by their provinces but are administered independently in regard to economy and law, and the mayor of a sub-provincial city is equal in status to the vice-governor of a province. Municipalities are independent and equivalent to a province. The term city is used here not as a city in the strict sense, but as an administrative unit, including both urban core and surrounding rural areas.

Since 1978, China has upgraded and reclassified many counties into cities, and many towns into counties. The total number of cities increased from 191 in 1978 to 661 in 2004, including 374 county-level cities, 283 prefecture-level cities (including 15 sub-provincial cities) and 4 central municipalities.

Similar to development across the provinces, development is quite uneven across cities. Table 5.1 compares the population, income and FDI in the largest Chinese cities in 2004. Cities in coastal provinces generally have higher income levels than inland cities (15 of the 17 cities with per capita income above $3,000 are located in eastern regions), especially in some south east coastal provinces, for example,

Table 5.1 Population, income and FDI for some cities in china, 2004

City	Population (million)	GDP per capita ($)	GDP per capita growth rate (2003–2004) (%)	FDI (million $)	FDI/GDP (%)	SO_2 pc (tons per 1000 people)
Zhuhai	0.86	7,848	3.32	510	7.73	43.53
Shenzhen	1.65	7,161	1.62	3,612	8.73	26.44
Guangzhou	7.38	6,799	8.82	2,401	4.83	24.53
Shanghai	13.52	6,682	11.21	6,541	7.27	25.85
Xiamen	1.47	4,850	5.60	570	5.34	36.72
Ningbo	5.53	4,733	12.84	2,103	8.07	36.25
Hangzhou	6.52	4,695	11.10	1,410	4.64	19.31
Beijing	11.63	4,477	8.64	3,084	5.96	10.78
Dalian	5.62	4,226	12.72	2,203	9.30	13.15
Nanjing	5.84	3,993	11.73	2,566	11.12	24.72
Tianjin	9.33	3,812	11.86	2,472	6.98	21.59
Qingdao	7.31	3,401	12.66	3,799	14.53	15.73
Jinan	5.90	3,336	10.09	483	2.47	11.87
Shenyang	6.94	3,321	10.72	2,423	10.55	5.13
Huhhot*	2.15	3,180	18.12	239	3.87	60.40
Yantai	6.47	3,043	16.37	1,857	9.42	12.55
Wuhan*	7.86	3,016	10.01	1,520	6.43	16.37
Fuzhou	6.09	2,832	7.25	1,360	7.27	8.33
Urumuchi*	1.86	2,757	8.81	15	0.26	45.88
Changchun*	7.24	2,572	7.03	902	4.86	4.31
Zhengzhou*	6.71	2,565	15.79	242	1.45	16.29
Chengdu*	10.60	2,510	8.28	332	1.26	13.24
Wenzhou	7.46	2,277	6.99	209	1.23	10.51
Taiyuan*	3.32	2,272	15.20	143	1.84	55.32
Kunming*	5.03	2,268	8.65	62	0.55	14.93

Continued

Table 5.1 Continued

City	Population (million)	GDP per capita ($)	GDP per capita growth rate (2003–2004) (%)	FDI (million $)	FDI/GDP (%)	SO_2 pc (tons per 1000 people)
Changsha*	6.10	2,179	13.11	501	3.66	9.03
Haikou	1.43	2,166	1.15	320	10.47	0.32
Shijiazhuang	9.18	2,159	10.63	352	1.78	20.29
Yinchuan*	1.38	2,135	9.42	64	2.79	10.68
Harbin*	9.70	2,110	9.87	405	1.99	4.47
Nanchang*	4.61	2,083	10.58	730	7.85	7.41
Qinhuangdao	2.76	1,995	9.17	202	3.68	19.03
Lanzhou*	3.08	1,991	6.53	–	–	17.54
Nantong	7.74	1,910	15.10	1,104	7.46	10.42
Xi'an *	7.25	1,701	8.18	276	2.08	12.48
Hefei*	4.45	1,616	17.42	316	4.43	5.38
Guiyang*	3.48	1,532	8.60	78	1.46	64.80
Shantou	4.88	1,501	7.11	78	1.07	5.41
Beihai*	1.48	1,328	7.83	20	1.01	17.89
Zhanjiang	7.16	1,176	9.48	71	0.97	6.62
Chongqing*	31.44	1,161	10.88	405	1.26	20.39
Nanning*	6.49	1,103	4.40	78	1.09	9.46
Lianyungang	4.69	1,074	13.29	247	4.90	9.53
Xining*	2.07	1,025	12.37	9	0.44	19.38

Note: * indicates cities in inland provincesRanked by GDP per capita. Cities in this table include:Four municipalities: Beijing, Tianjin, Shanghai, and Chongqing;26 provincial capital cities: Shijiazhuang, Taiyuan, Huhhot, Shenyang, Changchun, Harbin, Nanjing, Hangzhou, Hefei, Fuzhou, Nanchang, Jinan, Zhengzhou, Wuhan, Changsha, Guangzhou, Nanning, Haikou, Chengdu, Guiyang, Kunming, Xi'an, Lanzhou, Xining, Yinchuan, and Urumuchi (Lasa is not included due to lack of data);15 sub-provincial cities: Shenyang, Dalian, Changchun, Harbin, Nanjing, Hangzhou, Ningbo, Xiamen, Jinan, Qingdao, Wuhan, Guangzhou, Shenzhen, Chengdu, and Xi'an;Five special economic zones: Shenzhen, Zhuhai, Shantou, Xiamen, Hainan;14 coastal open cities: Tianjin, Shanghai, Dalian, Qinhuangdao, Yantai, Qingdao, Lianyungang, Nantong, Ningbo, Wenzhou, Fuzhou, Guangzhou, Zhanjiang, and Beihai. Some cities appear in several categories, for example, Guangzhou, the capital of Guangdong province, is also a sub-provincial city and a coastal open city. SO_2 per capita is sulphur dioxide emissions (tons per 1,000 people).

Source: China City Statistical Yearbook (2004, 2005).

Table 5.2 Spearman rank correlations between the variables in Table 5.1

	Population	**GDPpc**	**GDPgr**	**FDI**	**FDI/GDP**	**SO_2 pc**
Population	1					
GDPpc	0.07	1				
GDPgr	0.16	–0.02	1			
FDI	0.43*	0.73*	0.16	1		
FDI/GDP	0.011	0.59*	0.18	0.83*	1	
SO_2 pc	–0.20	0.41*	0.12	0.05	–0.04	1

Note: * Denotes statistical significance at 5% level.

Zhuhai, Shenzhen, and Guangzhou in Guangdong province; Xiamen in Fujian province; and Ningbo and Hangzhou in Zhejiang province. In terms of the per capita GDP growth, some inland cities have higher rates than the eastern cities, possibly thanks to the recent Western Development Programme. However, the gap between east and west remains considerable.[2]

The geographical distribution of FDI is also unbalanced. In terms of the total amount of FDI inflows, Shanghai, Qingdao, Shenzhen, and Beijing are the four largest recipients of foreign capital, accounting for more than 28 per cent of FDI inflows to China in 2004. Among cities with total FDI inflows above $1 billion, only Wuhan, the capital of Hubei province, is located in central China; others are all eastern cities. Similarly, among cities with a share of FDI over GDP above 5 per cent, the majority are located in eastern regions, except Wuhan (the capital of Hubei) and Nanchang (the capital of Jiangxi province).

Table 5.2 provides Spearman rank correlations between the variables in Table 5.1. A number of initial observations can be made. Firstly, it is clear that those cities with the highest GDP per capita are also those that receive the greatest volume of FDI. Secondly, it can be seen that the largest cities, in terms of population, also tend to receive higher levels of FDI. Finally, sulphur dioxide emissions per capita are clearly correlated with GDP per capita.

5.3 Environmental quality in Chinese cities

To monitor environmental quality, by 2004 China had established 2,389 environmental monitoring stations, including 1 general station, 41 provincial central stations, 401 prefecture-level stations, 1,914 county-level stations, and 32 nuclear monitoring stations. The environmental monitoring stations are responsible for monitoring conditions in water, air, ecology, aquatic bios, soil, noise, sea, and radiation. In this chapter we focus on water and air quality.

5.3.1 Water pollution

Table 5.3 provides general information about the quality of drinking water, and the quality and level of groundwater in cities in recent years. The proportion of cities reaching the drinking water quality standard of 80 per cent or above has decreased from 83 per cent (55 per cent + 28 per cent) in 2002 to 70 per cent (53 per cent + 17 per cent) in 2004, while the proportion in the less than 60 per cent group increased from 2 per cent to 23 per cent, illustrating the deterioration of drinking water quality. Turning to the level of groundwater, falling groundwater levels no longer appear to as much of a problem in 2004 compared to 2001. However, in more than half the monitored cities groundwater quality worsened over this period. SEPA reported that groundwater quality was mainly affected by human activity. The major pollutants in groundwater are nitrate, nitrite, nitrogen-ammonia, and chloride.

As discussed in Chapter 3, domestic sewage is the major source of water pollution. SEPA reported that industrial sectors discharged

Table 5.3 Drinking water quality, groundwater level and quality in cities

Rate of reaching drinking water quality standard					
	100%	**99.9% ~ 80%**	**79.9% ~ 60%**	**59.9% ~ 0**	**Total**
2002	26 (55%)	13 (28%)	7 (15%)	1 (2%)	47
2003	22 (47%)	9 (19%)	8 (17%)	8 (17%)	47
2004	25 (53%)	8 (17%)	3 (6%)	11 (23%)	47
Groundwater level					
	Rise	**Stable**	**Drop**		**Total**
2001	63 (34%)	8 (4%)	115 (62%)		186
2002	75 (34%)	34 (16%)	109 (50%)		218
2003	61 (31%)	73 (38%)	60 (31%)		194
2004	53 (28%)	78 (41%)	61 (32%)		192
Groundwater quality					
	Improvement	**Stable**	**Worsen**		**Total**
2004	39 (21%)	52 (28%)	96 (51%)		187

Note: # of cities reported in the table; and percentage in brackets.
Source: China Environment Yearbook (2002–2005).

44.9 per cent of the total wastewater in 2004, and their share of pollutants were, for example, COD and nitrogen-ammonia at 35.8 per cent and 32.7 per cent respectively.

5.3.2 Air pollution

Monitoring stations observe concentrations of SO_2, NO_2, and PM_{10} every day in a number of key cities. Tables 5.4–5.7 present the 20 the most polluted and the 20 the cleanest cities, according to annual average concentrations of SO_2, NO_2, PM_{10}, and the air pollution comprehensive index of 2004.[3] In terms of SO_2 and PM_{10}, the most polluted cities are mostly located in northern and central regions, for example, Linfen, Yangquan, Datong, Changzhi, and Taiyuan in Shanxi province; Jiaozuo, Kaifeng, Anyang, Luoyang, Sanmenxia, and Pingdingshan in Henan province; Chifeng and Baotou in Inner Mongolia; Zhuzhou and Xiangtan in Hunan province; and Yibin, Panzhihua, and Zigong in Sichuan province. The major industry sectors in these cities are mining and washing of coal, mining and processing of ores, processing of coke,

Table 5.4 Annual average SO_2 concentration in some cities in China, 2004

The most polluted cities	SO_2 concentration (mg/m^3)	The cleanest cities	SO_2 concentration (mg/m^3)
Yangquan	0.231	Lasa	0.003
Linfen	0.224	Beihai	0.005
Jinchang	0.198	Haikou	0.007
Yibin	0.155	Karamay	0.007
Datong	0.149	Fuzhou	0.010
Zunyi	0.135	Zhanjiang	0.012
Sanmenxia	0.132	Changchun	0.013
Jiaozuo	0.127	Hefei	0.013
Zhuzhou	0.123	Wuhu	0.017
Handan	0.121	Qiqiharr	0.019
Yichang	0.120	Maanshan	0.019
Chongqing	0.113	Shenzhen	0.023
Liuzhou	0.109	Zhuhai	0.024
Urumuchi	0.102	Changzhou	0.024
Chifeng	0.099	Xining	0.024
Anyang	0.094	Rizhao	0.024
Guiyang	0.094	Quanzhou	0.025
Changzhi	0.093	Xiamen	0.025
Luoyang	0.093	Huzhou	0.026
Shizuishan	0.090	Mudanjiang	0.027

Source: China Environment Yearbook (2005).

Table 5.5 Annual average NO_2 concentration in some cities in China, 2004

The most polluted cities	NO_2 concentration (mg/m^3)	The cleanest cities	NO_2 concentration (mg/m^3)
Guangzhou	0.073	Beihai	0.007
Shenzhen	0.072	Yuxi	0.011
Beijing	0.071	Zhanjiang	0.012
Chongqing	0.067	Haikou	0.013
Shanghai	0.062	Hefei	0.017
Wenzhou	0.062	Quanzhou	0.018
Ningbo	0.060	Lasa	0.020
Harbin	0.060	Jinchang	0.020
Urumuchi	0.058	Lianyungang	0.020
Jiaozhuo	0.056	Taiyuan	0.022
Changzhi	0.056	Qinhuangdao	0.023
Yangquan	0.055	Qujing	0.023
Linfen	0.055	Deyang	0.023
Nanjing	0.055	Changde	0.023
Hangzhou	0.055	Guiyang	0.024
Huzhou	0.054	Zhangjiajie	0.024
Wuhan	0.054	Maanshan	0.024
Tianjin	0.052	Qingdao	0.024
Suzhou	0.051	Mianyang	0.025
Datong	0.050	Luzhou	0.025

Source: China Environment Yearbook (2005).

and smelting of ferrous and non-ferrous metals, and so on. These cities are mostly reported in Table 5.7 because their SO_2 and PM_{10} pollutions contribute greatly to the comprehensive index. However, in terms of NO_2, some eastern cities enter the most polluted group, such as Beijing, Guangzhou, Shenzhen, Shanghai, Wenzhou, and Ningbo. However, the overall level of NO_2 pollution is lower than SO_2 and PM_{10} and therefore does not significantly affect the comprehensive index.

Table 5.7 shows the cleanest cities in China are generally coastal cities, for example Beihai, Haikou, Rizhao, Zhanjiang, Zhuhai, Xiamen, Fuzhou, Shantou, and Lianyungang; or those inland cities without heavy polluting industries such as Lasa, Guilin, Yuxi, Qiqiharr, and Karamay.

To put these air quality levels in context, in the EU air quality standards are set at 0.125 mg/m^3 for SO_2, 0.04 mg/m^3 for NO_2, and 0.04 mg/m^3 for PM_{10}. Similarly, the US Environmental Protection Agency sets its national ambient air quality standards at 0.078 mg/m^3 for SO_2, 0.1 mg/m^3 for NO_2, and 0.15 mg/m^3 for PM_{10}.[4] As can be seen, these standards are being exceeded by quite a margin in China's dirtiest cities. Although

Table 5.6 Annual average PM_{10} concentration in some cities in China, 2004

The most polluted cities	**PM_{10} concentration (mg/m^3)**	**The cleanest cities**	**PM_{10} concentration (mg/m^3)**
Panzhihua	0.256	Haikou	0.033
Linfen	0.219	Beihai	0.043
Kaifeng	0.198	Guilin	0.046
Baotou	0.186	Zhuhai	0.046
Datong	0.180	Zhanjiang	0.050
Weinan	0.175	Lasa	0.052
Taiyuan	0.175	Rizhao	0.058
Pingdingshan	0.174	Karamay	0.059
Changzhi	0.173	Shantou	0.059
Lanzhou	0.172	Xiamen	0.063
Zhuzhou	0.171	Wenzhou	0.068
Luoyang	0.165	Yantai	0.068
Yangquan	0.162	Shaoxing	0.072
Fushun	0.162	Fuzhou	0.074
Xuzhou	0.158	Mianyang	0.075
Xiangtan	0.153	Shenzhen	0.076
Zigong	0.151	Qinhuangdao	0.076
Tongchuan	0.151	Nanning	0.078
Beijing	0.149	Ningbo	0.079
Jinan	0.149	Huhhot	0.080

Source: China Environment Yearbook (2005).

air quality in China's cleanest cities is within US and EU air quality guidelines for SO_2 and NO_2, it is notable that even in these cleanest cities the EU PM_{10} standard is being exceeded.

It is also worth noting that such indices reflect the ambient concentrations of pollutants in *urban* areas of a city, but cannot reflect the total industrial pollution emissions of the city as an administrative unit.

SEPA also reported that 132 of 342 monitored cities (38.6 per cent of total) arrived at the national ambient air quality standard II (living standard), 141 (41.2 per cent) at standard III, and 69 (20.2 per cent) lower than standard III. Additionally, air quality in large cities is worse than that in middle and small cities. 66.1 per cent of citizens were living in cities where the air quality was under standard II.

Industrial waste gas is the major source of serious air pollution. For instance, in 2004, industrial SO_2 and soot accounted for 86.7 per cent and 81.4 per cent of total emissions in cities.

Acid rain is another serious problem. Cities in south China suffer the most from serious acid rain due to geographical conditions and

Table 5.7 Air pollution comprehensive index in some cities in China, 2004

The most polluted cities	Index	The cleanest cities	Index
Linfen	6.61	Beihai	0.60
Yangquan	6.16	Haikou	0.61
Datong	4.91	Zhanjiang	0.85
Jinchang	4.61	Karamay	1.03
Yibin	4.49	Zhuhai	1.29
Zhuzhou	4.20	Rizhao	1.31
Chongqing	4.14	Guilin	1.38
Jiaozuo	4.13	Fuzhou	1.42
Changzhi	3.98	Quanzhou	1.45
Panzhihua	3.91	Changchun	1.50
Yichang	3.88	Xiameng	1.52
Sanmenxia	3.85	Yuxi	1.52
Kaifeng	3.81	Hefei	1.53
Zunyi	3.73	Wuhu	1.54
Luoyang	3.66	Maanshan	1.55
Baotou	3.65	Qiqiharr	1.61
Weinan	3.64	Shantou	1.63
Anyang	3.61	Lasa	1.64
Urumuchi	3.56	Lianyungang	1.90
Pingdingshan	3.51	Changzhou	1.92

Source: China Environment Yearbook (2005).

climate, mixed with increased air pollution emissions. Some northern cities in Liaoning, Hebei, and Shaanxi provinces also suffer from acid rain. Table 5.8 compares the frequency and the pH value of city acid rain in recent years. We find that the proportion of cities without acid rain went from from 49.7 per cent in 2002 to 43.5 per cent in 2004, which means the number of cities suffering from acid rain increased. The proportion of cities with a more than 40 per cent frequency of acid rain also increased, from 24.0 per cent to 30.1 per cent. Of those cities suffering acid rain, the proportion with a rainwater pH value of less than 5.6 increased from 36.9 per cent in 2001 to 41.4 per cent in 2004.

Although to some extent a geographic imbalance exists in the distribution of income and FDI among Chinese regions, we do not find a consistent geographic imbalance for all pollutants. For example, the regional concentration of the most polluted cities for SO_2 is different from that for NO_2. Therefore, we infer that the relationship between income and the environment, as well as FDI and the environment, might depend on the pollutants chosen.

Table 5.8 City acid rain pH value and frequency

Frequency of acid rain							
	0	**0 ~ 20**	**20 ~ 40**	**40 ~ 60**	**60 ~ 80**	**80 ~ 100**	**Sub total > 40**
2001	41.2	23.7	10.9	8.0	9.1	6.9	24.0
2002	49.7	18.6	10.5	5.8	7.7	7.7	21.2
2003	45.6	18.7	7.4	6.8	11.1	10.5	28.4
2004	43.5	18.2	8.2	8.5	9.5	12.1	30.1
Average pH value of acid rain							
	≤ 4.5	**4.5 ~ 5.0**	**5.0 ~ 5.6**	**5.6 ~ 7.0**	**> 7.0**	**Sub total < 5.6**	
2001	3.3	18.3	15.3	63.1	–	36.9	
2002	6.0	12.4	14.2	50.5	16.9	32.6	
2003	8.8	15.6	12.9	48.9	13.8	37.3	
2004	10.8	17.5	13.1	44.2	14.4	41.4	

Note: Proportion of cities reported in the table.
Source: China Environment Yearbook (2002–2005).

5.3.3 Industrial water and air pollutants

For industrial water pollution, we examine discharges of total wastewater and specific water pollutants, including chemical oxygen demand (COD), hexavalent chromium compounds (CrVI), and petroleum-like matter. For industrial air pollution, we observe the emissions of total waste gas, and specific air pollutants, including sulphur dioxide (SO_2), soot and dust.

Wastewater refers to all the industrial wastewater discharged out of industrial factories, including wastewater from production processes, direct cooling water, mine groundwater in excess of the discharge standard, and domestic sewage mixed within industrial wastewater (indirect cooling water not included).

Figure 5.1 shows the sectoral distribution of wastewater discharges in 2004 for 70,462 investigated firms in China. The heavy wastewater polluting sectors are located in chemical products, paper products, electric and heat power supply, smelting and pressing of ferrous metals, and textiles. Within the electric and heat power supply sector, coal-fired power stations are the major source of wastewater.

The specific pollutants in wastewater refer to the net weight of the pollutants, which is equal to the average concentration of the pollutants multiplied by the total weight of wastewater in the reported period. The COD test is commonly used to indirectly measure the amount of organic compounds in water. It is a useful wastewater quality indicator.

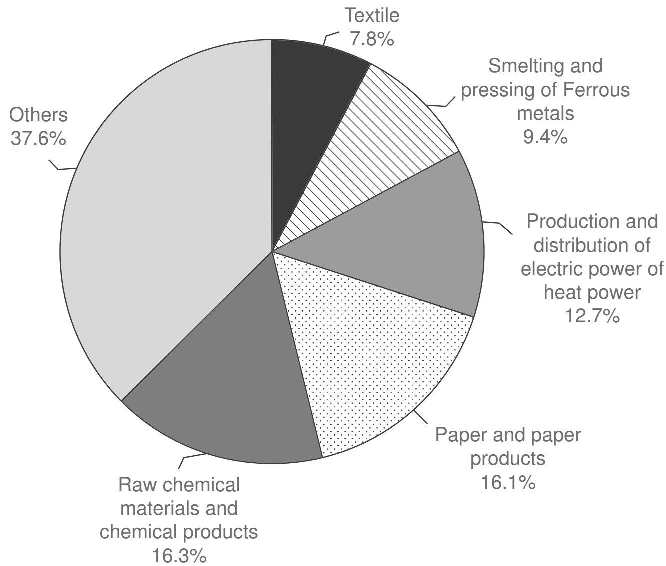

Figure 5.1 Industrial wastewater discharge by sectors in China, 2004
Source: China Environment Yearbook (2005).

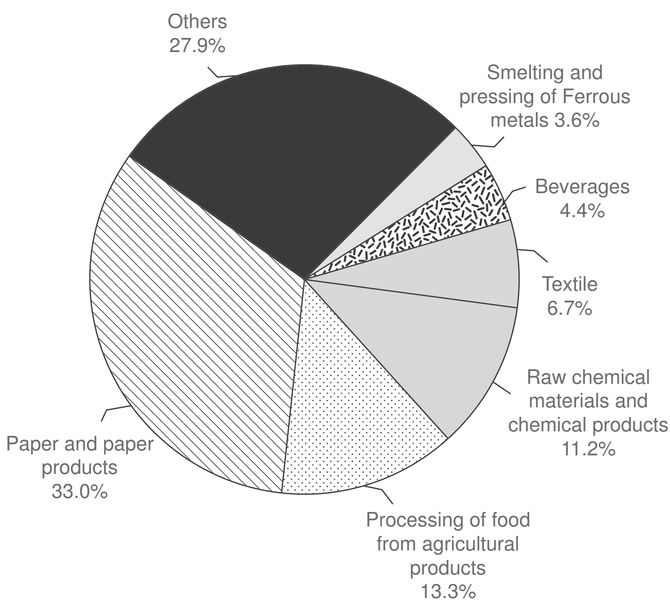

Figure 5.2 Industrial COD discharge by sectors in China, 2004
Source: China EnvironmentYearbook (2005).

The COD test determines whether or not wastewater will have a significant adverse effect upon fish or aquatic plant life. Figure 5.2 illustrates that COD is high in the wastewater discharged from the factories that produce paper, food, chemicals, and textiles.

The second specific pollutant is CrVI compounds, which are toxic if ingested or inhaled. CrVI is an established human carcinogen. Chronic exposure to CrVI compounds may cause permanent eye injury and can increase the risk of lung cancer. CrVI compounds are widely used as pigments for photography, and in pyrotechnics, dyes, paints, inks and plastics. They can also be used for stainless steel production, textile dyes, wood preservation, leather tanning, and as anti-corrosion and conversion coatings. Figure 5.3 shows the major sources of CrVI: smelting and pressing of non-ferrous metals, metal products, leather products, electronic equipment, smelting and pressing of ferrous metals and chemical products.

Petroleum-like matter refers to various kinds of hydrocarbon compounds. They float on the surface of the water and prevent gas exchange, leading to the deterioration of water quality. They can cause the death of fish and aquatic plants and therefore affect the life of aquatic birds, and they have a negative effect on the aquatic products

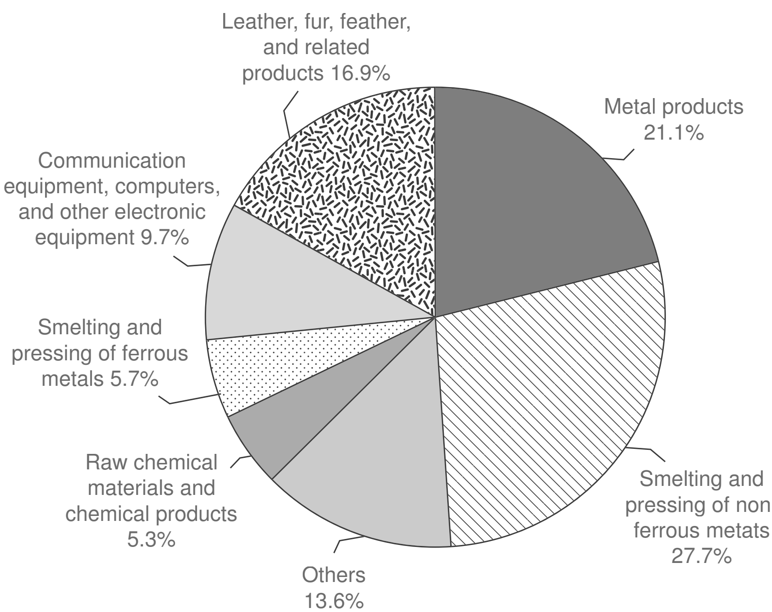

Figure 5.3 Industrial CrVI discharge by sectors in China, 2004
Source: China Environment Yearbook (2005).

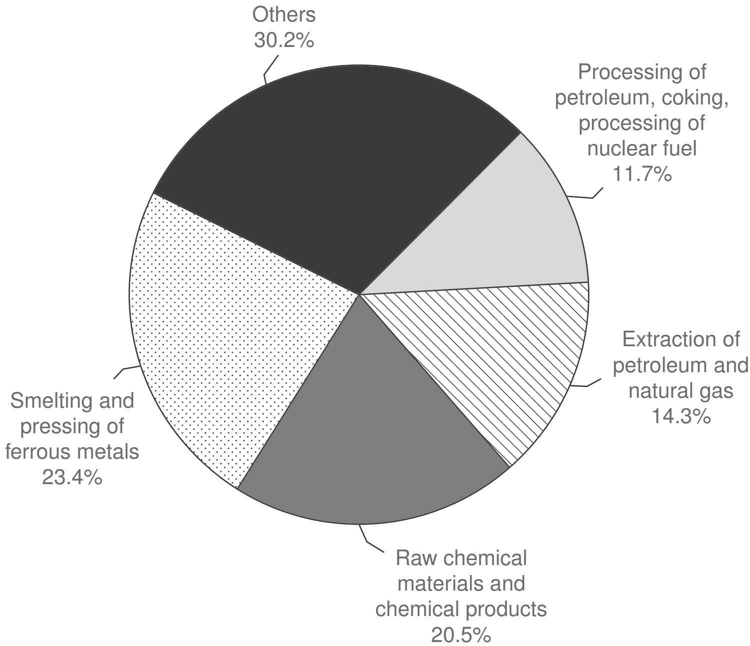

Figure 5.4 Industrial petroleum-like matter discharge by sectors in China, 2004
Source: China Environment Yearbook (2005).

industry. Figure 5.4 shows that about 70 per cent of petroleum-like matter comes from four sectors, smelting and pressing of ferrous metals, chemical products, extraction of petroleum and the processing of petroleum.

Industrial waste gas is the main source of air pollution. This refers to the volume of total emitted gas comprising pollutants caused through fuel combustion and industrial production processes such as smelting and processing of metals, chemical materials production, and paper production. The volume of waste gas is worked out under the standard conditions for temperature and pressure, that is 273 K (0°C) and 101.325 kPa (1 atmosphere of absolute pressure). Figure 5.5 shows that the most waste gas, pollution intensive industrial sectors are the production and distribution of electric power and heat, non-metallic mineral products, and the smelting and processing of ferrous metals. It is noticeable that within the power supply and non-metallic mineral products sectors, coal-fired power stations and cement manufacture

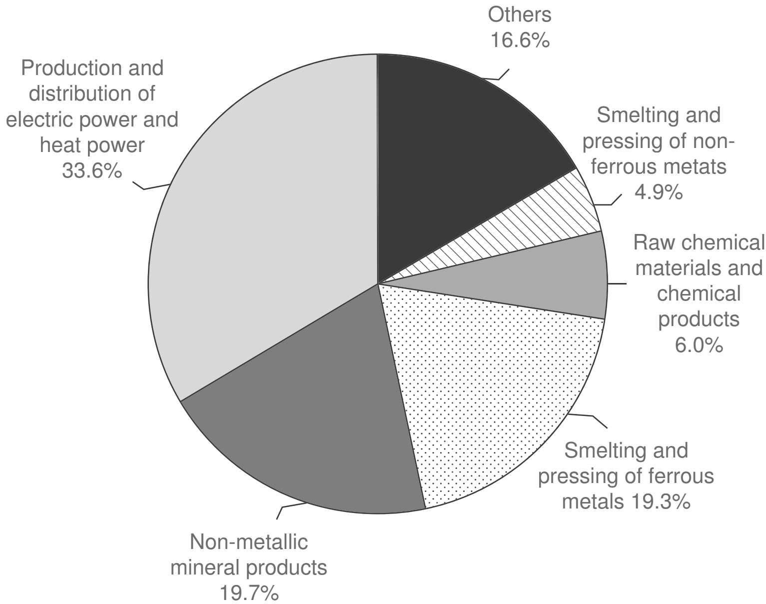

Figure 5.5 Industrial waste gas emissions by sectors in China, 2004
Source: China Environment Yearbook (2005).

respectively contribute 91 per cent and 81 per cent of the waste gas emissions in their sector.

Sulphur dioxide referd to the weight of SO_2 generated through fuel combustion, especially the burning of coal and oil, and production processes like smelting of non-ferrous ores. According to annual reports from SEPA, in recent years 85 per cent of SO_2 has come from fuel combustion, and 15 per cent from industrial processes. China's SO_2 emissions have been the highest in the world, and half of them are attributed to the burning of coal. Previous research has often used sulphur dioxide as an important indicator of air pollution. Excess SO_2 emissions will cause severe damage to human health, especially to the respiratory system, and can also result in acid rain. Figure 5.6 illustrates that the majority of industrial SO_2 emissions (57 per cent) are from the production and distribution of electric power and heat. SEPA also reported that of the emissions of SO_2 from power generation and distribution, 93.4 per cent are emitted from coal-fired power stations. Other sources of SO_2 emissions include manufacture of non-metallic

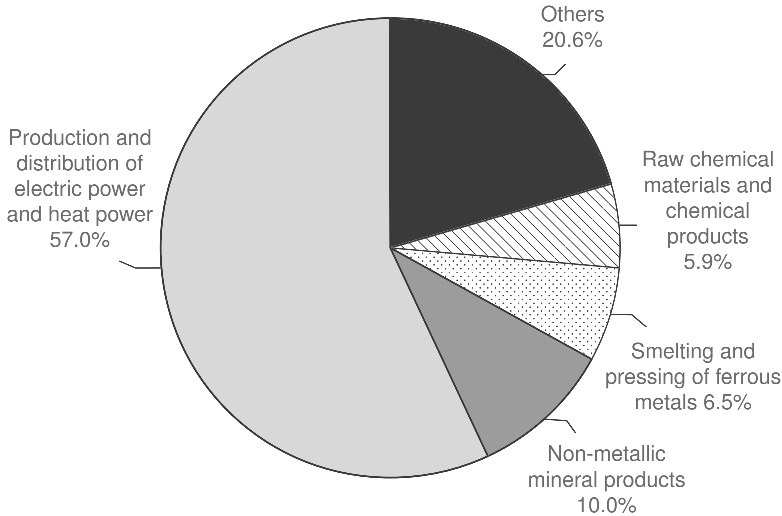

Figure 5.6 Industrial SO_2 emissions by sectors in China, 2004
Source: China Environment Yearbook (2005).

mineral products, smelting and processing of ferrous metals, and chemical products.

The level of SO_2 pollution in China is recorded in two ways: ambient concentration (ug/m^3) and mass emissions (tons). SO_2 ambient concentration, as mentioned in Table 5.3, is widely used as an air quality indicator. However, it combines all emissions of SO_2 from industrial, domestic and natural resources, and can be influenced significantly by climatic factors such as wind force and direction. Data on sulphur dioxide emissions are directly collected from factories and estimated by SEPA. Local SEPA bureaus calculate mass emissions from factories by combining factory self-reported data on fuel consumption and industrial processes and periodic boiler stack testing data. Although the mass emission data is as robust as ambient data, it is more accurate for estimating industrial pollution (Liang, 2006).

Industrial soot and dust are two kinds of suspended particulate matter. Soot refers to the weight of suspended particulates in the smoke from fuel combustion, especially that component of smoke caused by the incomplete burning of carbon-rich organic fuels; while dust comes from industrial production processes, for example, refractory dust from iron and steel firms, screen dust from coking firms, sintering machine dust,

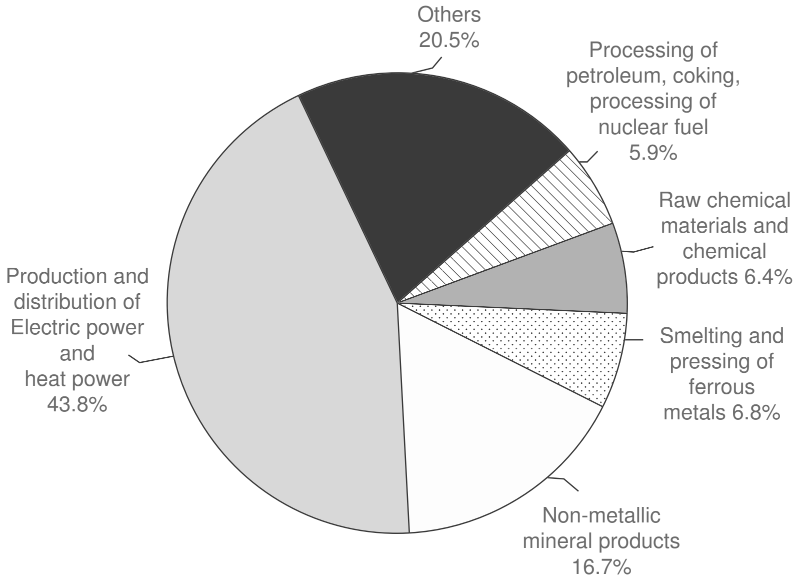

Figure 5.7 Industrial soot emissions by sectors in China, 2004
Source: China Environment Yearbook (2005).

lime kiln dust, and cement dust from construction materials.[5] Dust emissions are calculated using the following equation:

Industrial dust emissions = Volume of gas from dust exhaust system × Average dust concentration of gas at the discharge point of the precipitator × Uptime of dust exhaust system

A similar equation applies to soot.

These two types of suspended particulates are considered equally dangerous owing to both their particulate size and the chemical compounds present. They can stain clothing and can cause illness if inhaled. They are hazardous to the lungs and general health when the particles are less than 5 micrometres in diameter, since such particles are not filtered out by the upper respiratory tract.

Similar to SO_2 emissions, the major sources of industrial soot pollution are the electric and heat supply sector, non-metallic mineral products, smelting and processing of ferrous metals, chemical products, and processing and coking of fuels (Figure 5.7).

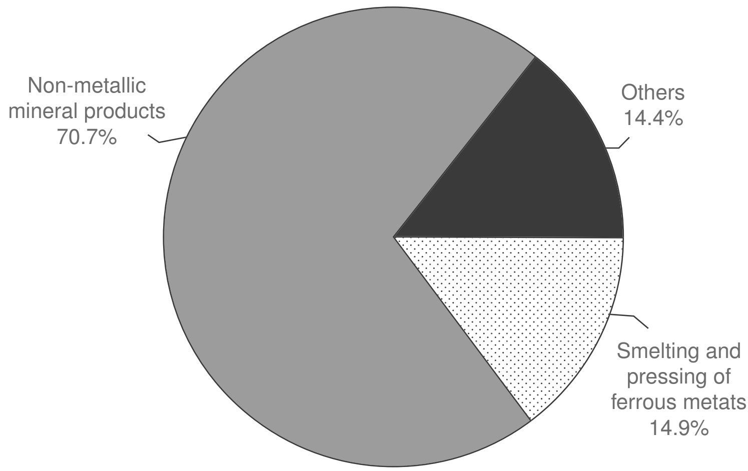

Figure 5.8 Industrial dust emissions by sectors in China, 2004
Source: China Environment Yearbook (2005).

In terms of dust, the non-metallic mineral products sector accounts for more than 70 per cent of total emissions. Smelting and processing of ferrous metals is also a major source of dust (Figure 5.8).

The China Environment Yearbook has reported several other pollutants in wastewater, including lead, arsenic, nitrogen-ammonia, and volatile phenol, among others. These pollutants are not considered in this study because a number of cities did not report these data. Therefore, in this chapter, we focus on the total volumes of industrial wastewater and waste gas, plus the emissions of three specific water pollutants and three specific air pollutants.

5.4 Methodology

In this chapter, we employ data from a panel of 112 main cities in China to estimate the relationship between income and eight environmental indicators. Then we examine the differences in environmental impact between domestic and foreign firms. We split foreign firms into two groups, those funded from Hong Kong, Taiwan and Macao (HTM), and those funded by other foreign economies.

In this section, we firstly introduce our model specifications and then describe our data and discuss the methodology issues.

5.4.1 Model specifications

In the light of previous literature on economic growth and the environment we start by estimating the following reduced-form equation for the emission of industrial pollutants:

$$Epc_{it} = \alpha + \gamma_i + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 Y_{it}^3 + \beta_4 (GIP / GDP_{it}) + \varepsilon_{it} \quad (5.1)$$

where *Epc* denotes per capita emissions, γ is city-specific intercepts, θ is time-specific intercepts, *Y* represents per capita income, *GIP/GDP* refers to the gross industrial product (GIP) normalized by city GDP, and ε is the error term. Subscripts *i* and *t* represent city and year, respectively.

Equation 5.1 is estimated for a mixture of the abovementioned eight industrial water and air pollution indicators (wastewater, COD, CrVI, petroluem, waste gas, SO_2, soot and dust) over the period 2001–2004 for a sample of 112 major cities in China (See Appendix 5.1 for data definitions and sources, and Appendix 5.2 for the cities selected for the sample).

Per capita income indicates the direct scale and technique effects of economic growth. Some studies use GDP per km^2 to measure scale effects and per capita GDP to capture technique effects. 'However, this is only appropriate when estimating *concentrations* of pollution. [In this chapter] pollution data are in the form of…emissions per capita and hence there seems no obvious way to separate scale and technique effects.' (Cole, 2003)

The share of industrial output in GDP is used to capture the extent to which structural change within the economy has affected pollution, i.e. the composition effects of growth. The year specific effects are included to pick up any effects that are common to all cities but which change over time; and the city specific effects pick up the effects specific to each city which do not change over time.

Our aim is to separate the impact of foreign owned firms on pollution from that of domestically owned firms. We therefore require a variable that captures the scale of activity of such firms within each city. While direct measures of FDI inflows are not available, we are able to decompose GIP into three components, each measured at city-level: industrial output for domestic firms (GIPd), the industrial output for firms from Hong Kong, Taiwan and Macao (GIPh) (that is Chinese-sourced firms), and the industrial output for firms funded by foreign countries (GIPf) (that is non-Chinese sourced firms). Thus Equation 5.1 becomes:

$$\begin{aligned} Epc_{it} = {} & \alpha + \gamma_i + \beta_1 Y_{it} + \beta_2 Y_{it}^2 + \beta_3 Y_{it}^3 + \beta_4 (GIPd / GDP_{it}) \\ & + \beta_5 (GIPh / GDP_{it}) + \beta_4 (GIPf / GDP_{it}) + \varepsilon_{it} \end{aligned} \quad (5.2)$$

In practice, we include per capita income (*Y*), and then add its quadratic term (*Y*2) and finally the cubic term (*Y*3). If a linear regression is considered, we expect a positive relationship between income and pollution at current economic development levels in China. If a quadratic function is estimated, we expect a standard EKC relationship (inverted-U) between income and pollution, that is $\beta_1 > 0$ and $\beta_2 < 0$. Following Grossman and Krueger (1995), we expect negative β_1 and β_3 and a positive β_2 in the cubic functions.

We expect that the greater the industrial output, the higher the industrial pollution emissions, which means a positive coefficient on GIP/GDP in Equation 5.1. Given the previous evidence that domestic firms in developing economies may be more pollution intensive than foreign owned firms (Eskeland and Harrison, 2003; Cole *et al*., 2008), we expect a positive sign on GIPd/GDP in Equation 5.2.

Previous literature suggests that the net effect of foreign investment may be positive and negative. Therefore, the signs for GIPh/GDP and GIPf/GDP are ambiguous. Furthermore, the signs may also depend on which sectors foreign capital has concentrated. It is not possible to get data on either foreign industrial output or FDI inflows/stocks by sector; however, the China Industrial Economy Statistical Yearbook presents paid-in capital by industrial sector in detail, which can be seen in Table 5.9 sorted by the share of domestic paid-in capital. Chinese-sourced capital is relatively high in sectors such as leather, fur, feather and related products; textile wearing apparel, footwear and caps; articles for cultural, education and sport activity; furniture; plastics; metal products; textiles; chemical fibres; and printing, reproduction of recording media. Non-Chinese-sourced capital is high in various kinds of machinery and equipment; foods; metal products; rubber; paper and paper products; beverages; processing of food from agricultural products; medicines; and raw chemicals and chemical products. Since the pollution intensity of these sectors varies according to pollution indicators, the environmental effect of Chinese-sourced and non-Chinese sourced firms may differ and depends on the pollution emissions estimated.

Dean *et al*. (2005) suppose that FDI from Chinese sources enters China for the purpose of producing for export and is expected to be concentrated in relatively unskilled, labour-intensive industries; while FDI from non-Chinese sources produces for the internal Chinese market and is expected to be concentrated in relatively more skilled, labour-intensive industries. They find Chinese-sourced FDI is significantly attracted by low environmental levies, but non-Chinese-sourced FDI is not. These findings offer indirect evidence that non-Chinese firms use cleaner technology. This conclusion is supported by a survey from Brandt and Zhu (2005) that during 1983–1992, of the cumulative value of technology import contracts between foreign and Shanghai firms, 23.9 per cent was from Japan, 20.5 per cent from Germany and 15.4 per cent from the United States. Also, as reported by the firms, the origin of imported equipment is mainly from these three technologically advanced countries.

Since the pollution intensity of these sectors varies according to the pollutant, the environmental effects of Chinese-sourced and

Table 5.9 Paid-in capital of industrial sectors in China, 2003

Sector	Domestic (%)	HTM (%)	Foreign (%)	Total capital
Leather, Fur, Feather and Related Products	4.86	60.91	34.23	21.05
Recycling and Disposal of Waste	6.11	8.78	85.11	0.26
Textile Wearing Apparel, Footware, and Caps	6.83	52.58	40.59	32.74
Articles for Culture, Education, and Sport Activity	7.90	62.98	29.13	17.17
Artwork and Other Manufacturing	8.67	53.58	37.75	13.86
Furniture	12.26	53.40	34.34	10.39
Plastics	12.89	49.86	37.24	52.97
Communication Equipment, Computers, and Other Electronic Equipment	17.01	24.62	58.38	190.26
Foods	19.54	25.06	55.40	38.50
Metal Products	19.71	38.83	41.46	44.47
Electrical Machinery and Equipment	22.44	24.99	52.58	85.03
Measuring Instruments and Machinery for Cultural Activity and Office Work	25.41	29.34	45.25	26.47
Rubber	26.37	18.39	55.24	21.80
Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products	31.03	34.11	34.86	13.12
Textile	32.06	40.44	27.50	87.47
Paper and Paper Products	33.34	21.80	44.86	46.62
Beverages	35.73	23.51	40.76	53.87
Chemical Fibers	41.12	34.50	24.38	23.63
Processing of Food from Agricultural Products	41.57	18.82	39.61	43.42
General Purpose Machinery	43.71	11.33	44.96	76.90
Printing, Reproduction of Recording Media	48.03	35.93	16.04	25.06

Table 5.9 Continued

Sector	Domestic (%)	HTM (%)	Foreign (%)	Total capital
Non-metallic Mineral Products	48.34	21.80	29.85	90.28
Medicines	49.99	13.28	36.74	44.74
Raw Chemical Materials and Chemical Products	54.57	12.93	32.50	146.88
Transport Equipment	57.62	9.64	32.74	149.45
Special Purpose Machinery	62.91	13.94	23.15	52.51
Smelting and Pressing of Non-ferrous Metals	77.67	9.55	12.78	53.96
Processing of Petroleum, Coking, Processing of Nuclear Fuel	81.17	9.07	9.76	47.86
Production and Distribution of Electric Power and Heat Power	87.00	5.66	7.35	330.13
Production and Distribution of Gas	88.06	3.38	8.56	22.34
Smelting and Pressing of Ferrous Metals	88.54	5.64	5.81	165.08
Extraction of Petroleum and Natural Gas	90.64	8.96	0.41	81.39
Mining and Processing of Nonmetal Ores	93.18	3.01	3.82	12.74
Production and Distribution of Water	96.23	1.25	2.52	60.10
Mining & Processing of Non-Ferrous Metal Ores	97.06	1.71	1.24	7.68
Mining and Processing of Ferrous Metal Ores	98.90	0.74	0.36	11.38
Mining of Other Ores	99.11	0.89	0.00	0.56
Tobacco	99.18	0.42	0.39	34.34
Mining and Washing of Coal	99.70	0.09	0.21	126.14

Note: HTM indicates the paid-in capital from Hong Kong, Taiwan and Macao. Total capital is in billion yuan.*Source:* China Industry Economy Statistical Yearbook (2004).

non-Chinese sourced firms are likely to differ by pollutant. However, any link found between foreign or HTM capital and a city's emissions may simply reflect the fact that different investors tend to concentrate in sectors of differing emission intensities. For instance, if foreign investors typically invest in industries which are inherently less emissions intensive than average then we would expect to find a negative relationship between emissions and the share of output in a city invested in by foreign-owned firms. Nonetheless, this does not mean that foreign owned firms are inherently cleaner than Chinese owned firms within the same industry, but simply reflects the nature of the industries that foreign owned firms invest in. One way to overcome this problem would be to include variables measuring each industry's share of total output within each city as determinants of that city's emissions. Unfortunately, industry level measures of output have proved to be unattainable at city-level.[6] We therefore accept that our results may be capturing the impact on emissions of the compositional pattern of FDI as much as (or more than) whether foreign firms are cleaner than domestic firms.

For these reasons, we assume firms funded by foreign countries are the cleanest and domestic firms the dirtiest. Additionally, if the signs of GIPh/GDP and GIPf/GDP are both positive, we expect that GIPd/GDP will have the largest effect on pollution emissions, followed by GIPh/GDP and GIPf/GDP.

In sum, the estimated results may differ by pollutant. Table 5.10 shows the expected signs of all the explanatory variables in Equations 5.1 and 5.2.

Table 5.10 Expected signs for the estimated coefficient in equations 5.1 and 5.2

Explanatory variables	**Signs**
Y: per capita GDP	$+^a, +^b, -^c$
Y^2: (per capita GDP)^2	$-^b, +^c$
Y^3: (per capita GDP)^3	$-^c$
GIP/ GDP	+
GIPd/GDP: GIP/GDP for domestic firms	+
GIPh/GDP: GIP/GDP for firms invested by Hong Kong and so on.	−/+
GIPf/GDP: GIP/GDP for firms invested by foreign courtiers	−/+

Note: a, b, and c indicate the linear function, quadratic function, and cubic function.

5.4.2 Data description

Pollution Emissions

Emissions data are collected from various years of the China Environment Yearbook (see Appendices 5.1 and 5.2) and are reported in terms of total emissions for a large selection of key enterprises in each city.[7]

The eight measurements of environmental quality are described in Section 5.3.3. We use the per capita emissions rather than concentrations. Previous evidence has illustrated that the relationship between income and pollution can vary depending on whether the pollutants are measured in terms of concentration or emissions.[8]

Cole and Elliott (2003) argue that concentrations and emissions data provide different information. City-level concentrations provide more information regarding the human health impact of a particular pollutant. In contrast, emissions provide more information on wider environmental issues and may have a weak relationship with concentrations. For instance, if the government plans to tackle the detrimental health impact from air pollution, they could execute a policy of heightening factory chimneys or encouraging firms to locate outside the city. These policies would reduce the city-level concentrations but would not reduce national emissions. Cole and Elliott (2003) also point out that concentrations data tend to be 'noisier' than emissions data and require the inclusion of some dummy variables to capture site specific effects, for example, variables to control for the nature of the observation site, measuring equipment, average temperature, and level of rainfall.

Comparing the advantages and disadvantages associated with concentrations and emissions data, and bearing in mind our aim of examining the impact of economic growth and foreign affiliates on industrial pollutions, we decided to use industrial pollution emissions data to represent environmental quality.

We chose pollution indicators following the criteria claimed in Antweiler *et al.* (2001) that useful pollutants should: 1) be a by-product of goods production; 2) be emitted in greater intensities by some industries than others; 3) have strong local effects; 4) be subject to regulations because of their adverse effects on the population; 5) have well-known abatement technologies; 6) have data available from a wide mix of countries.

As shown in Section 5.3.3, the selected eight pollution emissions are all generated from industrial production; are emitted in greater quantities in some industries than others; have strong local effects; are subject to regulations in different degrees; and have available data for a wide mix of cities in China.

The China Environment Yearbook reports industrial pollution emissions for a number of key enterprises investigated by local environmental protection bureaus. The number of selected enterprises and the proportion of enterprises vary across cities. Such data cannot provide the information of total industrial pollution emissions at city-level. Additionally, the data are not comparable. We had to convert available pollution emissions of selected enterprises to the emissions of all the enterprises in the city. In addition to pollution emissions and treatments, other data reported in the China Environment Yearbook only include a number of selected enterprises and their industrial output. The number of enterprises is not appropriate for converting to industrial pollution emissions because of the difference in firm sizes. In this case, we used industrial output to adjust the total industrial pollution emissions using the following equation:

$$E_{it} = \left[\sum_j e_{jt} \times \left(\frac{GIP_{it}}{\sum_j gip_{jt}} \right) \right] \quad (5.3)$$

where subscripts i, j and t denote cities, firms and years, respectively, e and gip are respectively the pollution emissions and gross industrial output from the investigated firms; and E and GIP are those for the city. Equation 5.3 implies that total industrial emissions are equal to the emissions of selected enterprises, divided by the share of the selected firm's output to the total industrial output in the city. We assumed that the emissions per unit of industrial product are the same within each city. Total emissions are then scaled by population to form per capita emissions. Although some limitations exist for this assumption, it is the only available method to arrive at the total industrial pollution emissions in a city.

Explanatory variables

Data for the explanatory variables are all collected from the China City Statistical Yearbook. All the values (per capita GDP, capital, and industrial output) are adjusted to 1990 prices using GDP deflator.

Tables 5.11 and 5.12 respectively provide the descriptive statistics for all variables and their correlations. The correlations matrix generally supports the sign expectations in Table 5.10.

Table 5.11 Descriptive statistics of variables

Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Medium**	**Max**
Wastewater (tons per person)	424	38.49	32.34	2.03	27.92	168.96
COD (tons per 10000 persons)	432	81.80	70.72	0.67	62.58	340.88
CrVI (kg per 10000 persons)	384	1.62	2.46	0.0021	0.50	13.83
Petroleum (tons per 1000000 persons)	424	46.33	51.17	0.026	25.46	236.16
Waste Gas (m^3 per person)	439	4.70	4.19	0.13	3.34	21.39
SO2 (tons per 10000 persons)	428	325.39	252.65	4.38	260.84	1,355.84
Soot (tons per 10000 persons)	436	138.54	103.47	0.74	107.83	693.93
Dust (tons per 10000 persons)	424	118.09	122.58	0.020	71.17	649.65
Y (1000 yuan)	428	8.55	6.37	1.94	6.56	48.04
GIP/GDP (100 yuan per yuan)	427	96.44	42.10	11.89	87.73	277.76
GIPd/GDP (100 yuan per yuan)	424	75.94	32.14	9.82	72.87	179.99
GIPh/GDP (100 yuan per yuan)	422	9.00	16.14	0	3.86	119.13
GIPf/GDP (100 yuan per yuan)	422	11.60	16.86	0	4.80	120.61

Note: extreme outliers have been removed for all dependent variable statistics; the descriptive statistics of the independent variables are those in the sample for SO_2 without extreme outliers.

Table 5.12 Correlations of the variables

	Waste-water	COD	CrVI	Petroleum	Waste gas	SO2	Soot	Dust	Y	Y2	Y3	GIP/GDP	GIPd/GDP	GIPh/GDP	GIPf/GDP
Y	0.470	0.111	0.430	0.226	0.551	0.537	0.128	–0.043	1.000						
Y2	0.377	0.076	0.390	0.155	0.502	0.469	0.088	–0.095	0.933	1.000					
Y3	0.288	0.049	0.341	0.098	0.451	0.379	0.060	–0.116	0.789	0.951	1.000				
GIP/GDP	0.531	0.222	0.421	0.295	0.622	0.645	0.196	0.123	0.679	0.577	0.439	1.000			
GIPd/GDP	0.406	0.188	0.203	0.322	0.561	0.515	0.301	0.329	0.309	0.265	0.234	0.721	1.000		
GIPh/GDP	0.249	0.147	0.409	–0.052	0.214	0.355	–0.056	–0.155	0.507	0.434	0.300	0.553	–0.081	1.000	
GIPf/GDP	0.248	0.032	0.268	0.177	0.271	0.291	–0.021	–0.139	0.630	0.527	0.367	0.598	–0.031	0.579	1.000

Note: extreme outliers are removed for the correlations between all dependent and independent variables; correlations between independent variables are those in the sample for SO_2 without extreme outliers.

5.4.3 Methodological issues

Equations 5.1 and 5.2 are estimated using two alternative functional forms in logs. However, Cole *et al.* (1997) argue that the quadratic logs function seems to provide a more realistic income–environment relationship than the quadratic levels function because of the symmetrical nature of the latter. The symmetry of quadratic levels function implies, first, that pollution levels will fall at the same rate as they increase and, second, that these pollution levels will become negative, probably in a short space of time. In contrast, a quadratic log function falls away gradually once it passes the turning point, because the curve asymptotically approaches zero. In addition, the distribution of the variables in both equations with positive skewness can be easily corrected by taking logs.[9]

The second problem faced when estimating the model is whether the unobserved individual-specific effects and time effects (γi and θt) should be treated as random variables or as parameters to be estimated for each cross-city observation *i* and time *t*. In this chapter we estimate both two-way fixed effects and random effects error component models. For our fixed effects models we initially used the within regression estimator, which is a pooled OLS estimator based on time-demeaned variables, or uses the time variation in both dependent and independent variables within each cross-sectional observation (Wooldridge, 2000). For our random effects models we chose the generalized least square (GLS) estimator, which produces a matrix-weighted average of the between and within estimator results.[10] We only report fixed effects results in this chapter. Random effects results were very similar to the fixed effects results.[11]

The next methodological issue concerns the exogeneity of per capita income, in response to the claim that the EKC may suffer from simultaneity bias due to causality moving from environmental degradation to income. A Davidson-MacKinnon test was employed to test the null of exogeneity of current income in fixed effects regressions for Equations 5.1 and 5.2. The number of telephone subscribers per head was used as an instrumental variable. The null hypothesis of exogeneity was not rejected in all cases, suggesting that simultaneity bias was not present. These are the Davidson-MacKinnon test results that we report in our results tables. In Tables 5.13–5.16, we therefore report results from models in which income is treated as exogenous. However, it is worth emphasizing the fact that even when we do instrument income using any of our alternative instruments, our results remain very similar to those in Tables 5.13– 5.16. Therefore, in sum, we are confident that our key findings are not being influenced by endogeneity between income and pollution.

Fourth, we tested for heteroskedasticity and autocorrelation. We employed a Breusch-Pagan test for heteroskedasticity. The results rejected the null hypothesis of homoskedasticity in all cases. We also estimated the following dynamic model for the residuals to test whether or not there was first-order autocorrelation.

$$\varepsilon_{it} = \rho\varepsilon_{it-1} + \upsilon_{it}, t = 2,.....,T$$

where $|\rho| < 1$ and υ_{it} ~ IID(0, σ_v^2).

The results show that the estimated $\hat{p}$'s are significant for a few cases, indicating that there is first-order autocorrelations within the panel.$\hat{p}$'s are not statistically different from zero in other regressions. Thus, heteroskedasticity and autocorrelation need to be corrected for if they are present.[12]

The next concern is the non-stationary process of the income and emissions data, which has been tested in some papers, such as Stern and Common (2001) and Cole (2003). However, all the samples in our dataset are extremely short, with only four observations for each city. Thus the stationary test is largely meaningless. It is impossible to take individual Augmented Dick-Fuller tests or panel unit root tests with only four time series observations.

Finally, according to current development levels in China, we expected that economic development would increase environmental pollution levels. We therefore expected most Chinese cities to be on the upsloping part of the curve. Therefore, we began with a simple linear model and then moved on to quadratic models. A cubic income term is also included in order to examine the possibility that pollution increase again at high income levels. However, every cubic relationship necessarily extended to plus or minus infinity, which was not realistic. In addition, the cubic term is generally not statistically significant at a 90 per cent confidence level. Although the cubic term was found to be significant for some pollutants, such as petroleum and SO_2, the turning point was not found (that is the curve increases monotonically). Therefore, only linear and quadratic equations were estimated.

In sum, linear and quadratic log specifications with random effects are reported on in this chapter.

5.5 Empirical results

We present our results in Tables 5.13–5.16. In each table, columns 1, 2, 7, and 8 provide linear and quadratic specifications of the simple relationship between income and emissions with no further controls. The quadratic specification (columns 2 and 8) provides a direct test of the environmental Kuznets curve (EKC) hypothesis. Columns 3, 4, 9, and 10 provide linear and quadratic specifications for Equation 5.1, while columns 5, 6, 11, and 12 provide the same for Equation 5.2.[13]

Wastewater

Table 5.13 starts the results with industrial wastewater and chemical oxygen demand. Columns 1–6 are the results for wastewater and columns 7–12 are those for COD. The Davidson-MacKinnon test results of exogeneity are provided, suggesting the exogeniety of current income. First order autocorrelation test (AR1) also suggests no such correlation within panels.

Column 1 for industrial wastewater shows a statistically significant and positive relationship between income and emissions of industrial wastewater. It confirms our expectation that economic growth induces more wastewater pollution at current income levels for all cities in China. The income elasticity is approximately 0.42, indicating that a 10 per cent increase in per capita income will increase per capita emissions of industrial water by 4.2 per cent. When a quadratic specification is considered, we find a statistically significant inverted-U shaped relationship between per capita income and per capita emissions. The estimated turning point is around RMB 35,098 at 1990 prices. Similarly, coefficients on per capita income are found in Columns 3–6. Therefore, for wastewater the quadratic models (columns 2, 4, and 6) provide evidence of an inverted-U EKC type relationship, with turning points between RMB 32,577 and RMB 35,098 (US $6,815 and US $7,342 at 1990 prices).[14] In our sample, only Karamay city passed this income level in 2003 and 2004, demonstrating that most Chinese cities are on the left side of the EKC curve, that is, economic growth has a positive effect on industrial wastewater pollution emissions. The estimated turning points from random effects are broadly similar to those in the fixed effects results.

Referring to the effects of industrial output, we find that it has a constant significant and positive impact on wastewater emissions in columns 3 and 4. Thus, structural changes within the economy are responsible for pollution levels. The structural changes from a traditional agricultural economy to the current dualistic economy (modern and traditional sectors) have increased pollution emissions. Further structural changes within the modern sectors (from manufacturing to service sectors), at higher income levels, may improve environmental quality.

Columns 5 and 6 decompose industrial output according to the ownership of enterprises. For wastewater, the industrial output of domestic

Table 5.13 Linear and quadratic log estimation results with fixed effects for industrial wastewater and COD

	Wastewater						COD					
Variables	**Column 1**	**Column 2**	**Column 3**	**Column 4**	**Column 5**	**Column 6**	**Column 7**	**Column 8**	**Column 9**	**Column 10**	**Column 11**	**Column 12**
Y	0.415	0.918	0.375	0.850	0.400	0.888	–0.418	0.525	–0.423	0.534	–0.285	0.469
	(2.65)***	(3.03)***	(2.42)**	(2.85)***	(2.22)**	(2.71)***	(1.13)	(0.70)	(1.16)	(0.72)	(0.82)	(0.67)
*Y*2		–0.129		–0.122		–0.126		–0.260		–0.264		–0.210
		(1.94)*		(1.86)*		(1.78)*		(1.43)		(1.48)		(1.22)
GIP/GDP			0.482	0.475					0.278	0.344		
			(3.50)***	(3.46)***					(0.85)	(1.07)		
GIPd/GDP					0.314	0.291					0.852	0.870
					(2.65)***	(2.44)**					(3.35)***	(3.45)***
GIPh/GDP					0.053	0.051					–0.016	–0.020
					(1.78)*	(1.70)*					(0.31)	(0.38)
GIPf/GDP					–0.012	–0.017					0.016	0.014
					(0.41)	(0.57)					(0.36)	(0.31)
Constant	2.553	2.115	0.520	0.138	1.266	0.945	–3.238	–3.134	–3.047	–2.896	3.907	4.121
	(9.38)***	(5.99)***	(0.82)	(0.21)	(2.16)**	(1.55)	(2.46)**	(2.34)**	(2.27)**	(2.12)**	(3.49)***	(3.66)***
R^2 (within)	0.068	0.079	0.103	0.113	0.101	0.111	0.098	0.106	0.101	0.109	0.088	0.096
AR(1)	None	None	None	None	None	None	Yes	Yes	Yes	Yes	Yes	Yes
DM	1.43	0.58	0.69	0.68	0.00	1.01	0.49	0.02	0.20	0.02	0.76	0.31
(p value)	(0.23)	(0.56)	(0.41)	(0.51)	(0.98)	(0.37)	(0.48)	(0.98)	(0.66)	(0.99)	(0.38)	(0.73)
Turning point FE		35,098		32,577		33,913						
Observations	424	424	423	423	398	398	322	322	321	321	300	300

Note: Robust z-statistics in parentheses. *, **, and *** indicate significant at 10 per cent, 5 per cent, and 1 per cent level, respectively. Turning point is in RMB at 1990 prices. DM is a Davidson-Mackinnon test of the null of exogeneity of income.

firms and Hong Kong, Taiwan and Macau owned firms is found to have a positive and significant impact on emissions, but the magnitude of the effects of these HTM firms is small, only one sixth of that on domestic firms. Foreign ownership has a negative, but insignificant, impact.

These results are supported by Table 5.9, in which Chinese-sourced firms have a significant share in wastewater pollution intensive sectors like textiles and textile related products; while foreign-funded firms have a high share in sectors that discharge less wastewater, for example, transport equipment, electrical machinery and equipment. Nevertheless, the results support our expectations that foreign invested firms are generally the cleanest while domestic firms are the dirtiest.

Chemical oxygen demand (COD)

With regards to COD, we do not find any significant relationship between per capita income and per capita emissions of COD in Columns 7–12. This result is different from Shen (2006), who finds a standard EKC relationship between income and COD emissions using province-level data from 1993 to 2002, and the turning point is around the sample mean. A possible explanation is that during our observation period (2001–2004), China's control over industrial COD had been relatively successful, and the national total discharge of industrial COD remained relatively stable and even declined slightly (see Table 3.2).

Industrial output has a positive effect on COD discharges but the effect is not statistically different from zero. The share of output from domestic firms is found to have a significant influence on COD emissions in Columns 11 and 12, at a 1 per cent significance level. A 10 per cent increase in the output from such firms will raise COD emissions by 8.5 per cent. Table 5.9 illustrates that domestic capital takes a significant share in several COD intensive sectors, such as smelting and pressing of ferrous metals, food processing, beverage, and chemical products. Hong Kong, Taiwan and Macao invested firms decrease COD pollution emissions and foreign invested firms increase COD emissions, but neither impact is statistically significant.

Hexavalent chromium compounds (CrVI)

Table 5.14 provides the results for hexavalent chromium compounds and petroleum-like matter.

In respect to CrVI, the coefficients on per capita income variables suggest expected signs but none of them are significant. Neither linear nor quadratic relationships are found between per capita income and CrVI emissions. Surprisingly, the shares of gross industrial output insignificantly decrease the discharges of CrVI, and no significant influence is found for firms from any sources.

Table 5.14 Linear and quadratic log estimation results with fixed effects for industrial CrVI and petroleum-like matter

	CrVI						Petroleum					
Variables	**Column 1**	**Column 2**	**Column 3**	**Column 4**	**Column 5**	**Column 6**	**Column 7**	**Column 8**	**Column 9**	**Column 10**	**Column 11**	**Column 12**
Y	0.686	0.965	0.732	1.000	0.858	1.142	0.759	2.249	0.762	2.248	0.517	2.207
	(0.99)	(0.80)	(1.04)	(0.82)	(1.10)	(0.88)	(1.84)*	(2.95)***	(1.84)*	(2.95)***	(1.09)	(2.71)***
*Y*2		–0.076		–0.073		–0.078		–0.367		–0.367		–0.417
		(0.28)		(0.27)		(0.27)		(2.32)**		(2.31)**		(2.54)**
GIP/GDP			–0.187	–0.187					0.513	0.521		
			(0.30)	(0.30)					(1.42)	(1.45)		
GIPd/GDP					–0.215	–0.227					0.488	0.418
					(0.41)	(0.43)					(1.63)	(1.40)
GIPh/GDP					0.190	0.189					0.073	0.069
					(1.49)	(1.47)					(0.97)	(0.91)
GIPf/GDP					–0.082	–0.085					0.245	0.234
					(0.70)	(0.71)					(3.16)***	(3.04)***
Constant	–2.045	–2.275	–1.298	–1.520	–1.582	–1.760	1.699	0.343	–0.557	–1.939	–0.359	–1.591
	(1.66)*	(1.54)	(0.45)	(0.51)	(0.62)	(0.67)	(2.32)**	(0.37)	(0.33)	(1.08)	(0.23)	(1.00)
R^2 (within)	0.030	0.030	0.031	0.031	0.038	0.039	0.013	0.030	0.020	0.037	0.054	0.075
AR(1)	None	None	None	None	None	None	None	None	None	None	None	None
DM (p value)	0.094	1.01	0.101	1.03	1.17	1.64	0.86	2.51	0.58	2.26	0.58	0.40
	(0.76)	(0.37)	(0.75)	(0.36)	(0.28)	(0.20)	(0.36)	(0.09)	(0.45)	(0.11)	(0.45)	(0.67)
Turning point								21,414		21,385		14,102
FE												
Observations	384	384	383	383	364	364	424	424	423	423	403	403

Note: Robust z-statistics in parentheses. *, **, and *** indicate significant at 10 per cent, 5 per cent, and 1 per cent level, respectively. Turning point is in RMB at 1990 prices. DM is a Davidson-Mackinnon test of the null of exogeneity of income.

Petroleum-like Matter (Petroleum)

As with wastewater, the results for petroleum-like matter provide evidence of a robust inverted-U shaped relationship between per capita income and emissions. The estimated turning point is RMB 17,233 and RMB 23,866 (US $3,605 and US $4,992 at 1990 prices), which is lower than for wastewater. In our sample, nine cities have passed this income level, indicating that scale effects have been overcome by technique effects in these cities. The estimated turning points are robust across fixed and random effects models.

The coefficients on GIP/GDP, GIPd/GDP and GIPh/GDP are all positive but not significant. The coefficient on GIPf/GDP is significant with the magnitude around 0.2, indicating that foreign owned enterprises increase the emission of petroleum-like matters. A possible explanation is that foreign funded enterprises have invested a great amount in the sectors discharging more petroleum-like matter, for example raw chemical materials and chemical products, medicines, and transport equipment.

Waste Gas and Sulphur Dioxide (SO_2)

Table 5.15 provides the results for waste gas and sulphur dioxide. For both pollutants only a linear relationship was found to exist with per capita income. The income elasticity on waste gas was approximately 0.3 in Columns 1 and 3, and that on SO_2 approximately 0.90.[15] A 10 per cent increase in GDP per capita in Chinese cities will lead to a 3 per cent increase in waste gas emissions and a 9 per cent increase in SO_2 emissions. Such a linear relationship between income and SO_2 is different from previous studies on Chinese SO_2 emissions (Liang, 2006; Shen, 2006). The findings in Liang (2006) were optimistic and conflicted with the fact that SO_2 emissions continued to increase in recent years. However, our results, to some extent, are consistent with the findings in Shen (2006).[16]

The share of total industrial output in GDP is found to be a significant determinant of the both pollutants, an effect that appears to be driven by both domestically and foreign owned firms since both of these latter variables are statistically significant. The results in Columns 5, 6, 11, and 12 support our expectation that domestic firms are the most pollution-intensive. Although the coefficients are all positive in Columns 5, 6, 11, and 12, we do not find any significant environmental impact for the HTM owned firms. A possible explanation is that the waste gas and SO_2 polluting sectors (production and distribution of electric and heat power, smelting and processing of ferrous metals) are mostly funded by domestic capital as shown in Table 5.9. The effect of foreign firms is positive for both air pollution indicators, but the magnitude is very small at around 0.06. This is probably due to quite a few foreign investments

Table 5.15 Linear and quadratic log estimation results with fixed effects for industrial waste gas and SO_2

	Waste gas						SO_2					
Variables	**Column 1**	**Column 2**	**Column 3**	**Column 4**	**Column 5**	**Column 6**	**Column 7**	**Column 8**	**Column 9**	**Column 10**	**Column 11**	**Column 12**
Y	0.396	0.676	0.320	0.627	0.281	0.585	0.904	0.776	0.823	0.703	0.921	0.786
	(2.39)**	(2.15)**	(2.01)**	(2.10)**	(1.52)	(1.80)*	(5.41)***	(2.47)**	(5.08)***	(2.32)**	(5.20)***	(2.48)**
Y2		–0.073		–0.080		–0.080		0.032		0.030		0.034
		(1.05)		(1.22)		(1.14)		(0.48)		(0.47)		(0.52)
GIP/GDP			0.756	0.761					0.744	0.744		
			(5.47)***	(5.50)***					(5.18)***	(5.17)***		
GIPd/GDP					0.501	0.493					0.550	0.554
					(4.30)***	(4.23)***					(4.69)***	(4.71)***
GIPh/GDP					0.041	0.040					0.047	0.047
					(1.35)	(1.33)					(1.53)	(1.54)
GIPf/GDP					0.062	0.061					0.062	0.063
					(2.12)**	(2.06)**					(2.11)**	(2.15)**
Constant	0.239	–0.001	–2.936	–3.220	–1.750	–1.975	3.736	3.849	0.622	0.729	1.293	1.394
	(0.82)	(0.00)	(4.61)***	(4.75)***	(3.02)***	(3.23)***	(12.56)***	(10.13)***	(0.93)	(1.03)	(2.21)**	(2.26)**
R^2 (within)	0.412	0.414	0.460	0.462	0.464	0.466	0.333	0.334	0.386	0.387	0.412	0.412
AR(1)	None	None	None	None	None	None	None	None	None	None	None	None
DM (p value)	0.49	0.74	0.27	0.44	2.61	0.78	0.47	0.51	0.18	0.35	2.72	0.33
	(0.49)	(0.48)	(0.60)	(0.65)	(0.11)	(0.46)	(0.49)	(0.60)	(0.67)	(0.70)	(0.10)	(0.72)
Turning point												
FE												
Observations	439	439	438	438	413	413	428	428	427	427	407	407

Note: Robust z-statistics in parentheses. *, ** and *** indicate significant at 10 per cent, 5 per cent, and 1 per cent level, respectively. Turning point is in RMB at 1990 prices. DM is a Davidson-Mackinnon test of the null of exogeneity of income.

in non-metallic mineral products, raw chemical materials and chemical products, which are the biggest sources of waste gas and SO_2. The positive effect on SO_2 emissions is different from the negative effects in Liang (2006) but consistent with small positive effects in He (2006).[17]

Soot and dust

Table 5.16 shows the results for industrial soot and dust. No significant relationship is found between income and emissions of soot or dust, although the correlation matrix shows that we might expect a negative sign. This finding is consistent with Shen (2006). Table 3.3 also shows the relatively successful control of industrial soot and dust from 2000. The share of industrial output in GDP is found to be a significant determinant of emissions and this effect appears to be entirely driven by the output from domestically owned firms. The shares of HTM owned output and foreign owned output both have positive but insignificant coefficients.

Summarizing across our various pollution measures we can see that the two water pollution measures, wastewater and petroleum, exhibit an inverted-U shaped relationship with income with a turning point beyond the sample income level for most cities. This suggests that emissions of these pollutants are increasing at a decreasing rate with per capita income, suggesting that the efforts of Chinese policymakers to tackle these two water pollutants have had little impact. Turning to the air pollutants, waste gas and SO_2, we find the quadratic income terms to be insignificant suggesting more of a linear relationship between income and emissions. For soot and dust the income terms are not statistically significant suggesting no clear relationship exists with per capita income.

With regard to our various measures of gross industrial product (GIP), it can be seen that aggregate GIP as a share of GDP is a positive determinant of six pollutants (except COD and CrVI) and is statistically significant for five of these. In terms of elasticities, we can see that a 1 per cent increase in GIP as a share of GDP will increase per capita emissions by between 0.475 per cent and 0.898 per cent, depending on the pollutant. In many cases, the majority of this increase would appear to come from domestically owned industry, with the elasticity on domestically owned GIP as a share of GDP varying from 0.291 per cent to 1.055 per cent, again depending on the pollutant. Where foreign owned output was also found to be statistically significant, in the case of waste gas and SO_2, its effect was much smaller, with elasticities between 0.061 and 0.063. For petroleum, the only GIP measure to be statistically significant was foreign owned GIP as a share of GDP, which exhibited a relatively large elasticity of between 0.234 and 0.245. This reflects the fact that foreign funded enterprises have invested a large amount in the sectors discharging petroleum-like matter,

Table 5.16 Linear and quadratic log estimation results with fixed effects for industrial soot and dust

	Soot						Dust					
Variables	**Column 1**	**Column 2**	**Column 3**	**Column 4**	**Column 5**	**Column 6**	**Column 7**	**Column 8**	**Column 9**	**Column 10**	**Column 11**	**Column 12**
Y	–0.118	–0.805	–0.215	–0.891	0.107	–0.418	–0.167	–0.962	–0.235	–0.957	–0.091	–0.805
	(0.23)	(1.38)	(0.42)	(1.46)	(0.24)	(0.79)	(0.33)	(1.19)	(0.47)	(1.16)	(0.19)	(1.00)
Y2		0.168		0.165		0.128		0.195		0.178		0.174
		(1.77)*		(1.75)*		(1.42)		(1.16)		(1.06)		(1.07)
GIP/GDP			0.898	0.896					0.841	0.823		
			(3.01)***	(2.99)***					(3.12)***	(3.00)***		
GIPd/GDP					0.571	0.592					1.04	1.055
					(2.89)***	(2.93)***					(3.99)***	(4.01)***
GIPh/GDP					0.034	0.034					0.039	0.04
					(0.77)	(0.79)					(0.62)	(0.64)
GIPf/GDP					0.005	0.01					0.001	0.006
					(0.11)	(0.23)					(0.02)	(0.13)
Constant	4.835	5.461	1.068	1.692	2.032	2.421	4.254	4.978	0.689	1.426	–0.213	0.374
	(5.34)***	(5.94)***	(0.74)	(1.24)	(2.06)**	(2.55)**	(4.72)***	(4.79)***	(0.53)	(1.02)	(0.18)	(0.30)
R^2 (overall)	0.061	0.075	0.131	0.144	0.134	0.142	0.044	0.053	0.077	0.084	0.128	0.134
AR(1)	None	None	None	None	None	None	None	None	None	None	None	None
DM (p value)	2.81	0.71	1.42	0.32	1.96	0.83	1.69	0.32	0.71	0.37	2.15	0.26
	(0.09)	(0.49)	(0.23)	(0.73)	(0.14)	(0.44)	(0.19)	(0.73)	(0.40)	(0.69)	(0.14)	(0.77)
Turning point RE (FE)												
Observations	436	436	435	435	415	415	424	424	423	423	403	403

Robust z-statistics in parentheses. *, **, and *** indicate significant at 10 per cent, 5 per cent, and 1 per cent level, respectively. Turning point is in RMB at 1990 prices. DM is a Davidson-Mackinnon test of the null of exogeneity of income.

for example raw chemical materials and chemical products, medicines, and transport equipment. Overall, we can conclude that foreign owned firms appear to have invested in sectors that are relatively intensive in the emission of petroleum, waste gas and sulphur dioxide.

5.6 Conclusions and policy implications

In this chapter, we used a panel of 112 Chinese cities over four years to examine the income–pollution nexus for several water and air pollution indicators. We also compared the net environmental effects of economic activities of domestic firms, Chinese-sourced affiliates from Hong Kong, Taiwan and Macao, and non-Chinese-sourced affiliates from other foreign economies.

Our pollution indicators included four industrial water pollution emissions, wastewater, chemical oxygen dioxide, hexavalent chromium compounds, and petroleum-like matter; and four industrial air pollution emissions, waste gas, sulphur dioxide, soot, and dust.

Although the environmental Kuznets curve is found to exist for two pollutants, the evidence from the majority of pollutant emissions confirms that at current income levels in China, economic development (with current technology levels and policies) will induce more industrial pollution emissions, that is, the net effect of economic growth on environment quality is negative. We also find that total industrial output has a strong positive effect on industrial pollution emissions, and the impact of industrial output differs by country of ownership. Domestic firms have the strongest positive effects on industrial pollution emissions; Chinese-sourced affiliates have moderate positive effects on one of the water pollution emissions, but an insignificant impact on air pollution; and foreign invested firms have significant and positive influences on the emissions of petroleum-like matter, waste gas and SO_2 with an insignificant effect in all other cases. It is likely that these effects largely reflect the pollution intensity of the sectors that foreign, HTM and domestic investors concentrate on.

If the environmental Kuznets curve exits for all pollution emissions at higher income levels in China, it does not suggest that China can outgrow environmental problems by simply emphasising economic growth without the need for paying special attention to the environment itself. Panayotou (2003) argues that government policy can affect the shape and height of the EKC through three channels. First, the turning point of the EKC may be delayed or advanced, weakened or strengthened by policy intervention. In addition to higher incomes, the environment could be improved by policy responsiveness to the growing demand for environmental quality, through the enactment of environmental legislation and the development of new institutions to protect the environment. Second, since it may take decades for low-income countries to pass the turning point, the accumulated damage in the meantime may far exceed the present value of higher future growth and a cleaner environment. Therefore, active environmental policies may be justified at present and the current cost of prevention may be more cost effective than future treatments. Third, the height of the EKC reflects the environmental price of economic growth, which depends on income levels, as well as market efficiency and policies. Therefore, to reduce the environmental price it is important to: remove harmful environmental subsidies, for example on energy and transport; enforce property rights; price resources at full cost; and internalize environmental costs though pollution taxes and tradeable permits.

Thus, the broadly positive relationship between income and emissions provides little scope for optimism and suggests that the increased stringency and enforcement of environmental regulations is crucial to alleviate pressure on the natural environment in China at the earlier stages of economic development and at every administrative level of the country.

The Chinese government does increasingly appear to accept the need for such regulations. In October 2007 attempts to protect the environment were boosted by the implementation of the Law of Property Rights. Similarly, in 2004 the Chinese premier, Wen Jiabao, announced that a measure of 'green GDP', which deducts the depreciation costs of environmental damage and resource depletion from gross GDP, would begin to replace gross GDP as a measure of true economic growth. A recent report indicates that growth of 'green GDP' was virtually zero in some provinces in the first half of 2007, suggesting that 'true' economic growth in China may be significantly lower than it appears once the depreciation of natural capital is taken into account.[18] Although there are some technical hitches to implementing green GDP as a performance measure by local government officials, it at least helps local government to pay more attention to environmental problems and increases public concerns for environmental protection. Central government should promote the process of a wide implementation of a green GDP index.

In 2006, Chinese Premier Wen Jiabao pointed out the importance of green development in his government work report. 'Wen has ordered local governments to establish accountability rules for implementing caps on sulphur dioxide and other pollutants, and demanded that local officials face inspections for pollution control' (Reuters, 16 August 2006). GDP (or economic growth) is no longer the key theme considered by local policy-makers, and environmental protection has been a factor in assessing the achievement of local officials in some provinces. Reuters also reported that China will rigorously enforce limits on industrial pollution to rein in rampant pollution and cool frenetic economic growth. Zhou Shengxian, head of SEPA, said that the central leadership and State Council are treating reductions in energy use and major pollutant emissions as two major hard targets and using the reduction of major pollutant emissions as an important means to promote coordinated, sustainable development. These two targets are the red lines that cannot be crossed.

Our results show that structural changes in the economy, especially those of domestic firms, to some extent have important roles in determining pollution levels. Therefore, future structural changes within domestic enterprises at higher income levels, from manufacturing to service sectors, are vital to improve environmental quality. Foreign invested firms seem to be the most efficient and have better environmental practices. Foreign firms may also have technology spillovers to local firms through imitation, employment turnover and supply chain requirements. However, technology transfer does not happen automatically. Local institutions are vital to promote the local capacity to assimilate, diffuse and retain technologies (OECD, 2002).

Since foreign affiliates have a significant impact on the emissions of some pollutants, it is recommended the government control investment in high energy consumption and high pollution sectors, but encourage more environmentally friendly investment. These will be enhanced by the new policies of the Chinese government. The National Development and Reform Commission released a new and substantially revised *Catalogue for the Guidance of Foreign Investment Industries*, which became effective on 1 December 2007 and replaces the previous catalogue adopted in 2004. The new catalogue implies that China is going to put emphasis on the 'quality' of investment, which is opposite to past emphasis on 'quantity'. For example, the catalogue shows that the Chinese government will 1) continue to encourage investment in all advanced technology and modern manufacturing, and services businesses such as modern logistics and service outsourcing, but discourage investment in traditional enterprise sectors; 2) encourage investment in sustainable resources and environmental protection, but restrict or prohibit investment in high resource use, high energy use and high pollution enterprises, as well as mining of certain rare minerals and energy resources; and 3) discourage investment in export oriented enterprises, which is a dramatic reversal of former policy.

All in all, only time will tell whether recent policies such as these will begin to lessen the environmental impact of China's burgeoning economy.

Appendix 5.1 Variable definitions and data sources

Variable	Definition/Source
Wastewater	Per capita emissions of industrial wastewater (tons per person). *Source*: China Environment Yearbook; population data from China City Statistical Yearbook.
COD	Per capita emissions of industrial chemical oxygen demand (tons per 10,000 persons). *Source*: as above.
CrVI	Per capita emissions of industrial hexavalent chromium compounds (kg per 10,000 persons). *Source*: as above.
Petroleum	Per capita emissions of industrial petroleum-like matter (tons per 1,000,000 persons). *Source*: as above.
Waste Gas	Per capita emissions of industrial waste gas (10,000 m^3 per person). *Source*: as above.
SO2	Per capita emissions of industrial sulphur dioxide (tons per 10,000 persons). *Source*: as above.
Soot	Per capita emissions of industrial soot (tons per 10,000 persons). *Source*: as above.
Dust	Per capita emissions of industrial dust (tons per 10,000 persons). *Source*: as above.
Y	Gross domestic product (GDP) per capita (1,000 yuan at 1990 price). *Source*: China City Statistical Yearbook.
GIP/GDP	Gross industrial product (GIP) normalized by city GDP (100 yuan per yuan). *Source*: as above.
GIPd/GDP	GIP normalized by GDP for the domestic firms (100 yuan per yuan). *Source*: as above.
GIPh/GDP	GIP normalized by GDP for Hong Kong, Taiwan and Macao invested firms (100 yuan per yuan). Such firms refer to all industrial enterprises registered as the joint venture, cooperative, sole investment industrial enterprises and limited liability corporations with funds from Hong Kong, Macao and Taiwan. *Source*: as above.
GIPf/GDP	GIP normalized by GDP for foreign countries invested firms (100 yuan per yuan). Such firms refer to all industrial enterprises registered as the joint venture, cooperative, sole investment industrial enterprises and limited liability corporations with foreign funds. *Source*: as above.

Appendix 5.2 Cities in the sample (number of cities in subgroups in brackets)

East (52)		**Central (31)**	**West (29)**
Municipalities (3)	Shandong (10)	Shanxi (5)	Municipality (1)
Beijing	*Jinan*	*Taiyuan*	*Chongqing*
Tianjin	*Qingdao*	*Datong*	Inner Mongolia AR (3)
Shanghai	*Zibo*	*Yangquan*	*Huhhot*
Hebei (5)	*Zaozhuang*	*Changzhi*	*Baotou*
Shijiazhuang	*Yantai*	*Linfen*	*Chifeng*
Tangshan	*Weifang*	Jilin (2)	Guangxi Zhuang AR (4)
Qinhuangdao	*Jining*	*Changchun*	*Nanning*
Handan	*Taian*	*Jilin*	*Liuzhou*
Baoding	*Weihai*	Heilongjiang (4)	*Guilin*
Liaoning (6)	*Rizhao*	*Harbin*	*Beihai*
Shenyang	Guangdong (8)	*Qiqiharr*	Sichuan (5)
Dalian	*Guangzhou*	*Daqing*	*Chengdu*
Anshan	*Shaoguan*	*Mudanjiang*	*Panzhihua*
Fushun	*Shenzhen*	Anhui (3)	*Luzhou*
Benxi	*Zhuhai*	*Hefei*	*Mianyang*
Jinzhou	*Shantou*	*Wuhu*	*Yibin*
Jiangsu (8)	*Foshan*	*Maanshan*	Guizhou (2)
Nanjing	*Zhanjiang*	Jiangxi (2)	*Guiyang*
Wuxi	*Zhongshan*	*Nanchang*	*Zunyin*
Xuzhou	Hainan (2)	*Jiujiang*	Yunan (2)
Changzhou	*Haikou*	Henan (6)	*Kunming*
Suzhou	*Sanya*	*Zhengzhou*	*Qujing*
Nantong		*Kaifeng*	Shaanxi (5)
Lianyungang		*Luoyang*	*Xi'an*
Yangzhou		*Pingdingshan*	*Tongchuan*
Zhejiang (7)		*Anyang*	*Baoji*
Hangzhou		*Jiaozuo*	*Xianyang*
Ningbo		Hubei (3)	*Yan'an*
Wenzhou		*Wuhan*	Gansu (2)
Jiaxing		*Yichang*	*Lanzhou*
Huzhou		*Jingzhou*	*Jinchang*
Shaoxing		Hunan (6)	Qinghai (1)
Taizhou		*Changsha*	*Xining*
Fujian (3)		*Zhuzhou*	Ningxia Hui AR (2)
Fuzhou		*Xiangtan*	*Yinchuan*
Xiamen		*Yueyang*	*Shizuishan*
Quanzhou		*Changde*	Xinjiang Uyghur AR (2)
		Zhangjiajie	*Urumuchi*
			Karamay

Part II

The Effect of Environmental Regulations on FDI in China

6
FDI and Environmental Regulations in China

6.1 Introduction

Central and local governments, as well as some industrial managers, have recognized China's increasingly serious environmental problems and have made an effort to reduce pollution and encourage cleaner production. The Chinese government now aims to transform its growth pattern and create a new scenario for scientific development. Environmental protection has been one of China's *national fundamental policies*. In some regions environmental quality is improving but economic growth is still the priority others. As their income rises and their education grows the general public appear to be increasingly aware of the threat of environmental degradation, particularly in the eastern regions. However, their impact on authority is still limited. In many places the enforcement of environmental regulations is weak and uneven, which discourages industries from reducing pollution and increasing efficiency. This disparity in economic growth and enforcement of environmental regulations has resulted in accumulated environmental problems, in certain areas particularly.

This chapter introduces China's environmental regulations and implementations within three key sections: a brief overview of the regulatory framework of environmental policy in China, in Section 6.2, with particular attention paid to the regulations for establishing new industrial projects and specifically those for foreign invested firms; Section 6.3 reviews the effects of environmental regulations, particularly the regional differences in industrial pollution treatment investment; Section 6.4 examines the implementation of environmental regulations and analyses the reasons for a lack of stringency in applying them.

6.2 Regulatory framework of environmental protection in China

China began to be responsible for its environmental protection in 1978 with the *Constitution of the People's Republic of China*.[1] China established the *Environment Protection Law* (EPL) in 1979 (provisional) and officially enacted it in September 1989.[2] The EPL specifies the basic principles governing the prevention of pollution and environmental protection and imposes a criminal responsibility for serious environmental pollution. Based on the EPL, China has had an established regulatory framework since 1979, with nine environmental protection laws, fifteen resource conservation laws, and more than 50 pieces of environmental administrative regulation. Over a thousand regulations have been issued by related ministries in central and local government. Environmental standards are another important component of this regulatory system. By the end of 2010, China had issued over 1,300 national environmental standards and a number of local environmental standards. All these laws, rules and standards form a comprehensive and complex legal framework on environmental protection (Environmental Protection in China 1996–2005, SEPA and official MEP website)[3].

There are three main features of the EPL: decentralized regulation, centralized monitoring system and self-regulation. Decentralized regulation establishes base level settings. The MEP lays out national environmental quality standards, sometimes minimum ones, while local environmental authorities can prescribe higher local standards and set their own standards if national ones are not adopted. Local government is responsible for the implementation of environmental regulations within their jurisdiction and for improving the environment. Centralized monitoring system refers to the fact that the MEP establishes the monitoring system, formulates the monitoring standards and strengthens monitoring management. Local regulators investigate and assess any environmental situations under their jurisdiction and draw up plans for environmental protection. Self-regulation means a responsibility system for environmental protection. These three features of EPL have shaped the following four basic principles for China's current environmental management system:

- Environmental impact report system: any project that may have a negative effect on the environment must go through an environmental impact assessment process. Article 13 of EPL states that a project's environmental impact statement must assess the pollution the project is likely to produce, its impact on the environment and what preventive and curative measures will be taken. It is only after verification by national or local regulatory authorities, that the project can be started legally.

- Synchronization (or *three-simultaneity*): Article 26 of the EPL states that the pollution preventing facility must be designed, constructed and operated simultaneously with the design, construction and operation of the main production line. The environmental authorities are in charge of checking the project design in the review process and monitoring the construction. After inspection and approval by the environmental authorities, the project can start operating.
- Registration and licensing system for the discharge of pollutants (self-reporting system): Article 27 of the EPL specifies that institutions and enterprises that emit pollutants must register with and report to the environmental protection authorities. They should report on the following six categories: (1) basic economic information (sector, major products and raw materials); (2) production process diagrams; (3) volume of water use and wastewater discharge, and pollutant concentrations in the wastewater; (4) waste gas volume and air pollutant concentrations (before and after treatment); (5) noise pollution by source; and (6) discharge of solid wastes. This is an important tool for controlling pollution.
- Pollution levy system: any firm whose pollutant discharge exceeds the designated standards will be charged an excess effluent fee. Charges are levied on 29 water pollutants and 22 air pollutants, as well as solid waste, radioactive waste and noise. Among the pollutants, the major focus for monitoring and levy collection is on chemical oxygen demand and total suspended solids for water, and SO_2 and flue dust for air. Funds from the pollution levy are used for pollution source control, damage remediation and development of environmental institutions. The lion's share of the levy has been used for pollution abatement. It should be noted that the charge paid for discharging does not legalize the pollution process. After paying the charge the enterprises may also face the costs of controlling and eliminating the pollution. To encourage pollution reduction, levy charges increase with the duration of non-compliance. After two years of paying the levy, polluters are subject to an annual five per cent increase in the charge rate. Under the levy system, polluters have to report on all their polluting emissions (water and air, noise, solid waste, and so on) and the local environmental authorities check the reports and then decide on the levy to collect. Penalties are imposed for false reporting

and non-cooperation. The levy design, verification and collection, and the development of the levy system are fully described in Wang and Wheeler (2002).

Figure 6.1 lays out the approval procedure for new industrial projects, with particular focus on the environmental aspects. The whole process reflects the EPL's synchronization principle.

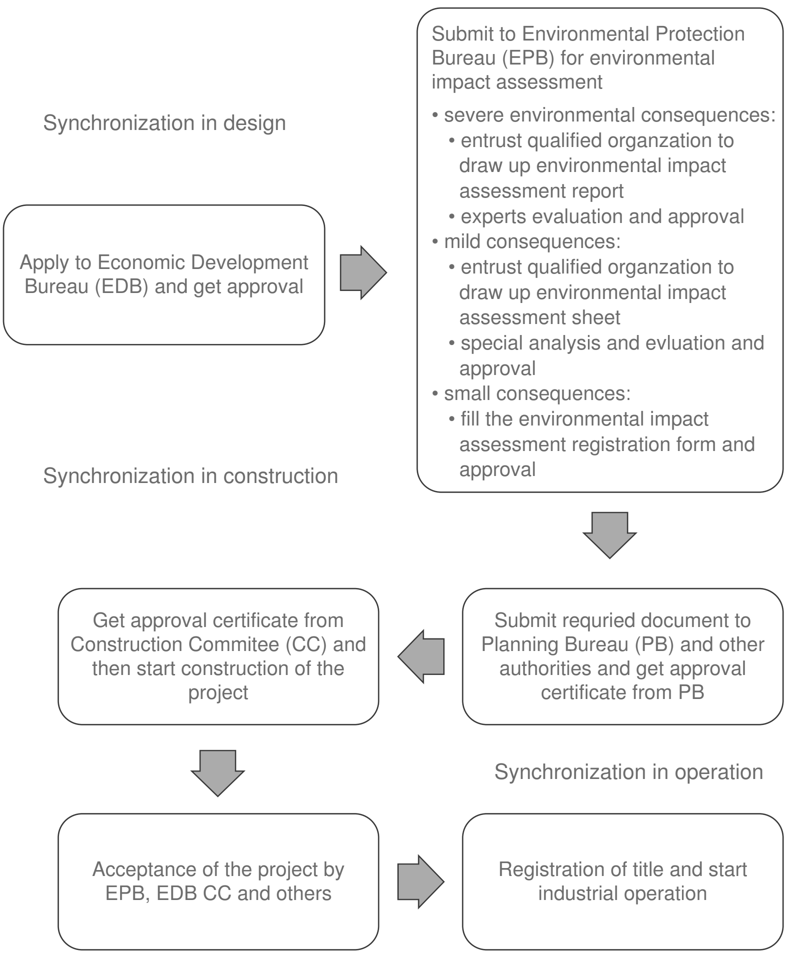

Figure 6.1 Approval procedures for new industrial projects

Environmental regulatory framework for foreign investment

Generally, there are no separate environmental standards for foreign investment, but foreign investors' environmental behaviour must abide by Chinese environmental laws and regulations and meet the environmental standards. There are some specific policies and administrative procedures governing and monitoring FDI with respect to environmental protection.

The *Provisions on Guiding Foreign Investment Direction* set out environmental protection requirements for foreign investment projects. It encourages investment in environmentally sound technologies and new technologies for controlling environmental pollution. It also limits foreign investment in exploiting rare and precious mineral resources and prohibits investment in projects that pollute the environment, threaten human health, or destroy natural resources.

Circular on Management of Foreign Invested Construction Projects, issued in 1992, states that foreign investors should abide by Chinese environment protection laws and regulations. They should prevent environmental pollution and ecological damage, and accept monitoring and supervision by environmental protection authorities. Foreign invested enterprises should also absorb foreign capital and introduce advanced technologies from overseas. There are also other regulations such as *Regulations on the Exploration of Offshore Petroleum Resources in Cooperation with Foreign Enterprises by Foreign Firms*, *Implementing Regulations on Joint Ventures*, *Project Construction and Operation in Part III of the Application Form for Establishing Foreign Invested Enterprises in China*, etc (Xian *et al.*, 1999).

6.3 Effects of environmental regulations

Tables 3.2, 3.3 and 3.4 show trends in industrial and household emissions of water pollutants, air pollutants and solid waste. Along with economic growth, the control of pollutants has worked, to some extent, in terms of industrial COD, ammonia, nitrogen, soot, dust, and solid waste emissions, as well as household SO_2 and soot emissions. Control of emissions has not been that successful for industrial SO_2 and household water pollutants. The total amount of industrial and household wastewater and waste gas continues to grow, as has been confirmed by the empirical findings in Chapter 5.

The achievement of controlling certain pollution emissions is because China's central and local government, as well as some enterprises, have invested a great deal of money in environmental pollution treatment annually. In 2010 this investment increased to RMB 665.42 billion (about $98.3 billion), which accounted for 1.66 per cent of the country's GDP. Out of this investment, RMB 422.4 billion (63.5 per cent) was used for city environmental infrastructure construction, including gas supply, central heating, sewerage projects, gardening and greening, and sanitation. RMB 20.3 billion (30.5 per cent) was invested in environmental components in new construction projects to comply with the three-simultaneity policy, which requires that the design, construction and operation of pollution treatment facilities are simultaneous with the design, construction and operation of new projects. About RMB 39.7 billion (6.0 per cent) was provided for treatment of industrial pollution sources, such as waste water, waste gas, solid waste, noise, and other pollution.[4]

Figure 6.2 shows the rising trend of investment in the treatment of industrial pollution from 1987 to 2010. Investment in 2010 was more than 11 times that in 1987. Investment peaked in 2007 then began to decline. One main reason was the dramatic rise in investment in environmental components for new construction projects to comply with the three-simultaneity policy laws (as shown in Figure 6.3). Since pollution treatment facilities are installed before the operation of any new industrial project, this three-simultaneity investment has decreased the need for investment in additional new projects to tackle industrial pollution. Therefore, the share of industrial pollution treatment projects in the total investment in treatment of environmental pollution has declined from more than 23 per cent in 2000 to less than 10 per cent, but it is still an important source for financing industrial pollution treatment projects.

A disparity in investment in industrial pollution treatment also exists across provinces. Figure 6.4 shows that the provincial share of investment in environmental pollution treatment relative to GDP varies across provinces, an imbalance that is not consistent with GDP levels. However, Guangdong, as the richest province in China, has made the highest contribution in dealing with its environmental pollution, and Tibet, which had the lowest regional output in 2010 also had the lowest share of environmental investment in GDP. It is interesting that the shares of most eastern regions (except Guangdong and Hebei) are below the national level of 1.66 per cent of GDP as shown by the dotted line in the figure. Three wealthy provinces, Jiangsu, Shandong, and Zhejiang, had lower levels of environmental investment relative to their GDP than many central and western regions (such as Ningxia, Guangxi, and Shanxi) whose economy was relatively weak. It means that some relatively poor regions have made more effort in terms of alleviating

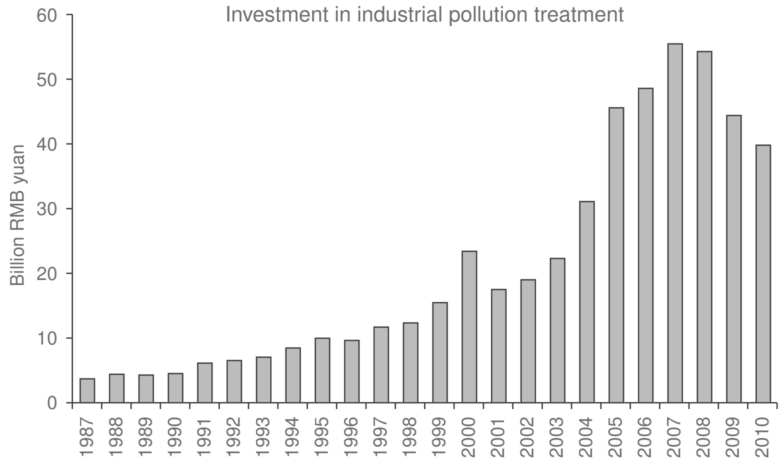

Figure 6.2 Investments in industrial Pollution treatment projects, 1987–2010
Source: China Statistical Yearbook (various years).

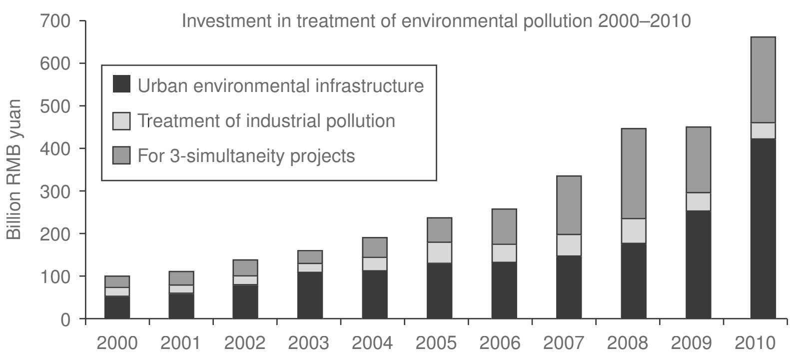

Figure 6.3 Investments in treatment of environmental pollution by category, 2000–2010
Source: China Environment Yearbook (2011).

environmental pollution. When leaving out Guangdong and Tibet from the calculaiton, the relationship between GDP and the proportion of pollution treatment investment in GDP is negative, as shown by the solid line in the figure. Note that provinces like Jiangsu, Shandong, and Zhejiang have been leaders in terms of FDI inflows to China.

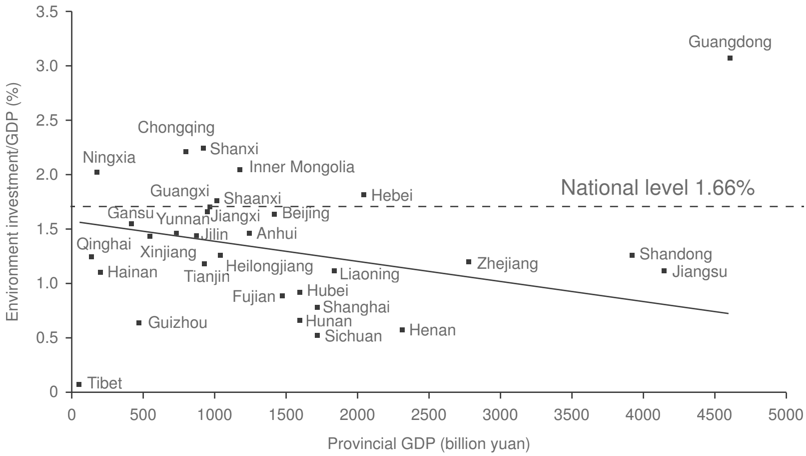

Figure 6.4 Provincial difference in pollution treatment investment per unit of GDP and GDP in levels, 2010

Source: China Statistical Yearbook (2010).

6.4 Implementation of environmental regulations

There are four approaches to implementing environmental measures in China (Matsuno, 2009). The first approach is orders and control: including control of the total amount of emissions; environmental impact assessments; three-simultaneity system; centralized pollution control; setting deadlines for control of sources; pollution discharge permits, and so on. The second approach is market instruments, such as: pollution levies; penalties; SO_2; and CO_2 emission trading; and subsidies for energy saving products. The third approach involves voluntary actions, for example: ISO 14000 standards; eco-model areas; environmental NGOs; and green GDP accounting pilot projects. The fourth method refers to public participation, which means that citizens monitor and report environmental issues through, for example, environmental protection hotlines, online reporting systems and complaints mailboxes, and that they participate in court for some issues. Orders and control used to be the main approach to implementing environmental regulations. Recently, methods from the second approach have been widely used, and those in the third and fourth approaches appear in many places.

Although China's regulatory framework seems comprehensive, its enforcement is weak. Ma (2007) and Wang (2006–2007) point out that the limited power of environmental authorities is one reason for the failure to implement environmental laws. Before upgrading to its current ministry level, SEPA had limited administrative powers, and was not allowed to participate fully in national decision-making. After upgrading, MEP has been granted more power but is still subject to decisions from other ministries and departments. Local environmental authorities are subordinate to local government. They are reliant on the government for both funding and enforcement, making it hard for them to act freely in the local interest, and protect the environment. Some local governments set economic growth as a priority and therefore interfere with the environmental protection authority and protect large, polluting enterprises. Current legislation only allows environmental authorities to make suggestions and issue fines or administrative penalties. They do not have the power to force a company to make changes within a certain time limit. Also, since the fines are usually small, it may cost more to obey the law than to break it. Many environmental violators receive administrative punishments rather than criminal penalties, so that the punishments are not that effective.

Although there is a comprehensive approval process for new industrial projects and all projects are required to do an environmental impact assessment, many projects with severe environmental consequences, particularly small enterprises, start construction without an environmental investigation or approval. Most of the time, the imposition of punishment on these violators is delayed (Wang, 2006–2007).

Environmental policy is set by the government, overseen by the environmental authorities and implemented by various government departments. In principle this is reasonable, but coordination between environmental authorities and other departments is poor, mainly because of the huge amount of overlap among departments. For example, water pollution is the responsibility of the environmental authorities, but water and groundwater are managed by the Ministry of Water Resource, sewage is dealt with by the Ministry of Construction, which also has the function of directing the use and protection of groundwater in cities. This problem has been solved in other countries through greater departmental communication, but is not being solved in China due to the lack of legislative clarity of each department's role, power, and responsibilities.

Additionally, the public lacks an awareness of environmental protection and participation in social supervision, which is also to the detriment of enforcing environmental regulations. Under the current legislative framework, it is difficult for the public to actually participate in the environmental impact assessment process (Wang, 2006–2007).

Furthermore, environmental regulatory stringency varies between regions. Environmental standards are set jointly by local and national regulators. Levy rates are formally established by a national regulator but actual levies are decided and collected by local regulators. Some local regulators protect polluting companies for economic reasons. Excessive pollution happens in some regions due to the failure of local government. The situation continues because of the lack of awareness amongst some local government officials of the environment, environmental laws and the rule of law in general. Therefore, local levies may vary from region to region for identical industries and pollutants. In addition, local regulatory inspections vary, some regions have better environmental management systems than others. As a result, regulatory strength differs across regions.

Weak environmental regulatory stringency in China provides an opportunity for some multinational corporations (MNCs) to take advantage of weak environmental standards to transfer their out-of-date technologies and pollution-intensive production to China. Xian *et al.* (1999) found that about 30 per cent of FDI in China was in pollution-intensive industries, of which 13 per cent was from highly pollution-intensive industries. In January 2008, IPE announced that over 300 MNCs have violated environmental regulations in China and only eight of them passed examination after controlling the pollution (Xinhuanet 2008). The majority of these MNCs are from the US, Japan, and European countries. None of their subsidiaries are polluting firms in their home countries due to strict environmental standards. The report also shows that a considerable number of these polluting foreign subsidiaries (about a third) are located in Shanghai, which has attracted over 15 per cent of national cumulative FDI inflows since 1979 (see Figure 2.7), but makes a relatively low investment in the environment (see Figure 6.4). It suggests that polluting firms would like to locate in regions pay relatively less attention to environmental protection.

6.5 Conclusions

Although China has established a system of environmental regulatory framework, the regulations are still relatively weak compared with developed, and even developing, countries. Such weak regulations combined with lax implementation may give profit-maximizing foreign investors an opportunity to take advantage by moving their pollution intensive production facilities to China. As in economic development, FDI inflows and levels of environmental deterioration, the stringency of environmental regulations differs across regions in China. Correlations between these variables are useful if we wish to model the determinants of foreign choices for inter-province plant location.

7
Theoretical and Empirical Studies on FDI and Environmental Regulations

7.1 Introduction

If foreign firms do transfer advanced technology and management know-how to domestic firms, they will thereby help to reduce industrial pollution in developing countries since they are generally believed to be cleaner than the domestic counterparts. However, this idea is at odds with the, so-called, pollution haven hypothesis (PHH) that FDI may be attracted to developing countries by their less stringent environmental regulations.

Traditional international trade theory tells us that trade is governed by comparative advantage, which postulates that the efficient exchange of goods leads to optimal outcomes. Multinational firms, as agents of free trade, seek cost reductions and respond to market imperfections. Higher domestic costs therefore provide the motivation for multinational corporations to expand their geographical range into other areas.

Stringent environmental standards in developed countries will drive up production costs of those firms with a higher sensitivity to pollution abatement costs by, for example, prohibiting certain inputs and outputs where strict emission standards requires the use of specific technologies. It may, therefore, be that profit-maximizing, pollution-intensive multinational firms will take the view that it is in their best interests to move operations, or part of an operation, to a developing country to take advantage of less stringent environmental regulations. Such a strategy could trigger competition to offer lax environmental policies in order to gain competitive advantage in 'dirty' goods production. A corollary is that developing countries may join a race to the bottom by undervaluing environmental damage in order to attract more FDI. Either way, the result is excessive levels of pollution and environmental degradation (Dean *et al.*, 2009). This phenomenon is the, so-called, race to the bottom or pollution haven hypothesis.[1]

To date, one of the most contentious debates in FDI and the environment literature focuses on whether inter-country differences in environmental regulations are turning poor countries into 'pollution havens'. This argument centres on the cost effectiveness of environmental regulations and presumes that there are environmental regulation-induced production cost differentials that encourage a firm to relocate its production facility.[2] Theoretical models of pollution havens, including Pearson (1987) and Baumol and Oates (1988), illustrate that developed countries control pollution emissions whilst developing countries do not, thereby becoming pollution havens.

Thus far the empirical results for tests of PHH are mixed. Levinson (1996b), Keller and Levinson (2002), List and Co (2000), Fredriksson *et al.* (2003) all find evidence that environmental stringency has some impact on inbound FDI locations in the US. Xing and Kolstad (2002) find that environmental regulations in host countries have a significant impact on outbound FDI from the US for heavily polluting industries. In contrast, Levinson (1996a) finds little evidence for inter-state pollution havens in the US, and Eskeland and Harrison (2003) suggest it is difficult to find a robust relationship between pollution abatement and US outbound FDI. For the evidence of other countries, Samarzynska-Javorcik and Wei (2005) find that the overall results are relatively weak when they examine the relationship between FDI and environmental stringency for firms in Eastern Europe and the former Soviet Union; Dean *et al.* (2009) find environmental stringency only affects FDI projects in China that originate from Hong Kong, Macao and Taiwan. In general, previous empirical studies suggest that there is little evidence to support the pollution haven hypothesis.

This chapter reviews the related theoretical and empirical literature in detail. It starts by reviewing existing theoretical and empirical studies of FDI and the environment. It then discusses some of the empirical findings of research into FDI patterns in China, and finally examines weaknesses in the previous empirical literature.

7.2 Trade and investment theory and the environment

According to the theory of comparative advantage, in order to allocate resources efficiently and hence maximize global output and income, countries should specialize in the production and export of products that use in their production a relatively large amount of the resources that the country has in relative abundance. Therefore, countries should produce and export products for which they have a comparative advantage, and they should import products in which they have a comparative disadvantage.

Pearson (1987) shows that the environmental medium (air, water, soil) provides a supply of assimilative capacity for waste disposal. In a country with low income levels, the absence of industry or low competing demand for these environmental services, the demand for waste disposal is low relative to supply, and therefore, the economic price of waste disposal services should also be low. A low price means a relative abundance. Other things being equal, this country would have a comparative advantage in dirty production, and a comparative disadvantage in clean production. Conversely, countries where assimilative capacity is exhausted and incremental residual discharge has a high cost, have a comparative disadvantage in dirty production and a comparative advantage in clean production. Thus, specialization through comparative advantage and international trade (investment) efficiently allocates resources, increases production and improves world welfare. Therefore, the supply and demand for environmental services can be treated as an additional factor in production, and that an efficient pattern of world production will reflect that factor.

Baumol and Oates (1988) set up a simple partial equilibrium model that focuses on the environmental impacts of international trade in a two-country (one rich, one poor), two-good (one whose production can, but need not, be dirty and one whose production is non-polluting) world where the rich country successfully adopts an environmental control programme while the poor country does not. They find several results:

1) The decision to use a dirty production process for dirty goods in a poor country will reduce the world price of that good and hence results in excess of world demand for the dirty good.
2) The poor country will produce more of the dirty good by using a dirty production process.
3) As a result, total world emissions of pollutants will be higher.
4) The consequence in the long run will be that the poor country will increase its comparative advantage in dirty goods by using dirty production processes, while the rich country will specialize in the other, less polluting product.

Baumol and Oates (1988) then claim that developed countries control pollution emissions. Developing countries will, therefore, become 'pollution havens'. Other theoretical studies (for example, Copeland, 1994) support the findings of Baumol and Oates (1988). However, the resulting pattern of production and trade is based on a general presumption that developing countries neglect the environment and pursue a pollution haven strategy which, according to Pearson (1987), is ill-founded.

The traditional approach to the trade–environment relationship declares that environmental damage is a result of market and government failures, or the existence of externalities, rather than the trade itself. Therefore the best solution is to internalize the externalities, that is, prices should reflect both private and social costs. Internalized social costs will generate higher prices for the environmentally damaging products and, as a result, will alter production, trade and investment patterns. However, the internalization is difficult to implement in reality. Runge (1994) points out that it is far easier to recommend that environmental externalities be 'internalized' than it is to implement and enforce internalization.

7.3 Empirical literature on FDI and environmental regulations

Recently, much of the literature on FDI has provided models of FDI that connect the sensitivity of investment location decisions to different factors, such as costs, infrastructures, local demand, and labour quality. A multinational firm is treated as one that wants to invest capital somewhere to maximize its profit, or to minimize production costs. The presumption is that production cost differentials are a sufficient inducement for a firm to relocate. Many empirical studies on FDI believe that stringent environmental regulations increase production costs by, for example, prohibiting certain inputs and outputs, demanding a levy for emissions that exceed certain standards, or requiring specific technologies to meet strict emission standards. Therefore, the multinational firm will locate in a region with weaker environmental standards. To examine the impact of environmental regulations on the location of FDI, we firstly introduce frameworks in FDI empirical research.

7.3.1 Three frameworks of foreign direct investment

In addition to the costs of the main factors of production which impact investment location choice, are there any other potential determinants that can influence an investment decision? Eskeland and Harrison (2003) concluded that there are three frameworks that explain the potential determinants of foreign investment.

The first is that the *factor proportions* explanation for trade can also be used to explain the pattern of foreign investment (Caves, 1982; Helpman, 1984; Brainard, 1993). If everything else is equal, foreign firms would like to locate in a country that has cheaper factors of those elements of production that they use in high proportions. Then the pattern of FDI can be captured through variables such as skill intensity, capital–labour ratio and wage differentials between countries.

Factor proportions alone, however, cannot satisfactorily explain foreign investment. Other foreign investment theories focus on the role of ownership. An important role is played by intangible assets such as superior knowledge and technology, and managerial abilities. This *intangible asset* theory of FDI was developed by Horstmann and Markusen (1989). To the extent that intangibles are usually linked to advanced technology, multinational firms may be better able to comply at a lower cost than local firms, thereby gaining a comparative advantage. Therefore, to capture the importance of intangibles as a motivation for FDI, a term is used when data are available.

The third framework is the *proximity-concentration trade-off* between multinational sales and trade, which is described in more detail by Brainard (1997). Some important factors (other than intangible assets and factor prices), such as tariff barriers and transport costs, will make firms locate near the target market. The protection of domestic markets has been one of the important attractions for foreign investment. Some trade measures, for example import penetration and export shares, are often employed to capture the importance of protected markets. Since there is a trade-off between the advantages of proximity and the benefits of concentration of production in one location in sectors where there are economies of scale, measures of economies of scale/concentration (for instance, the numbers of employees per plant) are important in such models.

7.3.2 Empirical evidence for the pollution haven hypothesis

Although there are many articles focusing on trade and the environment, few studies have looked at the relationship between FDI and environmental issues. Of those papers that do examine that relationship most of them are centred on US data, only a few studies look at developing countries and even fewer look at China.

Thus far, the empirical evidence for the existence of a consistent pollution haven effect is mixed. Generally, empirical studies suggest that there is little evidence to support the pollution haven hypothesis. Early non-parametric evaluations (Walter, 1982; Pearson, 1987) find that there is FDI in pollution-intensive industries but little evidence that it is influenced by differing pollution abatement costs, or has flowed faster into developing countries relative to industrial countries. Leonard (1988) finds evidence that governments in developing countries used lenient environmental regulations to attract FDI in the 1970s but that this incentive was not substantial enough to offset other main determinants of location, such as the level of training of labour, infrastructure and stability.

Dean *et al*. (2005) and Smarzynska-Javorcik and Wei (2005) summarize three approaches which have been adopted in recent econometric studies on whether or not FDI flows are a result of pollution haven effects. They are: (1) *inter-state plant location choice*; (2) *inter-industry FDI flows within a country* and; (3) *inter-country FDI location choice*. The results of these studies are mixed.

Using the first approach, Levinson (1996a) found little evidence that inter-state differences in environmental regulations affected US plant location choice. Levinson (1996b) employed a conditional logit model and found only one of six environmental stringency indicators had a significant but small impact on the location choice of new branch plants in the US. A similar approach was adopted by List and Co (2000), who estimated the effect of state environmental regulations on foreign multinational corporations' new plant location decisions from 1986 to 1993, using four measures of regulatory stringency. They found that environmental stringency and the attractiveness of a location are inversely related. Keller and Levinson (2002) tested whether FDI to US states responded significantly to relative changes in a state's environmental compliance costs. Keller and Levinson (2002) addressed the main drawbacks in previous studies. They controlled for unobserved heterogeneity among states and used a panel of pollution abatement cost indices that controlled for states' industrial composition. Their study robustly documents moderate effects of pollution abatement costs on capital and employees at foreign-owned manufacturing affiliates, particularly in pollution-intensive industries, and on the number of planned new foreign-owned manufacturing facilities. Similarly, Fredriksson *et al*. (2003), who used US state-level panel data from four industrial sectors over the period 1977–1987, found that environmental policy plays a significant role in determining the spatial allocation of inbound US FDI and that this effect depends critically on the exogeneity assumption of environmental policy.

There is a scarcity of research that assesses the relationship between the distribution of foreign investment and pollution intensity. One exception is the work of Eskeland and Harrison (2003), which adopted the second approach to examine the pattern of FDI across industries in Mexico, Venezuela, Morocco and Cote d'Ivoire. Their results suggest that it is difficult to find a robust relationship between pollution abatement and the volume of US outbound investment. They found a positive relationship between FDI share and the air pollution intensity of an industry but a negative relationship between FDI share and both water pollution and toxic release intensity. They also found that foreign ownership is associated with both lower levels of energy use and the use of cleaner types of energy. In addition, the results suggested that any impact of abatement costs on the distribution of FDI is small, if not zero. It is suggested that these results are because pollution abatement costs are only a small fraction of overall costs.

A paper employing the third approach is Xing and Kolstad (2002), which presents a statistical test on how US FDI is influenced by the environmental regulations of foreign host countries. To be specific, they have examined the relationship between the capital outflows of six US manufacturing sectors – including industries with high pollution control costs (chemicals and primary metals) as well as industries with more modest pollution control costs (electrical and non-electrical machinery, transportation equipment, and food products) – and the environmental policy of 22 destination countries. They argued that environmental regulatory stringency was not directly observed and hence used an instrumental variable approach to examine the effect of environmental regulations. The results showed that the laxity of environmental regulations in a host country is a significant determinant of FDI from the US for heavily polluting industries and is insignificant for less polluting industries.[3] Their findings provide indirect support for the pollution haven hypothesis. However, the small amount of data and the imperfect coverage of sulphur emissions data mean that care must be taken with the reliability of their results. A more recent paper, Smarzynska-Javorcik and Wei (2005) examined the relationship between cross-country FDI flows and environmental stringency for 143 multinational firms in 25 countries in Eastern Europe and the former Soviet Union. In this paper they emphasized a number of omitted variables from previous studies, such as bureaucratic corruption, which deters FDI but at the same time is correlated with the laxity of environmental protection. However, they found little evidence for the hypothesis that lower environmental standards attract investment, nor for the hypothesis that these countries are more attractive for pollution-intensive FDI. They found some evidence for the PHH when regressions employing treaties as the proxy for environmental standards in a host country, but the overall evidence is relatively weak and does not survive numerous robustness checks using other proxies of pollution intensity or regulatory stringency.

7.3.3 Empirical evidence on Chinese data

Recent empirical evidence on intra-country FDI location in China

Many researchers have focused on the geographical distribution of aggregate FDI flows among Chinese provinces. Wei *et al.* (1999) analyse the determinants of regional distribution of both pledged and realized FDI within China from 1985 to 1995. The unit root test results indicated the existence of a long-running relationship between the spatial distribution of FDI and a number of regional characteristics. The error components (random effect) model results suggest that pledged FDI is positively affected by the level of international trade, the number of scientists and researchers in total employment, GDP growth, preferential investment policy, improvement in infrastructure, and advances in agglomeration; while being negatively affected by wage rates and information costs. However, GDP growth, infrastructure and agglomeration do not have significant effects on realized FDI.

Using provincial data between 1990 and 1997, Coughlin and Segev (2000) examined the geographic pattern of FDI location within China. They extended the methodology of pervious studies by introducing some new control variables and testing the existence of spatial heterogeneity and spatial dependence. The ordinary least square (OLS) and spatial error regressions both suggest that only spatial dependence exists, that is, increased FDI in a province has positive effects on FDI in nearby provinces. Their findings on other control variables are consistent with past studies of FDI location choice among Chinese provinces and with studies of FDI location in general: economic size, productivity, and coastal location are positive determinants of FDI location; wage and illiteracy rates are negative determinants; and their infrastructure measures do not have significant effects on FDI.

Cheng and Kwan (2000) employed a dynamic model of foreign investment and use a Generalized Method of Moment (GMM) estimator to investigate the impact of the determinants on the stock of FDI in

29 Chinese regions from 1985 to 1995, and found that a large regional market, good infrastructure, and preferential policies have positive effects but that wages have a negative effect on FDI. The effect of education is positive but not significant. They also found a strong self-reinforcing effect of FDI on itself.

Gao (2002) concentrated on the effect of labour quality on the location of FDI within China from 1996 to 1999. Gao (2002) employed OLS, between effects, fixed effects, and random effects models and found that labour quality plays a significant and positive role in attracting FDI. The evidence in this paper also indicates that the location of FDI from developed economies, such as US and Japan, is more sensitive to labour quality than FDI from Asian developing economies. However, wages are not found to be a significant determinant and even have a positive coefficient in some specifications.

In a similar paper, Fung *et al.* (2002) examined the determinants of US and Japanese FDI location among Chinese regions from 1991 to 1997 using a generalized least square estimator and compared the results with investments from Hong Kong and Taiwan. GDP and certain policy variables were found to have significant positive impacts on inflows of FDI. Labour quality exerted a larger influence on Japanese investment than on US investment. Lagged wages are negatively related to FDI. However, compared with investment from Hong Kong and Taiwan, US and Japanese investments are more sensitive to local markets because they are mostly producing for the domestic Chinese market while FDI from Hong Kong and Taiwan is mostly producing for export. Labour quality does not have a strong influence on FDI inflows from Hong Kong and Taiwan because such investment is more concentrated in labour intensive industries that require relatively low labour skills. Additionally, a good infrastructure has a strong effect of FDI from Hong Kong and Taiwan but only a moderate effect on US investment and no effect on Japanese investment. Fung *et al.* (2003) examined the determinants of Japanese FDI in China using a regional dataset from 1990 to 2000 and formed a comparison with investment from Hong Kong. The main results were similar to those in Fung *et al.* (2002).

Amiti and Javorcik (2008) is the most recent paper to examine the determinants of entry by foreign firms using a comprehensive dataset, which includes 515 industries in 29 Chinese provinces during 1998– 2001. The analysis was based on a new economic geography model and focused on the relative importance of market and supplier access within and outside the province of entry, as well as trade costs and factor costs. The non-linear least square results suggest that market access and supplier access are the key determinants of FDI inflows. The presence of customers and suppliers in the province of entry matters more than the market and supplier access to the rest of China, which is consistent with market fragmentation in China due to underdeveloped transport infrastructure and informal trade barriers. In addition, production costs also play an important role in determining the location of FDI, but the effects are only around a quarter of the market and supplier access effects.

Using a comprehensive dataset of Chinese provinces, Chen (2009) investigated the agglomeration effect within and across regions on FDI location choice from three aspects, including regional and neighbouring urbanization, industrial concentration and foreign-specific agglomeration. The results suggest the existence of both within and across region agglomeration effects. All three measures of local agglomeration have a strong and positive impact on local FDI and industrial FDI location. It means that local provinces need to coordinate closely with their neighbouring provinces to attract more foreign investment. Urbanization and industrial specialization can significantly promote FDI inflows. Chen (2009) also found that education and government policy are beneficial for FDI inflows. Other variables, such as market size, wage, road density and trade cost, also have a significant impact on FDI location.

Empirical evidence on intra-country pollution havens in China

Di (2007) examined the relationship between abatement cost savings and FDI location choice among Chinese provinces using a nested logit model. After controlling the pollution intensity of industries, Di (2007) found that FDI in polluting industries tends to locate to regions with laxer environmental regulations. These dirty firms are more likely to locate in less-developed regions and are more sensitive to regulations, and prefer regions where they have more bargaining power with local government. Dean *et al.* (2009) further considered the origins of equity joint ventures (EJVs) in China, and find that HMT-funded EJVs in highly polluting industries are attracted by weak environmental standards but non-HMT-funded EJVs are not, regardless of the pollution intensity of the industry.

A recent study that searched for empirical evidence of intra-country pollution havens in China is Dean *et al.* (2009). In this study they estimated whether weak environmental regulations attracted foreign investment in China. Dean *et al.* (2009) derived a location choice model containing a firm's production and abatement decisions, agglomeration and factor abundance. They estimated a conditional logit model using a dataset that included information on 2,886 manufacturing joint venture projects, effective environmental levies on water pollution, and estimates of Chinese emissions and abatement costs across 3-digit ISIC industries and provinces between 1993 and 1996.[4] The results show that FDI flows to provinces with a high concentration of foreign investment, a relative abundance of skilled labour, a concentration of potential local suppliers, special tax incentives, and less state ownership. Environmental stringency only affects certain types of projects in highly polluting industries when investment originates from Hong Kong, Macao, and Taiwan, who are seemingly attracted to provinces with relatively weak environmental controls. This finding is consistent with the pollution haven hypothesis but contradicts the notion that pollution havens are generated by industrial country investors. In contrast, investment from non-Chinese sources appears not to be attracted by low levels of pollution levies, regardless of the pollution intensity of the industry. This is opposite to the pollution haven hypothesis. In sum, the results suggest little evidence for the pollution haven hypothesis.

7.4 Conclusions

The general lack of support for the pollution haven hypothesis in previous studies can be summarized as follows:

> First, as Pearson pointed out, 'environmental control costs are a small fraction of production costs in virtually every industry, and the effect on trade will be correspondingly small'.[5] This is reinforced by the results of Eskeland and Harrison (1997), where the empirical results show that environment costs may be too small relative to overall costs to impact the location decision. Second, FDI may be combined with new techniques, including the latest abatement technologies, rendering the relative stringency of the host country's environmental regulations unimportant. Third, if firms are producing for export, then they may have to meet the environmental product standards of developed countries in order to gain the access to these markets. Finally, firms may predict that there will be future increases in environmental regulations, and hence choose a production process today that will meet the higher standards of the future (Dean *et al.*, 2002).

Smarzynska-Javorcik and Wei (2001) point out there are two possible ways to summarize the existing empirical studies on pollution haven hypothesis. 'The first possibility is that the "pollution haven" hypothesis is after all just a popular myth that does not hold in reality. An alternative view is that the "pollution haven" hypothesis is valid but the empirical researchers have not tried hard enough to uncover this "dirty secret".'[6] There exist several weaknesses in previous studies that may have impeded the exposure of the 'dirty secret'.

First, in some studies, the absence of some important variables, such as relative factor abundance and agglomeration, will lead to omitted variable bias. Markusen and Zhang (1999), Head and Ries (1996), and Cheng and Kwan (2000) have demonstrated the importance of these variables in explaining FDI incidence (Dean *et al.* 2009).

Second, it is difficult to quantify international differences in environmental regulations (Smarzynska-Javorcik and Wei, 2001; Keller and Levinson, 2002). 'This difficulty is further exacerbated by the possibility that laws on the book may not be the laws that are actually enforced.'[7]

Third, Keller and Levinson (2002) and Levinson and Taylor (2008) both demonstrate that cross section analyses cannot control for unobserved heterogeneity among countries. These unobserved characteristics, such as unobserved resources and unobserved protection of polluting industries, may be correlated with both regulatory compliance costs and investment. If the estimation does not allow for these unobserved characteristics, it will generate an omitted variable bias to the predicted effect of regulatory compliances costs on investment. Therefore, using a continuous, time-varying (panel) dataset becomes important.

Finally, most literature uses cost based measures of environmental standard stringency. Copeland and Taylor (2003) developed a model linking a firm's production and abatement costs. It suggests a particular specification for testing a firm's responsiveness to changes in environmental regulations, which raises the possibility of specification error.

In Chapter 8, we address a number of these limitations by adopting a five-year panel dataset for 30 provinces in China that includes three measures of environmental regulations that vary across time and province, and a significant number of control variables, including measures of agglomeration and factor abundance. We control for unobserved heterogeneity by using the feasible generalized least square estimator.

8
Do Intra-Country Pollution Havens Exist?

8.1 Introduction

China has, in recent years, been one of the largest recipients of worldwide FDI inflows. However, there remains a significant disparity in the geographical distribution of FDI inflows within China. The majority of the FDI is concentrated in the eastern regions. Similarly, pollution emissions vary across regions. Simultaneously, China's environmental regulation standards are relatively weaker than those in developed countries, and the strength of the enforcement of those regulations is different across regions.

Using provincial socioeconomic and environmental data, this chapter investigates whether there exists an intra-country pollution haven effect in China. It therefore examines whether differences in the stringency of environmental regulations affect the choice of location for FDI in China.

We employed three measures of regional environmental stringency that vary across time and province. The first measure is the level of industrial pollution treatment investment by province, the second is the number of administrative punishment cases related to environmental issues by province, and the third is the average level of pollution emission charges by province. We also included a standard set of control variables that capture differences in income, labour costs and quality, infrastructure, agglomeration, population density, and so on between the provinces.

Our results suggest that environmental stringency does have a significant and negative effect on FDI, leading us to conclude that, *ceteris paribus*, FDI prefers to locate in regions with relatively weak environmental regulations, which provides some support for the existence of a pollution haven consistent effect within China.

This chapter is organized as follows. Section 8.2 presents the methodology and data, while Section 8.3 reports on and discusses the empirical results, with a final, concluding Section 8.4.

8.2 Methodology

We followed the methodology of previous studies on inter-state plant location choice and investigated the interaction between FDI flows and environmental regulations in China. This section firstly introduces the empirical models. It then explains how we constructed the explained and explanatory variables and how these variables capture provincial characteristics. Finally, a description of the data used in the empirical estimation is provided with some discussion on the selection of the estimators.

8.2.1 Estimating models

Esty and Gentry (1997) and Aliyu (2005) outline four types of FDI: market seeking, production platform seeking, resource seeking and low cost seeking. A MNC will view and compare different locations to assess differences in, for example, production costs, market size, government regulations, infrastructure, agglomeration effects and so on. To examine whether FDI is attracted to provinces with relatively weaker environmental enforcement, we observed the location of FDI across 30 administrative areas (for simplicity we refer to these as regions/provinces).[1]

An empirical model that is adopted by some FDI researchers is given by

$$FDI = f(X, \eta, \gamma) \tag{8.1}$$

where X is a vector of regional characteristics that may affect the inflows of FDI; η is the unobserved provincial/regional effect; and γ is the unobserved time effect.

When considering the impact of environmental regulations on foreign plant location choice, a variable ***ER*** (the vector of level of environmental stringency) is included in Equation 8.1 to give:

$$FDI = f(ER, X, \eta, \gamma) \tag{8.2}$$

where *FDI* is the amount of FDI inflow into region *i* in time period *t*; *ER* is the vector of measures to capture environmental stringency; X is the set of other regional characteristics that may affect FDI; η is the time-invariant regional effect; γ is the location-invariant time effect; and ε is the idiosyncratic error term.

FDI inflows are captured from the actually used values of FDI according to agreements and contracts. It measures the total amount of new FDI for the year, including investment from Hong Kong, Taiwan and Macao, and investment from foreign countries. The data are aggregated, comprising investment in all the sectors of the economy. FDI inflows cannot be broken down by source country or by industrial sector as a result of data unavailability.

Since the regions vary in size, we normalize the actually used FDI inflows by two measures of regional size, one is the value of FDI divided by regional GDP (*FDI/GDP*) and the other is FDI divided by regional population (*FDI/POP*). Scaling FDI by GDP or population does not affect the absolute value of FDI but allows FDI to be comparable across regions and time (see Appendix 8.1 for variable definitions and sources).

Factors that may influence provincial level FDI include environmental stringency, factor prices, infrastructure, and agglomeration effects.

The level of environmental stringency in different provinces is proxied by three variables:

- *EI1* – the share of investment in industrial pollution treatment projects as part of total innovation investment. Industrial pollution treatment investment is the total investment of enterprises in construction and installation projects, and purchasing of equipment and instruments required in pollution harnessing projects for the treatment of wastewater, waste gas, solid waste, noise and other pollution. Industrial pollution treatment investment is accounted in innovation investment, which is one part of the total investment in fixed assets. Environmental regulations require that pollution treatment facilities have to be designed, constructed and operated simultaneously with the design, construction and operation of the main project production line. A region with more stringent environmental regulations is expected to have relatively more investment in pollution treatment projects. Therefore, investment pollution treatment projects can be treated as environmental protection costs in any production project. We used the share of industrial pollution treatment investment in innovation investment to reflect local government effort on environmental protection. Since a small fraction of the sources of industrial pollution treatment investment comes from state budgetary appropriation of capital construction investment, in our sensitivity analysis we normalized industrial pollution treatment investment by the sum of investment in innovation and capital construction (*EI2*) and also by total investment in fixed assets (*EI3*). Details are in Appendix 8.2.

- *Punish* – the total number of administrative punishment cases filed by environmental authorities in each region normalized by the number of enterprises in that region.[2] Administrative punishment cases are those cases that breach environmental protection laws and regulations. According to the Measures on Administrative Penalty for Environmental Offences, the types of administrative punishment include: (1) warning; (2) fine; (3) confiscation of illegal gains; (4) compelling to stop producing or using; (5) revoking licence/permit or other permission certificates; and (6) other types of administrative punishments from the EPL's laws and regulations. If the environmental illegal activity transgresses criminal law and the enterprise is suspected of a crime, the case should be transferred to a judicial authority to investigate the criminal responsibility according to law. We normalized the number of cases by the number of enterprises. It is possible that the normalized punishment cases captured the level of firms violating the environmental regulations. However, given the generally weak environmental regulation stringency in China, we expect that in regions where more enterprises are punished, the environmental regulations are more stringently applied. *Punish* measures the prosecution costs against firms that breach the laws and regulations and hence is a proxy for the strength of enforcement of regional environmental legislation.
- *Charge* – a pollution emission charge normalized by the number of organizations that paid this charge. Pollution emission charge refers to the total amount of (1) pollutant emission charges exceeding the discharge standards; (2) sewage discharge levy; and (3) another four kinds of charges, including increasing levy standards, double charges, overdue charges and compensation fines. Pollutants include water and air pollution, solid waste, noise and others. Although supervised by central government, the pollution charge is implemented by regional governments. *Charge* measures the penalty cost to firms if they emit pollutants above the emission standards. Therefore it reflects provincial differences in implementation of the pollution levy system.

These three measures are time variables, which improves upon the 0–3 type of measure of environmental stringency used in Smarzynska-Javorcik and Wei (2005). Since more stringent environmental regulations will generate higher pollution taxes or higher pollution abatement costs for the firm, the environmental regulation stringency variables should have a similar impact to factor prices on foreign investment location choice. It is expected that FDI is attracted to provinces with weaker regulations, as in a lower share of investment in industrial pollution treatment investment, with a lower number of normalized administrative punishment cases related to environmental issues, and/or with a lower normalized pollution emission charge.

Since the pollution emission charge is more visible to enterprises than administrative punishment cases and environmental investment, we expect that *Charge* has the strongest impact on FDI location choice, followed by *Punish* and *EI1*, respectively.

Our control variables are as follows:

Manufacturing wage is included as a proxy for factor price differences across each region. The quality of labour force in a region is captured by two measures, labour productivity and illiteracy rate. Population density is employed as a proxy for land prices and potential market size (assuming that labour mobility between provinces is low). The availability and quality of infrastructure also impacts the overall cost of doing business and hence is an important factor to FDI location. We included both railway density and road density to measure the quality of regional transportation networks and thus to proxy the cost and availability of material inputs. Gross regional product (*GRP*) per capita is included to capture the average quality of the government, general infrastructure and the effect of market size differences across regions. We used regional gross industrial product (GIP) to capture the industrial agglomeration effect whereby firms locate where hubs of economic activity already exist (Bartik, 1988). GIP measures the concentration of whole industrial sectors and also the regional availability to provide intermediate inputs.[3]

The regional fixed effects capture the effects specific to each region that do not change over time (including the unobserved preferential policies such as tax benefits and subsidies to foreign firms and exports). The year specific effects measure any effects that are common to all provinces but which change over time.

According to the literature, foreign investors seek locations with comparative advantages, such as the cheapness of factors that they use in higher proportions. It is expected that foreign investment will be attracted to provinces with relatively low labour costs, like low wages. there is a positive relationship between wages and local income levels. Some empirical studies on intra-country FDI flows, such as Wei *et al.* (1999), Coughlin and Segev (2000), Cheng and Kwan (2000), and Fung *et al.* (2003), find significantly negative effects of wages on aggregate FDI flows in China. Conversely, wages are also found to be positively related to FDI flows (Gao, 2002). To specify the real impact of wages on FDI inflows, we addeds wage squared to our estimations and expected an inverted-U relationship between FDI and wages. When wages are below a benchmark, foreign investors are attracted to provinces with high wage levels because labour cost is not the most important determinant compared to other factors, such as high regional income and good infrastructure. But when wages are above the benchmark, FDI is deterred by wages because they become more important to the standard profit function.

Since low labour cost is associated with low labour quality, foreign investment will be attracted by high illiteracy rate and/or low labour quality. However, some previous studies, such as Cheng and Kwan (2000), Gao (2002), and Fung *et al.* (2002), found that FDI prefers to locate to regions that have a high percentage of enrolment in higher education. Therefore, the impact of illiteracy rates and productivity are ambiguous.

According to work by Head and Ries (1996) and Dean *et al.* (2005), it is expected that FDI would flow into provinces with better industrial agglomeration and infrastructure. Therefore we expected a positive coefficient on *GIP* and transportation infrastructure variables. In addition, foreign investors seeking a large local market would be expected to invest in areas that have a large consumption capability and potential, which can be proxied by population density and per capita income. However, population density also proxies land price. In more densely populated areas, land price is usually higher than in less densely populated areas. The sign of the coefficient on population density is ambiguous.

Our five-year time period panel of data helped to control for unobserved heterogeneity. We presumed that all the control variables were exogenous. However, environmental regulation stringency may be endogenous partly because the regions with relatively low FDI inflows may lower their environmental regulation standards in order to attract more FDI, and partly because FDI is an important engine of growth and hence helps to improve regional environment and environmental standards. Simultaneously, FDI could have an impact on other control variables, such as income, wages, population density and infrastructure quality. We therefore employed a one-year lag for all independent variables to minimize any possible causality links from FDI to the explanatory variables. Another reason to lag the independent variables is that the impact of these variables on FDI is unlikely to be immediate.

The estimating equation is therefore:

$$\ln(FDI_{it}) = \alpha + \beta_1 \ln(ER_{it-1}) + \beta_2 \ln(\text{GRP per Capita}_{it-1}) + \beta_3 \ln(Wage_{it-1}) + \beta_4 (\ln(Wage_{it-1}))^2 + \beta_5 \ln(GIP_{it-1}) + \beta_6 \ln(\text{Pop. Density}_{it-1}) + \beta_7 \ln(\text{Rail Density}_{it-1}) + \beta_8 \ln(\text{Road Density}_{it-1}) + \beta_9 \ln(\text{Illiterate Rate}_{it-1}) + \beta_{10} \ln(\text{Productivity}_{it-1}) + \eta_i + \gamma_t + \varepsilon_{it} \quad (12)$$

where i refers to province, t refers to year.

We first regressed the model, only including the major explanatory variable *ER*, and then adding the control variables one by one in accordance with the selection of control variables in previous studies on China's intra-country FDI location choice. Regional GDP per capita and wage rate are commonly used determinants of FDI and so we introduced them into the model as control variables from the beginning. GIP and population density are omitted in many studies. We therefore add them next in order to check whether they had significant and stable impacts on FDI. Infrastructure variables and labour quality variables were also controlled in some previous studies and their selection usually depended on the emphasis of the papers. We therefore include these variables later on in the regressions. In addition, adding the independent variables incrementally is helpful to finding out whether *ERs* have stable and significant effects on FDI inflows.

We used the log transformation model which could help to correct the positive skewness of variables and make the error term close to homoskedestic.[4]

If there is no effect of the stringency of environmental regulations on FDI across regions, we would expect $\beta_1 = 0$. If $\beta_1 < 0$, we cannot reject the hypothesis that FDI is attracted to provinces with lower regulatory stringency.

The expected signs of the coefficients were as follows:

Coefficients	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}
Expected Signs	−	+	+	−	+	−/+	+	+	−/+	−/+

8.2.2 Data description

A complete description of definitions and sources for all the variables is provided in Appendix 8.1. The China Statistical Yearbook (various years) was used to compile data on manufacturing wages, illiteracy rate, infrastructure, agglomeration, market size and population data. The China Industrial Economy Statistical Yearbooks provided the labour productivity for all foreign funded enterprises. The raw data for the three environmental regulation standard variables were collected from the China Environment Yearbook. Because one-year lags are used for all independent variables in the estimation, all the independent variables for 30 regions are taken from 1998–2002. FDI data used for estimations are therefore from 1999–2003.

To gauge the consistency of the sample with what is known about the provincial distribution of foreign investment, Table 8.1 compares the provincial shares of total actually used FDI values in the sample.

Table 8.1 FDI distribution by province, 1997–2003

Province	**FDI at 1990 constant price (USD 10 000)**	**FDI at 1990 constant price (RMB 10 000)**	**Shares of National FDI (per cent)**
Beijing	10611	58152	**4.07**
Tianjin	10425	56729	**3.97**
Hebei	5433	29560	2.07
Shanxi	1453	7937	0.56
Inner Mongolia	569	3139	0.22
Liaoning	13082	71982	**5.04**
Jilin	1814	9862	0.69
Heilongjiang	2370	12819	0.90
Shanghai	22473	123330	**8.63**
Jiangsu	41995	231648	**16.21**
Zhejiang	12695	70472	**4.93**
Anhui	1926	10536	0.74
Fujian	21328	116404	**8.15**
Jiangxi	3643	20225	1.42
Shandong	19362	107168	**7.50**
Henan	3089	16822	1.18
Hubei	6275	34616	2.42
Hunan	4687	25673	1.80
Guangdong	63197	345308	**24.17**
Guangxi	3397	18377	1.29
Hainan	3047	16568	1.16
Chongqing	1644	8921	0.62
Sichuan	2374	13100	0.92
Guizhou	222	1208	0.08
Yunnan	698	3789	0.27
Tibet	0	0	0.00
Shaanxi	2036	11064	0.77
Gansu	277	1523	0.11
Qinghai	91	514	0.04
Ningxia	122	671	0.05
Xinjiang	117	640	0.04
Sum	**260450**	**1428755**	**100**

It illustrates, consistent with Figure 2.7, that most FDI inflows were located in eastern regions/provinces: Guangdong; Jiangsu; Shanghai; Fujian; Shandong; Liaoning; Zhejiang; and Beijing.

Table 8.2 (were all values are at 1990 constant price) shows the summary data for the provincial characteristics in 2002.[5] The maximum value of *EI1* is found in Ningxia with RMB 910 per RMB 10,000 innovation investment, while the lowest investment share is only RMB 31.65 in Shanghai. For *Punish* the most stringent province is Heilongjiang with 5,877 cases per 1,000 enterprises, and the weakest province is Qinghai with 75. In terms of *Charge*, Shanghai is the most stringent province, where the charge is more than RMB 32,793 per organization, and Hainan is the lowest with a charge of RMB 2,775 per organization. We found that the values of our three environmental stringency variables varied widely between provinces, and a province could appear to be stringent using one measure of environmental regulations but not when using another. The correlation matrix (see Table 8.3) shows that these three environmental stringency variables do not have a strong correlation and we even find an insignificant negative correlation between *Punish* and *Charge*.

The correlation matrix also shows that our FDI variables seem to have a negative correlation with *EI* and *Punish*, but a positive correlation with *Charge*. The correlations between the two FDI variables and other independent variables implies that FDI prefers to flow into provinces with better infrastructure, higher population density, higher income level, better agglomeration, higher quality of labour and higher labour costs.

There is possible endogeneity between environment regulation and FDI. We considered the two-way causality using an instrumental variable approach. The endogeneity test suggests that of our three environmental variables, two are exogenous and only EI is endogenous. We found consistent negative and significant effects of EI on FDI inflows using the instrumental variables approach. However, the result is sensitive to the selection of instrumental variables and estimators. Therefore in this chapter we report estimated results based on one-way causality from environmental regulations to FDI.

The correlation matrix shows that per capita income is highly correlated with wages, population density and infrastructure variables, probably because per capita income might encompass similar things. So the effect of income on FDI is probably accompanied by strong side effects via these variables. Due to their importance, and the availability of data, we could not drop any of these variables or enlarge the sample size to remedy this multicollinearity problem. However, multicollinearity does not actually bias the results but just produces large standard errors for income

Table 8.2 Provincial characteristics in 2002 (all values are at 1990 constant price)

Province	FDI/GDP* (yuan/ 10000 yuan)	FDI/ POP (yuan)	EI1 (yuan/ 10000 yuan)	Punish (case/1000 firms)	Charge (yuan/ organization)	GRP per capita (yuan)	Manufacturing Wage (yuan)	GIP (100 million yuan)	Population Density (persons per km^2)	Rail Density (km/ $10000km^2$)	Road Density (km/ $10000km^2$)	Illiterate Rate (per cent)	Productivity (yuan/ person)
Beijing	495	657	315	229	18916	15312	9497	1708	847	677	8547	5.4	66663
Tianjin	519	663	611	256	8907	12045	7663	1789	891	603	8581	6.7	61220
Hebei	112	62	262	433	7266	4906	4736	2311	354	241	3320	7.8	42067
Shanxi	72	28	418	822	9010	3308	4260	925	211	196	3821	6.4	47136
In. Mongolia	34	16	197	1165	4327	3897	4388	535	22	56	661	13.5	51482
Liaoning	389	293	280	4451	11147	6989	5657	2631	288	261	3298	5.2	44956
Jilin	63	31	305	524	5662	4485	5487	1169	144	190	2198	4.4	113101
Heilongjiang	60	37	703	5877	6836	5481	4735	1339	81	117	1344	6.5	46886
Shanghai	724	1395	32	176	32794	21876	11885	4166	2621	414	10139	8.2	66363
Jiangsu	702	623	166	264	13918	7745	6200	7463	719	131	5862	14.3	53099
Zhejiang	439	465	294	268	3839	9062	7157	5263	456	128	4484	13.5	32884
Anhui	77	25	191	412	5395	3131	4497	1143	456	160	4860	17.9	60328
Fujian	411	325	326	267	7084	7264	6133	1979	289	121	4513	13.7	37445
Jiangxi	471	165	72	460	4041	3137	4475	640	253	142	3643	10.8	26283
Shandong	400	288	484	267	14681	6267	4716	6188	594	187	4839	11.2	35999
Henan	63	24	313	512	9241	3464	4218	2316	576	215	4296	9.1	43656
Hubei	240	114	222	456	6090	4477	4793	1932	320	127	4594	15.1	63844
Hunan	182	67	202	660	6195	3533	5337	1130	316	131	4038	8.4	41774
Guangdong	475	429	210	195	5947	8089	7912	8815	423	113	5835	7.0	35459
Guangxi	127	38	151	411	6619	2744	5360	635	210	119	2448	9.5	47779
Hainan	520	227	78	133	2775	4200	5053	142	236	63	6140	8.9	42054
Chongqing	96	36	142	832	11117	3416	5497	661	379	88	3788	10.3	59041
Sichuan	63	21	264	255	4628	3103	5303	1473	178	60	2293	13.6	49243
Guizhou	28	5	157	156	5269	1697	5019	429	226	111	2601	18.7	9276
Yunnan	28	8	309	113	7200	2787	6343	711	110	60	4184	23.1	55359
Shaanxi	115	39	226	955	5470	2973	5058	810	179	141	2271	15.6	99224
Gansu	15	4	373	225	6630	2418	5427	557	58	52	894	21.1	39205
Qinghai	54	21	110	75	3827	3459	5821	112	7	15	333	24.8	81609
Ningxia	37	13	910	1389	9864	3124	5142	145	87	119	1704	17.5	38201
Xinjiang	7	3	147	243	4455	4511	5590	494	12	17	518	8.2	34454

Table 8.3 Variables correlation

	FDI/GDP	**FDI/POP**	**EI1**	**Punish**	**Charge**	**GRP per capita**	**Wage**	**(Wage)^2**	**GIP**	**Pop. density**	**Rail density**	**Road density**	**Illiterate rate**	**Productivity**
FDI/GDP	1.000													
FDI/POP	0.859	1.000												
EI1	–0.095	–0.120	1.000											
Punish	–0.108	–0.113	0.154	1.000										
Charge	0.294	0.601	0.060	–0.014	1.000									
GRP per capita	0.617	0.904	–0.084	–0.029	0.700	1.000								
Wage	0.511	0.781	–0.108	–0.062	0.568	0.862	1.000							
(Wage)^2	0.475	0.791	–0.134	–0.108	–0.162	–0.083	0.654	1.000						
GIP	0.544	0.553	0.019	–0.027	0.409	0.488	0.433	0.409	1.000					
Pop. density	0.502	0.807	–0.143	–0.157	0.801	0.865	0.674	0.742	0.429	1.000				
Rail density	0.393	0.616	–0.010	0.007	0.465	0.723	0.555	0.571	0.120	0.606	1.000			
Road density	0.697	0.798	–0.098	–0.173	0.538	0.771	0.695	0.701	0.456	0.729	0.723	1.000		
Illiterate rate	–0.321	–0.353	0.004	–0.229	–0.150	–0.421	–0.345	–0.322	–0.266	–0.279	–0.451	–0.430	1.000	
Productivity	0.007	0.148	–0.114	0.054	0.114	0.253	0.359	0.334	–0.002	0.181	0.251	0.159	–0.147	1.000

variables, which may cause income to become insignificant. We estimated the model using a generalized least square estimator, which produced better results than an ordinary least square estimator (see Section 8.2.3).

The values of all the data are deflated by the GDP deflator, which is set to 100 for the year 1990.[6] All the FDI data, measured in US dollars, are converted to RMB at the average rate of the year. Table 8.4 provides the descriptive statistics for each of our variables.

8.2.3 Selection of estimators

A problem faced when estimating the model is whether the unobserved individual-specific effects and time effects (η_i and γ_t) should be treated as random variables or as parameters to be estimated for each cross region observation *i* and time *t*. In this chapter we estimate both two-way fixed effects and random effects error component models. For our fixed effects models we initially used the within regression estimator, which is a pooled OLS estimator based on time-demeaned variables, and then we used the time variation in both dependent and independent variables within each cross-sectional observation (Wooldridge, 2000). For our random effects models we chose the generalized least square (GLS) estimator, which produces a matrix-weighted average of the between and within estimator results.[7]

Few assumptions are required to justify the fixed effects estimator. In the estimation, however, η_i and γ_t are not assumed to have a distribution, but are treated as fixed and estimatable. The random effects estimator requires no correlation assumptions, that is η_i ~IID $(0,\sigma_\eta^2)$, γ_t ~IID $(0,\sigma_\gamma^2)$, and ε_{it} ~IID $(0,\sigma_\varepsilon^2)$ are independent of each other. In addition, all the independent variables (***ER*** and ***X*** in Equation 2.4.2) are independent of η_i, γ_t, and ε_{it} for all *i* and *t*.

In order to calculate whether ε_{it} is uncorrelated with the independent variables, we used the Hausman specification test under the null hypothesis H_0: $E(\varepsilon_{it} | X_{it}) = 0$.[8] We compared the covariance matrix of the regressors in the fixed effects model with those in the random effects model in order to find out whether the random effects specification is powerful and parsimonious. The Hausman specification test results are reported in Appendix 8.3. The results of the Hausman specification tests suggest that, in most cases, the individual effects and time effects could be adequately modelled by random effects models.

When using data on different provinces with a variation of scale, the variance for each of the panels will differ. The Breusch-Pagan test results reject the null hypothesis of homoskedasticity in our models. Both the fixed effects and random effects estimators can solve the problem of

Table 8.4 Descriptive statistics of the variables

Variable	Obs.	Mean	Std. Dev.	Min.	Medium	Max.
FDI/GDP (FDI in RMB per 10 000 RMB yuan GDP)	149	265.80	271.11	6.76	140.66	1140.13
FDI/POP (FDI in RMB per capita)	149	188.62	276.04	3.19	42.89	1395.25
EI1 (RMB per 10 000 RMB yuan innovation investment)	150	342.20	216.12	31.65	289.32	1163.74
EI2 (yuan per 10 000 RMB yuan Inno.Inv.+ Capital Construction Inv.)	150	92.63	57.22	6.19	80.43	285.53
EI3 (yuan per 10 000 RMB yuan total investment in fixed assets)	150	55.04	35.78	4.46	44.71	185.08
Punish (Cases per 1000 enterprises)	148	452.34	701.53	29.18	267.30	5877.36
Charge (RMB yuan per organization)	150	4319.00	2363.26	1467.24	3679.30	17649.92
GRP per capita (RMB yuan)	150	4765.65	3591.10	1255.09	3376.21	21876.21
Wage (RMB yuan at 1990 price)	150	4720.76	1549.53	2614.68	4399.02	11885.36
GIP (100 million RMB yuan at 1990 price)	150	1556.23	1713.53	79.41	912.00	8815.18
Pop. Density (persons per km^2)	150	376.11	460.55	6.99	251.56	2700.00
Rail Density (km/10 000 km^2)	150	151.39	145.08	8.38	109.65	690.83
Road Density (km/10 000 km^2)	150	3341.10	2110.37	204.76	3053.05	10138.71
Illiterate Rate (per cent)	150	13.13	6.46	4.36	12.11	42.92
Productivity (RMB yuan/person at 1990 price)	150	41039.37	18996.94	9276.10	35999.46	156645.80

heteroskedasticity across panels. However, neither controls for possible autocorrelation within the panels. In order to test whether or not the errors follow an autoregressive process of order one AR(1), we apply the following dynamic regression model:

$$\varepsilon_{it} = \rho\varepsilon_{it-1} + \nu_{it}, t = 2,\ldots,T \tag{8.4}$$

where $|\rho| < 1$ and $\nu_{it} \sim$ IID(0, σ_ν^2).

The null hypothesis is H_0: $\rho = 0$. Thus, ρ should be estimated from the regression of ε_{it} on ε_{it-1}, for all $t = 2, \ldots,$ T. The t statistics (see Table 8.5) for $\hat{\rho}$ show that we reject the null hypothesis for all log models. That is, there is AR(1) autocorrelation within panels in our log specifications.

One solution of AR(1) autocorrelation is to include the lagged dependent variables in the right hand side of Equation 8.3 and construct a dynamic model. In that case, an alternative estimation method is the system Generalized Method of Moment (GMM) estimator by Blundell and Bond (1998) for AR(1) panel data models. System GMM estimator can tackle the problems of heteroskedasticity and autocorrelation as well as the endogeneity of variables. However, GMM estimator requires two or more lags of all the right hand side variables as instruments. Due to our relatively short panel we cannot use the GMM estimator.

Another solution is to use the feasible generalized least square (FGLS) estimator. In this study, we have a large number of panels (30 provinces) relative to time period (5 years). The FGLS estimator is appropriate for such a case.[9] FGLS models allow cross-sectional correlation and heteroskedasticity. It also allows models with heteroskedasticity and no cross-sectional correlation. In addition, it is possible to relax the assumption of autocorrelation within panels. FGLS is therefore more efficient than the other two estimators mentioned above.

Since the GLS estimator is less efficient than the FGLS estimator, the random effects results are relatively weak even though the GLS estimator is not rejected in most specifications by the Hausman specification tests. We therefore concentrated on the FGLS estimation results. Estimations are run using Stata 9.[10]

8.3 Empirical results

We only report the FGLS log results because of the advantages outlined above. We also include a series of sensitivity checks. For example, we normalized industrial pollution treatment investment by the sum of investment in innovation and capital construction (*EI2*), and by the total investment in fixed assets (*EI3*). Results from the sensitivity checks

Table 8.5 Autocorrelation tests

	Levels					
	EI1		***Punish***		***Charge***	
	FDI/GDP	**FDI/POP**	**FDI/GDP**	**FDI/POP**	**FDI/GDP**	**FDI/POP**
$\hat{\rho}$	0.064	–0.136	0.076	–0.129	0.067	–0.142
T Statistics	0.67	–1.38	0.79	–1.30	0.70	–1.44
p-value	0.504	0.169	0.430	0.197	0.488	0.153
	Logs					
	EI1		***Punish***		***Charge***	
	FDI/GDP	**FDI/POP**	**FDI/GDP**	**FDI/POP**	**FDI/GDP**	**FDI/POP**
$\hat{\rho}$	0.258	0.254	0.265	0.260	0.220	0.218
t Statistics	2.92	2.86	2.97	2.91	2.54	2.50
p-value	0.004	0.005	0.004	0.004	0.012	0.014

are broadly similar to our main results. In this section, we also compare our main results with those of previous empirical studies.

Tables 8.6–8.11 present the FGLS regression results for the impact of different levels of environmental stringency on two measures of provincial FDI inflows using data in logs for thirty provinces. Tables 8.6 and 8.7 are the results for *EI1*, Tables 8.8 and 8.9 for *Punish*, and Tables 8.10 and 8.11 for *Charge*.[11]

In Table 8.6, the dependent variable is the amount of FDI inflow divided by the regional GDP (*FDI/GDP*). The results show that the share of industrial pollution treatment investment has a negative effect on FDI inflows into a province. The coefficients in each of the nine regressions are relatively stable and statistically significant. In column (10) the coefficient (–0.062) indicates that a 10 per cent increase in the share of environmental investment of a province leads to a 0.62 per cent decrease in the amount of FDI inflow to regional GDP. Therefore, stringent regional environmental regulations have a detrimental effect on FDI inflows.

Turning to the other explanatory variables, as expected, per capita income generally has a positive and statistically significant coefficient, which means that the richer the province, the more foreign investment it attracts. Among all the independent variables, per capita income level has the strongest effect on FDI inflows. The coefficient could be treated as the income elasticity of FDI inflows. From column (10), a 10 per cent increase in provincial income level could lead to a more than 34 per cent increase in *FDI/GDP*.

Table 8.6 FGLS regression results on FDI/GDP for log data with EI1

FDI/GDP	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
EI1†	–0.071	–0.081	–0.083	–0.087	–0.11	–0.11	–0.063	–0.062	–0.063	–0.062
	–(2.30)**	(–2.92)***	(–2.93)***	(–2.69)***	(–3.20)***	(–3.16)***	(–2.00)**	(–2.09)**	(–1.94)*	(–2.03)**
GRP per		2.77	2.53	2.82	3.20	3.48	3.41	3.38	3.42	3.44
capita		(5.02)***	(4.10)***	(4.03)***	(4.32)***	(4.66)***	(4.98)***	(5.00)***	(4.78)***	(4.86)***
Wage			0.23	5.76	5.82	3.22	5.34	5.42	6.41	6.49
			(0.65)	(1.56)	(1.63)	(0.81)	(1.45)	(1.45)	(1.69)*	(1.68)*
Wage^2				–0.33	–0.33	–0.19	–0.32	–0.34	–0.38	–0.40
				(–1.48)	(–1.52)	(–0.78)	(–1.44)	(–1.49)	(–1.67)*	(–1.71)*
GIP					–0.51	–0.60	–0.25	–0.15	–0.23	–0.16
					(–1.76)*	(–2.00)**	(–0.80)	(–0.47)	(–0.70)	(–0.50)
Pop. density						–1.14	–1.01	–1.07	–1.07	–1.13
						(–1.50)	(–1.49)	(–1.57)	(–1.60)	(–1.68)*
Rail density							–0.21	–0.23	–0.22	–0.25
							(–1.98)**	(–2.20)**	(–2.08)**	(–2.32)**
Road density							0.42	0.45	0.42	0.45
							(4.14)***	(5.03)***	(4.25)***	(5.30)***
Illiterate rate								0.27		0.27
								(2.36)**		(2.34)**
Productivity									–0.17	–0.18
									(–1.37)	(–1.47)
Constant	6.82	–18.798	–18.56	–44.122	–44.69	–27.27	–40.74	–40.77	–43.42	–43.51
	(35.48)***	(–3.68)***	(–3.64)***	(–2.45)**	(–2.55)**	(–1.28)	(–2.11)**	(–2.08)**	(–2.23)**	(–2.20)**
Wald χ^2	4902.89	6449.04	6788.36	5384.91	5486.04	5717.34	7051.28	7398.75	6546.07	7071.95
Observations	149	149	149	149	149	149	149	149	149	149

Note: z-statistics in parentheses; † all the independent variables are in logs; *, **, and *** indicate significant at 10 per cent, 5 per cent, and 1 per cent level, respectively. Province and time dummies are included.

Table 8.7 FGLS regression results on FDI/POP for log data with EI1

FDI/POP	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
EI1†	−0.079	−0.080	−0.083	−0.094	−0.10	−0.10	−0.062	−0.063	−0.062	−0.062
	(−2.61)***	(−2.59)***	(−2.74)***	(−2.75)***	(−2.97)***	(−2.93)***	(−1.93)*	(−2.02)**	(−1.86)*	(−1.96)**
GRP per		3.38	3.04	3.43	3.71	3.99	4.04	3.97	3.98	3.98
capita		(6.13)***	(4.93)***	(4.93)***	(5.04)***	(5.42)***	(6.04)***	(6.03)***	(5.69)***	(5.74)***
Wage			0.37	7.95	7.87	5.53	7.48	7.52	8.52	8.54
			(0.99)	(2.24)**	(2.25)**	(1.41)	(2.03)**	(2.02)**	(2.25)**	(2.22)**
Wage^2				−0.46	−0.45	−0.32	−0.45	−0.46	−0.50	−0.52
				(−2.11)**	(−2.10)**	(−1.36)	(−2.01)**	(−2.04)**	(−2.21)**	(−2.24)**
GIP					−0.35	−0.42	−0.057	0.056	−0.036	0.045
					(−1.13)	(−1.31)	(−0.18)	(0.17)	(−0.11)	(0.13)
Pop. density						−0.96	−0.88	−0.93	−0.86	−0.92
						(−1.25)	(−1.21)	(−1.28)	(−1.20)	(−1.28)
Rail density							−0.16	−0.19	−0.17	−0.20
							(−1.43)	(−1.68)*	(−1.52)	(−1.78)*
Road density							0.45	0.47	0.44	0.47
							(4.47)***	(5.17)***	(4.59)***	(5.47)***
Illiterate rate								0.27		0.27
								(2.29)**		(2.23)**
Productivity									−0.16	−0.17
									(−1.25)	(−1.34)
Constant	6.79	−24.54	−24.50	−59.51	−59.41	−44.54	−58.28	−58.10	−61.11	−60.91
	(37.03)***	(−4.80)***	(−4.77)***	(−3.43)***	(−3.46)***	(−2.10)**	(−2.96)***	(−2.94)***	(−3.10)***	(−3.05)***
Wald χ^2	8255.26	9891.48	10168.32	8913.67	9078.33	9316.90	12471.36	13105.58	12174.31	13239.35
Observations	149	149	149	149	149	149	149	149	149	149

Note: z-statistics in parentheses; † all the independent variables are in logs; *, **, and *** indicate significant at 10 per cent, 5 per cent, and 1 per cent level, respectively. Province and time dummies are included.

Table 8.8 FGLS regression results on FDI/GDP for log data with punish

FDI/GDP	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Punish†	–0.043	–0.043	–0.041	–0.051	–0.074	–0.078	–0.082	–0.076	–0.081	–0.076
	(–2.06)**	(–1.94)*	(–1.74)	(–2.13)**	(3.05)***	(–3.01)***	(–3.16)***	(–2.79)***	(–3.23)***	(–2.85)***
GRP per		2.90	2.92	3.13	3.50	3.79	3.84	3.93	3.70	3.85
capita		(5.02)***	(4.52)***	(4.51)***	(4.83)***	(5.13)***	(5.94)***	(6.01)***	(5.65)***	(5.75)***
Wage			–0.089	5.42	6.43	3.41	4.78	4.45	5.99	5.73
			(–0.21)	(1.35)	(–1.70)*	(–0.81)	(–1.24)	(–1.14)	(–1.51)	(–1.42)
Wage^2				–0.33	–0.39	–0.21	–0.30	–0.30	–0.36	–0.36
				(–1.36)	(–1.67)*	(–0.84)	(–1.28)	(–1.24)	(–1.50)	(–1.48)
GIP					–0.49	–0.62	–0.41	–0.36	–0.39	–0.36
					(–1.75)*	(–1.98)**	(–1.36)	(–1.19)	(–1.32)	(–1.17)
Pop. density						–0.94	–0.98	–1.03	–0.97	–1.02
						(–1.26)	(–1.57)	(–1.61)	(–1.58)	(–1.63)
Rail density							–0.30	–0.31	–0.30	–0.31
							(–2.87)***	(–2.89)***	(–2.86)***	(–2.90)***
Road density							0.44	0.45	0.44	0.46
							(4.44)***	(5.05)***	(4.58)***	(5.28)***
Illiterate rate								0.22		0.21
								(1.88)*		(1.83)*
Productivity									–0.14	–0.16
									(–1.16)	(–1.32)
Constant	6.62	–20.24	–19.67	–44.12	–48.62	–31.19	–39.87	–38.85	–43.17	–42.58
	(47.34)***	(–3.78)***	(–3.44)***	(–2.30)**	(–2.66)***	(–1.40)	(–2.00)**	(–1.93)*	(–2.16)**	(–2.10)**
Wald χ^2	5027.47	5287.33	5059.49	4945.25	6701.13	6263.02	8235.71	8374.58	8231.85	8466.13
Observations	147	147	147	147	147	147	147	147	147	147

Note: z-statistics in parentheses; † all the independent variables are in logs; *, **, and *** indicate significant at 10 per cent, 5 per cent, and 1 per cent level, respectively. Province and time dummies are included.

Table 8.9 FGLS regression results on FDI/POP for log data with punish

FDI/POP	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Punish†	−0.043	−0.047	−0.045	−0.054	−0.074	−0.074	−0.078	−0.071	−0.076	−0.070
	(−2.20)**	(−1.97)**	(−1.89)	(−2.26)**	(−2.78)***	(−2.57)**	(−2.62)***	(−2.33)**	(−2.66)***	(−2.38)**
GRP per		3.55	3.37	3.63	3.95	4.28	4.46	4.46	4.30	4.36
capita		(6.50)***	(5.45)***	(5.34)***	(5.40)***	(5.79)***	(6.99)***	(6.99)***	(6.52)***	(6.58)***
Wage			0.096	7.63	8.13	5.54	6.64	6.49	7.83	7.67
			(0.23)	(1.98)**	(2.17)**	(1.33)	(1.72)*	(1.67)*	(1.97)**	(1.91)*
Wage^2				−0.45	−0.48	−0.34	−0.41	−0.41	−0.47	−0.47
				(−1.92)*	(−2.08)**	(−1.33)	(−1.73)*	(−1.73)*	(−1.95)*	(−1.94)*
GIP					−0.42	−0.48	−0.20	−0.13	−0.18	−0.13
					(−1.34)	(−1.40)	(−0.63)	(−0.40)	(−0.55)	(−0.39)
Pop. Density						−0.69	−0.82	−0.83	−0.76	−0.77
						(−0.90)	(−1.18)	(−1.19)	(−1.11)	(−1.13)
Rail density							−0.26	−0.26	−0.25	−0.26
							(−2.25)**	(−2.31)**	(−2.22)**	(−2.28)**
Road density							0.46	0.47	0.46	0.48
							(4.72)***	(5.17)***	(4.90)***	(5.43)***
Illiterate rate								0.21		0.20
								(1.77)*		(1.68)*
Productivity									−0.13	−0.14
									(−1.05)	(−1.14)
Constant	6.55	−26.34	−25.52	−58.88	−61.28	−47.77	−56.75	−56.29	−60.33	−59.97
	(49.65)***	(−5.19)***	(−4.72)***	(−3.19)***	(−3.40)***	(−2.16)**	(−2.80)***	(−2.76)***	(−2.97)***	(−2.92)***
Wald χ^2	7444.30	9495.49	9524.93	8280.40	8966.73	8852.64	13005.62	13285.83	13022.54	13589.33
Observations	147	147	147	147	147	147	147	147	147	147

Note: z-statistics in parentheses; † all the independent variables are in logs; *, **, and *** indicate significant at 10 per cent, 5 per cent, and 1 per cent level, respectively. Province and time dummies are included.

Table 8.10 FGLS regression results on FDI/GDP for log data with charge

FDI/GDP	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Charge†	–0.054	–0.14	–0.15	–0.12	–0.098	–0.14	–0.22	–0.18	–0.21	–0.18
	(–0.49)	(–1.30)	(–1.40)	(–1.01)	(–0.84)	(–1.16)	(–2.00)**	(–1.66)*	(–1.86)*	(–1.54)
GRP per capita		2.94	2.73	2.89	3.11	3.47	3.50	3.47	3.47	3.47
		(4.87)***	(4.15)***	(3.95)***	(3.98)***	(4.42)***	(5.02)***	(5.01)***	(4.78)***	(4.80)***
Wage			0.14	3.87	4.38	0.49	1.99	2.37	2.89	3.26
			(0.34)	(0.94)	(1.07)	(0.11)	(0.49)	(0.58)	(0.69)	(0.77)
Wage^2				–0.23	–0.26	–0.039	–0.12	–0.15	–0.17	–0.20
				(–0.90)	(–1.03)	(–0.14)	(–0.48)	(–0.61)	(–0.66)	(–0.78)
GIP					–0.23	–0.31	0.13	0.15	0.13	0.14
					(–0.72)	(–0.94)	(0.39)	(0.46)	(0.38)	(0.42)
Pop. density						–1.39	–1.54	–1.52	–1.63	–1.61
						(–1.67)*	(–2.27)**	(–2.22)**	(–2.40)**	(–2.34)**
Rail density							–0.37	–0.36	–0.38	–0.37
							(–3.45)***	(–3.34)***	(–3.44)***	(–3.34)***
Road density							0.42	0.44	0.42	0.44
							(3.92)***	(4.39)***	(3.93)***	(4.46)***
Illiterate rate								0.22		0.22
								(1.69)*		(1.68)*
Productivity									–0.16	–0.16
									(–1.25)	(–1.32)
Constant	6.90	–19.58	–18.74	–35.64	–38.32	–14.44	–24.28	–26.01	–25.81	–27.59
	(–7.06)***	(–3.57)***	(–3.38)***	(–1.81)*	(–1.95)*	(–0.60)	(–1.15)	(–1.23)	(–1.22)	(–1.29)
Wald χ^2	4233.42	4850.38	5313.72	4558.54	4456.13	4891.34	7336.94	7180.77	6906.39	6817.20
Observations	149	149	149	149	149	149	149	149	149	149

Note: z-statistics in parentheses; † all the independent variables are in logs; *, **, and *** indicate significant at 10 per cent, 5 per cent, and 1 per cent level, respectively. Province and time dummies are included.

Table 8.11 FGLS regression results on FDI/POP for log data with charge

FDI/POP	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Charge†	–0.043	–0.14	–0.16	–0.098	–0.091	–0.13	–0.21	–0.18	–0.20	–0.17
	(–0.38)	(–1.31)	(–1.47)	(–0.84)	(–0.77)	(–1.10)	(–1.92)*	(–1.65)*	(–1.75)*	(–1.50)
GRP per capita		3.65	3.32	3.57	3.67	3.99	4.15	4.06	4.07	4.02
		(6.30)***	(5.18)***	(4.95)***	(4.78)***	(5.25)***	(6.27)***	(6.15)***	(5.85)***	(5.77)***
Wage			0.28	6.69	6.82	3.02	4.18	4.50	5.19	5.47
			(0.68)	(1.67)*	(1.70)*	(0.67)	(1.02)	(1.09)	(1.23)	(1.29)
Wage^2				–0.39	–0.40	–0.19	–0.25	–0.28	–0.31	–0.33
				(–1.59)	(–1.63)	(–0.68)	(–0.99)	(–1.10)	(–1.18)	(–1.28)
GIP					–0.097	–0.15	0.30	0.35	0.31	0.34
					(–0.29)	(–0.45)	(0.89)	(1.02)	(0.88)	(0.97)
Pop. density						–1.22	–1.42	–1.37	–1.45	–1.41
						(–1.45)	(–1.92)*	(–1.87)*	(–1.96)**	(–1.92)*
Rail density							–0.31	–0.30	–0.32	–0.31
							(–2.69)***	(–2.65)***	(–2.72)***	(–2.68)***
Road density							0.45	0.47	0.44	0.46
							(4.20)***	(4.52)***	(4.19)***	(4.57)***
Illiterate rate								0.21		0.21
								(1.63)		(1.58)
Productivity									–0.15	–0.16
									(–1.19)	(–1.25)
Constant	6.73	–26.23	–25.48	–54.22	–54.99	–32.42	–42.16	–43.47	–44.37	–45.52
	(6.81)***	(–4.93)***	(–4.65)***	(–2.81)***	(–2.85)***	(–1.36)	(–1.96)**	(–2.02)**	(–2.05)**	(–2.09)**
Wald χ^2	6988.72	8136.79	8700.20	7749.89	7766.79	8301.63	12585.14	12298.18	12247.58	12082.78
Observations	149	149	149	149	149	149	149	149	149	149

Note: z-statistics in parentheses; † all the independent variables are in logs; *, **, and *** indicate significant at 10 per cent, 5 per cent, and 1 per cent level, respectively. Province and time dummies are included.

The signs for the coefficients for manufacturing wages and wage square are consistent with our prior expectations, and reveal an inverted-U relationship between FDI and wages. Although they remain relatively stable in absolute values, they are not significantly different from zero in most regressions and only achieve marginal significance in the final two columns. For column (10), the turning point is 8.11, equivalent to RMB 3,336 yuan (or $698).[12] From the descriptive statistics reported in Table 8.4, manufacturing wages in most Chinese provinces are higher than this level. Table 8.2 shows that in 2002, the provincial manufacturing wages are all above RMB 4,000 yuan (the lowest wage is found in Henan with RMB 4,218 yuan), that is, high wages currently deter FDI in China.

GIP is intended to capture the degree of industrial agglomeration in a province and is expected to have a positive effect on FDI. However, none of the coefficients on *GIP* are positive and a statistically significant negative coefficient is found in regressions (5) and (6).[13] The coefficient on *population density* is found to be negative and only significant at 10 per cent in the final column. It appears that FDI locates in less densely populated areas, possibly due to higher land prices.

We now consider our infrastructure variables. The *railway density* coefficient is contrary to our expectations. It has a significant negative effect on FDI inflows and is also found in all the other regression results in Tables 8.6–8.11. A possible explanation is the relatively lower railway density in some coastal provinces with higher incomes and higher shares of FDI inflows. For example, Guangdong attracted the greatest FDI flows in China and its GDP accounts for about 10 per cent of the total. However, the railway length is 2,112.5 km with a density of 0.01 km/km^2, which ranks 11th from bottom and only slightly higher than the average level in the country.[14] The situation in other FDI preferred provinces, such as Hainan, Fujian, Zhejiang and Jiangsu, is similar to that of Guangdong. Although other eastern regions, such as Beijing, Tianjin, Shanghai, Liaoning, Hebei and Shandong, have very high railway densities, these six regions account for 28 per cent of national GDP and 36 per cent of FDI inflows, compared with 31 per cent GDP and 50 per cent FDI inflows for the other five provinces with lower railway densities. In contrast, another measure of a region's infrastructure, *road density*, has a positive and significant coefficient in all regressions in all six tables. The value of the coefficient remains relatively stable.[15] The different results in railway density and road density are consistent with the real situation of transportation infrastructure in China. Over the past 30 years, central and local governments have invested a great amount of money to improve the highway construction (at all classes) because the road transportation network is regarded as an important sign of urbanization and modernization. 'Building roads is the first step to becoming rich' has been a common saying since the 1980s. Therefore, rich regions always have high road density but not necessarily a high railway density.

The rate of illiteracy in a province has a positive and significant coefficient as expected, indicating that FDI prefers to locate to regions with a high proportion of unskilled labour. Similarly, our measure of productivity has a consistent sign but it is not significant, indicating that provincial productivity does not appear to play an important role in investment location decision-making.

Using per capita FDI inflows (*FDI/POP*) as our dependent variable, the specifications of Table 8.7 are the same as those in Table 8.6. The coefficients for *EI1* in these two tables are very similar. Therefore, for both FDI measures, a 10 per cent increase in industrial pollution treatment investment in a province would lead to an approximate 0.62 per cent decrease in the amount of per capita FDI inflows into the province. The coefficients on other independent variables are robust across all regressions, except *age* and *squared wage* which both become more significant. The turning point in the final regression is 8.21, equivalent to RMB 3,683 yuan (or $770) in level. Again, it indicates that wages have a negative effect on FDI inflows at current wage levels in China.

Tables 8.8 and 8.9 show the FGLS regression results when we use *Punish* to measure the strictness of environmental regulations. The coefficients on punishment cases are negative and statistically significant in all regressions in Tables 8.8 and 8.9, and the absolute values are relatively stable. In column (10) of Table 8.8, the coefficient is –0.076, which means that a 10 per cent increase in the environmental litigiousness of a province leads to a 0.76 per cent decrease in the amount of *FDI/GDP*. As a result, provinces with stricter environmental standards attract less FDI.

The effect of per capita income is still significantly positive. Similar to the *EI1* results, the coefficients on manufacturing wages do not have a significant effect on *FDI/GDP* but do have a significant effect on *FDI/POP*; and the turning point is also below RMB 4,000 yuan (3,497 in regression (10) in Table 8.9). *GIP* and *population density* remain negative and insignificant. The results for *railway* and *road density* are similar to the *EI1* regressions. Their coefficients are robust for both signs and magnitude. The performance of ratse of *illiteracy* and *productivity* are also similar to those in previous tables.

In terms of the results using normalized pollution emission charges, Tables 8.10 and 8.11 both indicate that foreign investors would like to locate to provinces with lower pollution emission charge standards, those provinces with weaker implementation of environmental standards. However, the results are not as significant as *EI1* and *Punish*. And a 10 percent increase in the pollution charge standard may lead to an approximately 1.8 per cent decrease in *FDI/GDP* or *FDI/POP* inflows. Compared to the industrial pollution treatment investment and administrative punishment cases, foreign investors are more sensitive to pollution emission charges, possibly because it is more visible to the investors and has a more direct impact. The magnitudes of the coefficients on our three measures of environmental regulations are consistent with our expectation that *Charge* has the strongest elasticity, while *EI1* has the weakest. However, the impact of Charge is only significant at 10 per cent level in regressions (7)–(9).

The results of per capita income and infrastructure variables are very similar to those in the previous four tables. However, wage and squared wage are now insignificant in the regressions on both measures of FDI. The *GIP* coefficient becomes positive in most regressions, although it still not different from zero. Population density becomes negatively significant, indicating that foreign investment prefers less populated provinces where land prices are lower. The coefficient on the illiterate rate is less significant but remains stable in magnitude. The results of productivity do not change.

We also applied some additional sensitivity checks to labour quality and manufacturing wage. We include the percentage of enrolment in different levels of education to substitute for the rate of illiteracy. We found positive but insignificant results for primary school enrolment; positively significant results for junior high school enrolment; and negative but insignificant results for both senior high school and higher education enrolments. These results support our premise that FDI is attracted to regions with relatively low education levels. We also included interaction terms for certain variables, for example, wage × income, wage × rate of illiteracy and wage × productivity. The results remained broadly similar.

Turning to the two alternative measures of the share of industrial pollution treatment investment, the results do not change the main results. The coefficients on *EI2* and *EI3* remain negative and stable in magnitude; however, they are not statistically different from zero in some regressions estimating on both measures of FDI inflows. The results of the other independent variables are very similar, including *EI1*.

Comparison with previous empirical evidence

In contrast to the majority of existing studies of the PHH we do find consistent support for the existence of a pollution haven hypothesis within China. When we consider the effect of per capita income on aggregate FDI inflows to Chinese regions we find a strong and positive effect which is consistent with previous studies.

With respect to wages, we included wage squared in the first estimating equation and found an inverted-U relationship between FDI and wages. At current wage levels in China, our finding that wage deters FDI inflows is consistent with most empirical studies focusing on China. We did not find a robust result for agglomeration effects, which is usually omitted in other studies. The measurement of agglomeration effects varies across empirical studies so in future research we will try alternative measures of agglomeration.

Growth of population density was used in Wei *et al.* (1999) as a control variable to proxy the improvement in agglomeration effects and was found to be insignificant in all regressions for the realized FDI inflows, and with a negative sign when controlling for autocorrelation. In our case, population density was found to be significantly negative in the main results; a possible explanation is that it reflects regional land prices.

Infrastructure was measured differently in other studies; however, most of them are measured by the characteristics of transportation (densities of highway, paved road, railway, waterway, and so on) and do not get constant significant results. Cheng and Kwan (2000) estimated the regression separately with all roads, paved roads and railways and also found the unexpected sign in the case of railways that is consistent with our findings. Gao (2002) combined the density of roads, railways and waterways and found the effects of transportation were not different from zero. A possible explanation for Gao's finding is that the strong negative effect of railway density, which is found in our results, may offset the positive effect of road density.

In terms of our labour quality variables, Coughlin and Segev (2000) employed similar measures and found that labour productivity was a positive determinant of FDI while the rate of illiteracy was negative, which is opposite to our findings. Other studies used the percentage of enrolment in different levels of education as the proxy for education or labour quality (Cheng and Kwan, 2000; Gao, 2002; Fung *et al.*, 2002, 2003), and the results showed that education at junior and senior high schools, we well as higher education, generally had positive and significant impact on FDI inflows while the impact of primary school education was not significant. Our sensitivity check results using similar measures are also opposite to those in previous studies. Cheng and Kwan (2000) argued that it is not surprising because at the beginning of China's open door policy, FDI was not attracted to areas with higher education attainment but to South China, due to preferential government policies and its geographical proximity to Hong Kong. Such a situation also exists during our sample period (1999–2003) even though China has been open for 20 years. This might be a possible explanation for our contrary results. The second reason is that illiteracy rate data is noisy because it measures the education level of household populations, which may be affected by labour migration. Another explanation is that we use different normalization of FDI inflows (*FDI/GDP*) and (*FDI/POP*) rather than FDI level data in USD at a constant price. Our normalization does not reflect the absolute level of FDI but the relative abundance of foreign investment. It may generate different signs for some control variables.

8.4 Conclusions

This chapter uses provincial data for China to examine whether foreign investment is more or less likely to be attracted to provinces with stringent environmental regulations.

We employ three proxies for the stringency of environmental regulations across the provinces. They are the share of industrial pollution treatment investment in innovation investment in each province, the normalized administrative punishment cases and the normalized pollution emission charges. We also use two measures of FDI inflows, FDI divided by regional GDP and FDI divided by regional population. The regression results from the FGLS estimator indicate that industrial pollution treatment investment and administrative punishment cases have significant negative effects on both measures of FDI inflows, while the impact of pollution emission charges is also negative, although less significant. That is to say FDI prefers to locate in regions with weaker environmental regulations. Thus, to a certain extent, we find evidence to support the existence of intra-country pollution havens within China. These results are robust for data in logs rather than in levels. The results for random effects estimators are somewhat weaker.

The results also find that other independent variables are significant determinants of investment. Income level has a strong positive impact on the amount of FDI inflow. FDI is also found to be attracted to provinces with low manufacturing wages, good infrastructure, and a low educational level. FDI is found to prefer locating in regions with a low population density when we include pollution charge to proxy environmental regulations. It shows the importance of a reliable infrastructure and factors of production in the investment location decision. Our results for income, wage and infrastructure are consistent with most previous studies; however, the results for population density and quality of labour force are different.

Our findings provide some policy implications. Three decades of fast economic growth under the present growth mode has made China one of the largest pollution producers in the world with, probably, the dirtiest air and increasingly polluted water resources. 'Unless ecological balance is restored within the medium term, environmental limits could choke off further economic growth' (Woo, 2007).

In this growth process, FDI has played an important role. It is regarded as an engine or catalyst for economic growth, a carrier of advanced technological and managerial knowledge that can drive the technological upgrading of the economy. Evidence from this chapter suggests that FDI is not always an unalloyed blessing. Foreign investors may seek institutional voids in developing countries and attempt to locate in pollution havens where environmental regulation is not stringent.

If a fast economic development is endurable, a sustainable development policy is needed that requires a rethink about the location of population centres and types of investment, including the type and sector of FDI. Policies could include encouraging more environmentally friendly knowledge and human capital intensive FDI and controlling FDI in high energy consumption and high pollution sectors. The negative effect of environmental stringency on FDI can be offset by the improvement of some factors that are attractive to FDI, for example the quality of the infrastructure.

One limitation in this chapter is that the data do not allow us to disaggregate FDI from different sources and/or into different industry sectors. Therefore, we cannot examine whether certain types of FDI from certain countries in certain industrial sectors prefer to locate in regions with weak environmental regulations.

The second limitation is that we do not consider some other factors related to government characteristics which may have an impact on FDI, such as the provincial difference in corruption. Corruption, as a detriment of FDI inflows, has recently been considered in cross national FDI location choice models. China has been widely recognized as a country with a serious corruption problem that still attracts a large share of FDI inflows. The next question we wish to ask therefore is whether the difference in provincial levels of corruption and governance quality encourage or deter FDI inflows in China.

Appendix 8.1 Variables definitions and data sources

Variable	Definition/Source
FDI/GDP	FDI divided by regional GDP (yuan per 10000 yuan). *Source*: China Statistical Yearbook
FDI/POP	FDI divided by regional population (yuan per capita at 1990 price). *Source*: China Statistical Yearbook; GDP deflator data from Econ Stats, http://www.econstats.com
EI1	Investment in industrial pollution treatment project divided by total innovation investment (yuan per 10000 yuan). *Source*: China Environment Yearbook; Innovation investment data as FDI.
Punish	Total number of administrative punishment cases filed by the regional environmental authorities divided by the number of enterprises (cases per 1000 enterprises). *Source*: China Environment Yearbook; number of enterprises as FDI.
Charge	Pollution emission charge divided by the number of organizations paid the charge (yuan per enterprise, at 1990 price). *Source*: China Environment Yearbook.
GRP per capita	Gross regional product per capita (yuan at 1990 price). *Source*: as FDI.
Wage	Average wage of staff and workers in manufacturing (yuan at 1990). *Source*: as above.
GIP	Regional gross industrial output value (100 million yuan at 1990 price). *Source*: as above.
Pop. density	Regional population density (persons per km^2). *Source*: as above; area data from http://www.usacn.com
Road density	Regional highway density (km per 10000 km^2). *Source*: as above.
Rail density	Regional railway density (km per 10000 km^2). *Source*: as above.
Illiterate rate	Regional illiterate rate and semi-illiterate rate aged at 15 and above; values for 2000 are calculated as the average of the values in 1999 and 2001. *Source*: as FDI.
Productivity	Overall labour productivity for all foreign funded industrial enterprises (yuan per person per year, at 1990 price); values for 1998 are the average of those for 1997 and 1999. *Source*: China Industrial Economy Statistical Yearbooks.

Appendix 8.2 Normalization of the share of the environmental investment

The sources of industrial pollution treatment investment are state budgetary appropriations, special fund for environmental protection (which is mainly from the pollution emission charge), and other funds like domestic loans, foreign investment and enterprise fundraising.

The investment monies are spent on construction and installation projects, and purchasing of equipment and instruments required in pollution harnessing projects for the treatments of wastewater, waste gas, solid waste, noise and other pollution.

All of these investment monies should be accounted to investment in innovation, which refers in general to technological innovation of the original facilities (including renewal of fixed assets) by the enterprises and institutions, as well as corresponding supplementary projects for production or welfare facilities and related activities. It includes the investment in all projects, arranged both by innovation and by capital construction, of moving whole factories to a new site so as to meet the requirements of urban environmental protection or safe production; and projects in state-owned units, listed neither by capital construction nor iby innovation, of moving whole factories to a new site so as to meet the requirements of urban environmental protection or safe production (China Statistical Yearbook).

Therefore, we normalized the industrial pollution treatment investment by the investment in innovation, as in the variable we used in the main text, *EI1*. But, considering that a small fraction of the industrial pollution treatment investment comes from the state budget for capital construction, we also constructed two alternative variables for the share of environmental investment. *EI2* is normalized by the sum of investment in innovation and capital construction; and *EI3* is normalized by the total investment in fixed assets. Total investment in fixed assets is classified into four parts: investment in capital construction, investment in innovation, investment in real estate development and other investment in fixed assets.

Although the coefficients of *EI2* and *EI3* are less significant than that of *EI1*, the results reported in the tables are roughly consistent with our main results.

Appendix 8.3 Hausman specification test

For a random effects estimator (GLS estimator) we assumed that the error (ε_{it}) is uncorrelated with the independent variables (X_{it}), that is $E(\varepsilon_{it}|X_{it}) = 0$. In the case $E(\varepsilon_{it}|X_{it}) \neq 0$ the GLS estimator $\hat{\beta}_{GLS}$ becomes biased and inconsistent for β. However, the within estimator $\tilde{\beta}_{Within}$ is always unbiased and consistent for β because the within transformation wipes out the individual effects. So we undertook the Hausman specification test to find out whether $\hat{\beta}_{GLS}$ is BLUE (best linear unbiased estimator), consistent and asymptotically efficient under the null hypothesis H_0: $E(\varepsilon_{it}|X_{it}) = 0$.

The Hausman statistic is distributed as χ^2 and is computed as

$$H = (\tilde{\beta}_{Within} - \hat{\beta}_{GLS})'(V_{Within} - V_{GLS})^{-1}(\tilde{\beta}_{Within} - \hat{\beta}_{GLS})$$

where

$\tilde{\beta}_{Within}$ is the coefficient vector from the within estimator;
$\hat{\beta}_{GLS}$ is the coefficient vector from the GLS estimator;
V_{Within} is the covariance matrix of the coefficients from the within estimator; and
V_{GLS} is the covariance matrix of the coefficients for the GLS estimator.

If H_0 is not rejected, there is no systematic difference between these two estimators, hence the GLS estimator β_{GLS} is efficient (Baltagi, 2005). We rejected the GLS estimator only if the p-value was less than 0.05, which meant, in these cases, the random effects specification was not appropriate. The results below show that the GLS estimator produces efficient results in most specifications except in two cases for level data. Therefore, we also estimated Equation 2.4.5 using the GLS estimator.

Table A8.3.1 Hausman specification test results

	Levels									
	EI1		***Punish***		***Charge***		***EI2***		***EI3***	
	FDI/GDP	FDI/POP	FDI/GDP	FDI/POP	FDI/GDP	FDI/POP	FDI/GDP	FDI/POP	FDI/GDP	FDI/POP
χ^2 Statistics	5.71	10.30	**21.66**	10.53	13.56	**19.28**	16.05	14.00	7.99	14.62
p-value	0.839	0.415	**0.006**	0.395	0.094	**0.037**	0.098	0.233	0.630	0.201
	Logs									
	EI1		***Punish***		***Charge***		***EI2***		***EI3***	
	FDI/GDP	FDI/POP	FDI/GDP	FDI/POP	FDI/GDP	FDI/POP	FDI/GDP	FDI/POP	FDI/GDP	FDI/POP
χ^2 Statistics	7.36	10.34	8.58	8.16	10.50	9.05	9.30	8.13	4.21	8.44
p-value	0.920	0.737	0.857	0.881	0.725	0.828	0.811	0.882	0.994	0.865

Part III

Corruption, Government, FDI, and the Environment in China

9
Literature Review

9.1 Introduction

Modelling FDI is complicated because so many explanatory variables impact on it. Among these determinants, one factor that has recently attracted more attention by researchers is corruption in host countries. Wei (2000) argues that the 'popular press and policy circles seem to believe that corruption does reduce inward FDI, as suggested by the opening quote from James D. Wolfensohn', ninth president of the World Bank:[1]

> We need to deal with the cancer of corruption ... We can give advice, encouragement, and support to governments that wish to fight corruption – and *it is these governments that, over time, will attract the larger volume of investment* (emphasis added).
>
> James D. Wolfensohn[2]

From the 1990s, the disparity in international investment location led some studies to examine the structural determinants of FDI inflows. Except for the studies that explore the effect of environmental regulations, another line of research examines the impact of corruption on cross-country patterns of FDI, such as Wheeler and Mody (1992), Hines (1995), and Wei (2000). These studies employ a cross-country, perception based, corruption index in FDI location decision models on the assumption that corruption has a negative effect on FDI flow into a country.

However, corruption does not always seem to deter FDI. Some countries, for example, China, Indonesia, and Thailand, attract a large amount of FDI in spite of their perceived high levels of corruption, which prompts empirical studies focusing on cross-country analyses.

Studies in the 1990s did not find a consistent negative correlation between corruption and FDI (for example Wheeler and Mody, 1992; Hines, 1995). However, more recent analyses have reported a statistically significant negative impact of corruption on FDI (for example Wei, 2000; Smarzynska-Javorcik and Wei, 2000; Du *et al.* 2008a, b).

Additionally, some researchers examined the role of governance in foreign capital flows, such as Globerman and Shapiro (2002, 2003) and Globerman *et al.* (2006), suggesting that investment in governance infrastructure helps to attract foreign investment.

A deficiency in empirical studies that examine the effect of environmental regulations is that government corruption and/or governance are rarely modelled. An exception is Smarzynska-Javorcik and Wei (2005), who take into account corruption in a host country as a possible deterrent to FDI when examining inter-country pollution haven effects in 24 transition economies.

A deficiency in empirical studies focusing on corruption or governance is that most of them examine whether differences in corruption and/or governance across countries have an impact on FDI inflows, but few of them consider the differences in corruption within a country. In 2005 Kao *et al.* investigated the relationship between inter-province governance efficiency and FDI in China and found that, after controlling other variables, FDI is attracted to provinces with more effective government. Du *et al.* (2008a, 2008b) examined the impact of government institutions on regional location choice of FDI using firm-level data. Government corruption is one of the four indicators of regional government institutions and has a detrimental effect on FDI. However, the measure of corruption is simple and is based on the perception of foreign firms.

Within the existing literature, only Fredriksson *et al.* (2003) investigated the impacts of inter-state environmental regulations and corruption on inbound US FDI. They used the normalized number of convictions of public officials to measure the bureaucratic corruption of each state in their empirical model. So far no study has considered whether the differences in inter-province environmental regulations, government corruption and/or governance have an impact on FDI location choice in China.

This chapter is organized as follows. It starts with a brief review of the definition of corruption and the measurement of corruption. It then describes the relationship between corruption and governance before laying out the empirical evidence on corruption/governance and FDI and the evidence on the pollution haven hypothesis, allowing for the impact of corruption on FDI inflows.

9.2 Corruption and governance

9.2.1 What is corruption?

Svensson (2005) adopts the common definition that corruption is 'the *misuse* of public office for private gains'. This is legalistic definition because misuse involves legal norms. However, some other authors, for example He (2000), employ the definition that corruption is 'the *use* of public power and public resources for private interests'. This is a strict definition as it includes all behaviour utilising public power for private benefit.

In this book, we prefer the former definition, which captures bribes, sale of government property, embezzlement of government funds, abuse of public power, and so on.

Picci (2005) defines three types of corruption assessment: judicial assessment, societal assessment and corruption indices. Since the extent to which corruption crimes are successfully prosecuted by the judiciary depends on many factors, judicial data are rarely used. Social assessment 'may follow personal experience, hearsay or the observation of indirect effects of corruption.... Such a social assessment of corruption is facilitated by the presence of a free press, that processes and gives visibility to information that individual citizens would otherwise obtain with difficulty, particularly regarding grand corruption cases'.[3] Corruption indices are the summary of phenomena correlated with corruption, such as public honesty or measures of the quality of governance. Most corruption indices are subjective, being based on the perception of the phenomena. They are created through questionnaires, surveys, interviews, or data analysis.

Kaufmann *et al.* (2006) outline three broad ways to measure corruption:

1) By gathering the informed views of relevant stakeholders. These include surveys of firms, public officials and individuals, and views of outside observers in non-governmental organizations, multilateral donors, and the private sector. These are the only available data currently used for large-scale cross-country comparisons and monitoring of corruption over time.

2) By tracking countries' institutional features. This provides information on opportunities and/or incentives for corruption, such as procurement practices and budget transparency. They do not measure actual corruption but indicate the possibility of corruption. These are not developed for large countries and have no time dimension, as yet.
3) By careful audits of specific projects. These provide information about malfeasance in specific projects but not about country-wide corruption so tend to be one-offs. They are not suitable for cross-country comparisons or monitoring over time.

Survey-based corruption indices are therefore well-developed and widely used in cross-country analyses. Well-known indices include Transparency International's (TI) Corruption Perception Index, The World Bank's Control of Corruption Index, International Country Risk Guide's (ICRG) index of the Political Risk Services Inc., the corruption index in the World Competitiveness Yearbook of the Institute for Management Development (IMD), and the corruption index in the Global Competitiveness Report of the World Economic Forum. The TI and ICRG indices are the most widely applied in cross-country studies of FDI and corruption.

Golden and Picci (2005) discuss the weaknesses of these survey-based measures. The main concern is that the real degree of reliability of the survey information is unknown. For example, respondents involved in corrupt activity may under-report their involvement, while those not involved lack accurate information. TI attempts to solve this problem by aggregating information from multiple surveys, but this aggregation effort may be less successful.[4] There is also a concern that the reliability of a corruption index may deteriorate over time. There is a danger that the survey respondents report what they believe based on highly publicized results of the most recent corruption index, rather than the real corruption that exists. The measures may well become endogenous to the index itself.

As a result of their concerns, Golden and Picci (2005) developed an objective measure of corruption for Italian regions for the mid-1990s which compared the difference between a measure of the total amount of investment in infrastructure over time and a measure of the physical quantity of public infrastructure, for example, kilometres of roads and railways, number and size of public buildings, and so on. Regions with large differences between these two measures suggest that money has been siphoned off due to mismanagement, fraud, bribes, kickbacks, or embezzlement, and hence are perceived as having a higher corruption level. However, this measurement is based on the assumption that regional corruption levels are unlikely to demonstrate much year on year variation. This is similar to Kaufmann *et al.* (2006) measurement of corruption by audit.

Within the limited intra-country corruption literature, Fridriksson *et al.* (2003) use the number of convictions of public officials per 1,000 public employees as a measure of corruption for US states, known as *judicial assessment* in Picci (2005).

However, no measure of corruption can be 100 per cent reliable. Kaufmann *et al.* (2006) argue that all efforts to measure corruption using any kind of data (subjective or objective) involve an irreducible element of uncertainty. There is always imprecision in specific measures and specific measures of corruption are imperfectly related to overall corruption.

9.2.2 Governance and corruption

Corruption cannot be considered in isolation. The quality of government is strongly correlated with levels of corruption. The World Bank states: 'bad governance is associated with corruption, distortion of government budgets, inequitable growth, social exclusion, lack of trust in authorities.'[5]

Picci (2005) discusses the relationship between corruption, governance efficiency and effectiveness. Picci (2005) argues that corruption may cause inefficiency, because a corrupt official aims to extract, for example a valuable rent, from a project, and hence is interested in keeping this project running for a long period, resulting in the efficiency of the bureaucracy being reduced. This inefficiency may then lead to further corruption. In terms of the relationship between corruption and effectiveness, a corrupt official may be tempted to spend more on public projects which are easier to extract unlawful rents from. Examples are known as white elephant projects.

However, Aidt (2003) analyses the existence of one category of corruption, efficient corruption, based on second-best reasoning. The notion is that, given the unavoidable distortions created by various government procedures or policies, corruption can promote allocative efficiency by allowing agents to circumvent these procedures or policies. Corruption enhances allocative efficiency through two channels: (1) corruption speeds up bureaucratic procedures, and (2) corruption causes competition for government resources, which results in more efficient services. However, this argument is based on a number of problematic assumptions and the most fundamental weakness is the assumption that the government failure that corruption attempts to correct is exogenous, when such failure in itself is unrelated and may well have been put in place and maintained by the corrupt official in the first place.

Previous research (Globerman and Shapiro, 2002; Globerman *et al.*, 2006) suggests 'good' governance is characterized by economic freedom, secure property rights, a minimum cost of complying with regulations and restrictions on trade, honest government officials, efficient civil services, and a transparent legal system. Good governance promotes successful performance and hence encourages FDI by increasing the scope for profitable business activities (Globerman *et al.*, 2006).

The measures of governance vary across studies but a typical measure is the risk rankings provided by some international organizations. Some studies directly use corruption as the measure of governance. In Globerman and Shapiro (2002) and Globerman *et al.* (2006) a broad composite index is employed which includes measures of political instability, rule of law, graft, regulatory burden, voice and political freedom, and government effectiveness. This governance index was developed by Kaufmann *et al.* (1999a, 1999b) and updated by Kaufmann *et al.* (2003). Governance therefore offers a broader measure of corruption than that employed in most empirical studies.

9.3 Empirical evidence

9.3.1 Empirical evidence on corruption and FDI

There are many papers analysing the consequences and causes of corruption, but only a few of them look at the relationship between FDI and corruption. Wheeler and Mody (1992), Hines (1995), Wei (2000), Smarzynska-Javorcik and Wei (2000), and Habib and Zurawicki (2002) are the only papers we are aware of that examine the effects of corruption on FDI. These studies have failed to find a consistently negative relationship between corruption and FDI.

Wheeler and Mody (1992) developed and estimated a non-linear capital expenditure model for US multinationals. The model includes measures of agglomeration economies and RISK, which is a combined measure of risk extracted from Business International (BI, now a subsidiary of the Economist Intelligence Unit) that includes indicators of political stability, inequality, corruption, red tape, quality of the legal system, cultural compatibility, attitude towards foreign capital, and general expatriate comfort (including the risk of terrorism). They focus on US manufacturing and electronics investment in 42 countries in the

1980s and fail to find a significant correlation between the size of FDI and the host country's risk level. The results also suggest that agglomeration economies are the dominant influence on foreign investment and short-term incentives have a limited impact on location choice.

Hines (1995) analysed US outward investment activities after the Foreign Corrupt Practices Act (FCPA) of 1977, which prohibits American individuals and corporations from bribing foreign government officials. The FCPA may have led US multinational firms to avoid joint ventures in more corrupt countries. Hines (1995) investigated four indicators of US business activities in bribe prone countries: FDI, capital/labour ratios, joint venture activity, and aircraft exports. The BI index was used to measure a country's corruption levels. Controlling for the growth of the host country's GDP, the results suggested that corruption negatively affected the growth of US-controlled FDI from 1977 to 1982, as well as the other three indicators. However, considering the influence of FCPA on total FDI from US and non-US investors, Hines (1995) failed to find a significantly negative correlation between total inward FDI and corruption level in the host countries.

Wei (2000) studied whether corruption had a negative effect on FDI and how big this effect was relative to the host country's tax on foreign corporations. This paper used a modified Tobit specification to estimate bilateral investment from 12 source countries and 45 host countries. It employed three measures of corruption, the BI index, the ICRG corruption rating and the TI index. It found that either an increase in the corruption level in a host country or an increase in the tax rate reduced inward foreign investment. An increase in the corruption level from that of Singapore to that of Mexico would have the same effect on inward FDI as raising the tax rate by 18 to 50 percentage points, depending on the specification. It also found that American investors were averse to corruption in host countries, but not necessarily more so than other investors, despite the FCPA of 1977.

Smarzynska-Javorcik and Wei (2000) is the first paper that uses firm-level data to estimate the impact of corruption in a host country on foreign investors' choice between a joint venture and full ownership. It presented a simple model of foreign investor's choice of entry mode as affected by the extent of corruption in the host country. On the one hand, having a local partner lowers the transaction costs of dealing with local corrupt officials; on the other hand, sharing ownership may lead to technology leakage. The hypothesis is that, conditional on foreign investment taking place, the foreign investor with sophisticated technology prefers a wholly-owned firm, but with a constant technological level, the higher the corruption (up to a limit), the more inclined the foreign investor will to be choose a joint venture. Two corruption indexes are adopted: the TI index and the WDR index (which is based on a survey undertaken in 1996 by the World Bank in preparation for the Word Development Report, 1997). Empirical tests suggest that host country corruption reduces inward FDI and shifts the ownership towards joint ventures. Technologically more advanced firms are found to be less likely to engage in joint ventures. Additionally, US firms are more averse to joint ventures in more corrupt countries, which may be due to the FCPA of 1977.

Habib and Zurawicki (2002) adopted a dual approach to examine the impact of corruption on FDI: the effect of corruption in the host country, and the effect of the absolute difference in corruption levels between the host and home countries. This study employed the data of bilateral FDI flows from seven home countries to 89 host countries for three years (1996–1998). The TI index was used to measure corruption. The empirical results provided support for the negative effects of corruption on FDI for both OLS and Probit model specifications. Foreign investors, on the whole, did not support corruption because it was difficult to manage, risky and costly, and could create operational inefficiencies.

Using a panel data of 6,288 US firms in China, Du *et al.* (2008a) showed that US firms preferred to locate in regions with better protection of intellectual property rights, lower levels of government intervention in business operation, lower degrees of government corruption, and better contract enforcement. They also found FDI are attracted to regions with higher foreign and domestic horizontal agglomerations across regions and vertical agglomerations between upstream and downstream industries. Similar results were found in Du *et al.* (2008b) with more comprehensive data, including foreign firms in China from US, EU, Japan and Korea. Furthermore, they found foreign horizontal agglomeration could mitigate the negative impact of weak institutions on FDI inflows, while the evidence of the interaction between institutions and domestic horizontal or vertical agglomerations was mixed. Both papers defined government corruption in a region as the proportion of private entrepreneurs answering 'Yes' to the question: 'is it necessary to have stricter policies against government corruption in your region?' from the Survey of China's Private Enterprises. Similar to TI and ICRG corruption indices, this index is perception based but is much simpler.

One deficiency in the abovementioned studies is that the stringency of environmental regulations is rarely modelled, or equivalently, corruption is rarely modelled in the studies focusing on the pollution haven hypothesis issue. Smarzynska-Javorcik and Wei (2005) did include corruption as a possible deterrent to FDI in a pollution haven hypothesis model. They found that local corruption deters FDI and with this improvement they found some support for the pollution haven hypothesis but the overall evidence of pollution havens was relatively weak and not robust to sensitivity checks.

Few of the previous studies considered cross-state/province analysis. Fredriksson *et al.* (2003) addressed these two shortages by estimating the impacts of state-level bureaucratic corruption and environmental policy on inbound US FDI. They developed a theoretical model presuming that corruption affects FDI via two channels: the impact on the supply of public goods and the effect on environmental stringency. They used state-level panel data for four industry sectors from 1977 to 1987. The results suggested that environmental policy and corruption are both important for the spatial allocation of inbound US FDI, and that the estimated effect of environmental policy was quite sensitive to the exogeneity assumption.

Fredriksson *et al.* (2003) motivated us to re-examine the intra-country pollution haven effect in China, controlling for the impact of provincial corruption and governance quality on FDI inflows.

9.3.2 Empirical evidence on governance and FDI

In terms of the relationship between FDI and governance quality, Globerman and his co-authors contributed greatly to the empirical literature. Their results generally suggested that good governance is particularly important for promoting FDI in developing countries. Globerman and Shapiro (2002) used their own composite index to examine the effects of governance infrastructure on both FDI inflows and outflows for a broad sample of developed and developing countries from 1995 to 1997. They also controlled for human capital and environmental regulations. The results indicated that governance infrastructure was an important determinant of both FDI inflows and outflows. Investment in governance infrastructure not only attracted capital but also created the conditions under which domestic MNCs emerged and subsequently invested abroad. Investment in governance infrastructure was however subject to diminishing returns, so that FDI inflows were promoted most successfully for smaller and developing countries. In terms of environmental regulations, environmental protection and remediation encouraged inward FDI. The results rejected the race to the bottom hypothesis and suggested that weakening environmental protection regimes is more likely to discourage FDI.

Globerman and Shapiro (2003) examined the importance of governance for US FDI using the same measure of governance. They adopted a two-stage estimation procedure. The first stage estimated the probability that a country is an FDI recipient and the results suggested that countries that fail to achieve a minimum threshold of effective governance are unlikely to receive any US FDI. The second stage focused on the countries that received US FDI inflows and the results indicated that governance infrastructure is an important determinant of the amount received.

Using a similar measure, Globerman *et al.* (2006) examined the role of governance infrastructure in determining inward and outward FDI for twenty emerging and transition economies in Europe between 1995 and 2001. The results again demonstrated that governance is an important determinant for both capital outflows and inflows for all countries.

The empirical studies mentioned above have made a great contribution to the literature about the impact of corruption/governance on FDI, although they have produced mixed results. What these studies have in common is the fact that they rely on perception-based measures of corruption/governance. However, reliable objective indices of corruption/governance are difficult to generate using hard data. Alternatively, Kao *et al.* (2005) used objective data to construct a governance efficiency index based on the definitions of governance efficiency by IMD and the methodology in Tang and Tang (2004b).[6] Kao *et al.* (2005) was the first paper to investigate the relationship between governance efficiency and FDI in China using panel data for Chinese provinces from 2000 to 2004. They assumed that the fewer bureaucratic practices amongst government officials, the more effective the government. They found that more effective governments attract more FDI. In addition, other variables such as wages, infrastructure, level of free trade, income, and so on are also important determinants of FDI for Chinese provinces.

9.4 Conclusions

Previous studies suggested that corruption was assumed to be an obstacle of FDI while good governance attracted FDI. Previous studies showed us that corruption level and government quality may also play important roles in attracting FDI inflows to China. These government characteristics were usually omitted in the majority of previous FDI literature, especially in intra-country FDI location choice studies, due to the unavailability of data. Therefore, we had to construct indices to measure regional differences in corruption level and government quality.

Corruption has been commonly recognized as an urgent problem that needs to be tackled. Xi Jinping, China's new Communist Party leader, stresses the need to fight against injustice and corruption in the future. What is the level of corruption and/or anti-corruption in China? Do corruption and/or anti-corruption levels vary across regions? Do some regions have more efficient government than others and to what extent? These are interesting questions investigated in the following two chapters.

10
Corruption, Anti-corruption, and Governance in China

10.1 Introduction

Corruption has been a significant social and political problem in China since 1978, when economic reforms started. It has been a *social pollution*, contributing to problems such as environmental degradation, social and political stability, and decreased credibility of government officials. From the early 1990s, the Chinese government began to prioritise anti-corruption work and enhance anti-corruption efforts. However, corruption remains socially widespread and results in large economic losses (Hu, 2001). Corruption is considered the second greatest public concern behind unemployment (He, 2000).

This chapter consists of five key sections. Section 10.2 summarizes the four stages of corruption that China has experienced since the early 1980s, including the social and economic background and the characteristics of corruption. It also describes the types of corruption in China and the corresponding economic losses. The development of anti-corruption activities in China is then expounded in section 10.3, which also analyses why corruption is still a serious problem in China after years of the government fighting against it. In Section 10.4 we discuss the relationship between corruption and FDI inflows. In Section 10.5 we construct a measure of anti-corruption using the normalized number of registered cases related to corruption and dereliction of duty for the period 1998–2003. In Section 10.6, we develop a province-level government efficiency index by combining 40 separate indices covering all aspects of governance, aggregated to provide an overall standardized index of good governance for each province for each year.

10.2 Corruption in China

Measuring corruption is difficult, particularly in China where there is a lack of transparency. According to the corruption perception index (CPI) provided by Transparency International, China is ranked in the middle of the surveyed countries (Table 10.1). Corruption in China increased gradually during the 1980s, but rose sharply in the 1990s. After 1998, corruption became relatively stable. The corruption perception score has decreased since the 1980s and reached its lowest level in the mid–1990s. From 1998–2010, China's average corruption perception score was 3.4 on a scale of one (highly corrupt) to ten (highly clean). Due to increased anti-corruption efforts, there was a slight improvement, but corruption is still widespread in China.

Ni and Wang (2003) examined changes in the number of corruption cases, the money involved, the number of people involved, and the number of officials above division director/county administrator level who have been sentenced. They divided the extent of corruption into four stages.

Table 10.1 Corruption perception index for China

Year	Rank	Score*	No. of survey	No. of countries ranked
1980–1985	N/A	5.13	N/A	N/A
1988–1992	N/A	4.73	N/A	N/A
1995	40	2.16	4	41
1996	50	2.43	9	54
1997	41	2.88	6	52
1998	52	3.5	10	85
1999	58	3.4	11	99
2000	63	3.1	11	90
2001	57	3.5	10	91
2002	59	3.5	11	102
2003	66	3.4	13	133
2004	71	3.4	16	146
2005	78	3.2	14	159
2006	70	3.3	9	163
2007	72	3.5	9	179
2008	72	3.6	9	180
2009	79	3.6	9	180
2010	78	3.5	9	178

Note: *CPI Score relates to perceptions of the degree of corruption as seen by business people and country analysts and ranges between ten (highly clean) and 0 (highly corrupt).

Source: Transparency International (http://archive.transparency.org/ [Accessed 11 June 2012].

The first stage was 1980–1988. When economic reform began around 1980, the difference in income between different strata of the population was not significant. Corruption was rare. Following economic reform, the coastal regions developed quickly. However, the earnings of government officials remained at a low level. This income difference caused increasing individual corruption that peaked in 1986 and then decreased, due to a growing concern about corruption in society and government. The forms of corruption in this period were related to bribes to support smuggling, absorbing foreign investment and importing overseas advanced technology and equipment.

The second stage was after 1989 and was due to the existence of dual-track economic systems during the transition period, which provided incentives and opportunities for corruption.[1] Some government officials abused their power and engaged in the fraudulent buying and selling of resources. Such officials were called *Guandao* in Chinese, that is official/bureaucratic profiteers. The second peak of corruption was reached in 1989. After the 1989 Tiananmen Square event, the government strengthened anti-corruption efforts so that corruption was contained.[2] This stage finished in 1992. The amount of money involved in the first and second stages was still relatively small.

The third stage is from 1993 to 1998. In the 1990s economic reform extended to the factor market. Some new forms of corruption appeared in the fields of finance, security, and the transfer of property rights. The money involved in this kind of corruption increased dramatically. Meanwhile, the loopholes and weaknesses in regulation and the lack of experience and technology in the anti-corruption agencies dealing with the new forms of corruption made this stage the most serious period of corruption in China. Group and gang cases increased, involving many officials at different administrative levels. These corruption cases directly affected ordinary daily lives and made a bad impression on the people. The peak occurred in 1997. After that the government paid more attention to the enforcement of regulations, rather than only investigating large or key corruption cases.[3] This change led to a sharp decrease in corruption in 1998.

From 1999 corruption entered a fourth stage. In the 2000s, the growth rate of corruption has been slow. Anti-corruption activities have become more systematic and the regulatory framework has improved. Table 10.2 shows the number of registered cases and people under direct investigation by the People's Procuratorate during this period. These cases include corruption and bribery, as well as abuse and dereliction of duty. There was a decrease in the total number of corruption cases from

Table 10.2 Registered cases under direct investigation by procuratorate 1999–2010

Year	No. of cases	No. people in cases	No. people in key cases
1999	38,382	43,533	2,200
2000	45,113	50,784	2,872
2001	45,266	50,292	3,013
2002	43,258	47,699	2,925
2003	39,562	43,490	2,728
2004	37,786	43,757	2,960
2005	35,028	41,447	2,799
2006	33,668	40,041	2,736
2007	33,651	40,753	2,706
2008	33,546	41,179	2,687
2009	32,439	41,531	2,670
2010	32,909	44,085	2,723

Source: China Statistical Yearbook (various years).

2001. However, the number of large/key cases involving money and the number of officials above division director/county administrator level have significantly increased relative to previous stages. It illustrates that corruption involving a great amount of money and high officials has become a serious problem.

In the 1980s, few corruption cases involved more than RMB one million yuan, while in the fourth stage there have been more scandals involving bribery or misappropriation of phenomenal sums of money. Xinhua Net compares high official corruption cases between 2003 and 2010. Thirteen high officials above provincial/ministerial level were sentenced for corruption in 2003 and eleven in 2010. However, the average amount of bribery involved increased from RMB 4.19 billion per person to RMB 9.83 billion per person.[4] In addition to corruption of high officials, it is worth noticing that even some middle and low level cadres embezzled huge sums of money. For example, the so-called 'land granny', Luo Yaping, a middle ranking official who worked in the land department of a district in Fushun city, Liaoning from 2004–2007, was sentenced to death after amassing of huge fortune, including the misappropriation of RMB 34.27 million of public funds, bribes of RMB 300,000 and possession of property worth RMB 32.55 million with unstated source of large amount of properties.

Corruption has been widespread throughout society. Pei (2007) pointed out that corruption was concentrated in sectors with extensive state involvement, for example, infrastructure projects, land transactions, real estate, government procurement, financial services, and highly regulated areas like health care, social security, transportation and postal services. A survey in 2006 showed that half the 3,067 corruption cases were related to infrastructure projects and land transactions. Corruption had also spread into new areas, such as the private sector, culture and education.

Referring to Hu (2001), the main types of corruption in China were tax evasion; rent seeking; involvement in the underground economy where the management of goods is legal, but the income is illegal; and the abuse of public investment and public expenditure.

The economic loss to corruption published by the government was RMB 49.13 billion (about $5.94 billion) from 1983–2002.[5] But this amount of money is based on the economic loss that has been investigated. Ni and Wang (2004) predicted that this investigation rate was only 10 per cent, which meant that the real corruption rate was ten times the amount published by the government. This would make the real economic loss from 1983–2002 RMB 500 billion (about $60 billion), an average of RMB 25 billion (about $3 billion) a year.

However, this prediction is conservative according to other researchers. Hu (2001) predicted an annual economic loss in the late 1990s of about RMB 987.5–1257.0 billion (about $119.3–$151.9 billion), accounting for 13.2–16.8 per cent of GDP. Tax evasion was the largest economic loss through corruption, accounting for 7.6–9.1 per cent of GDP. Illegal management of public investment monies and public expenditure was the second largest, accounting for 3.4–4.5 per cent of GDP. Rent-seeking behaviour led to losses of about 1.7–2.7 per cent of GDP. Income from the underground economy in illegal goods (for example smuggling, drugs, and trafficking) was the fourth largest loss, accounting for 0.4–0.5 per cent of GDP.

Pei (2007) estimates that the direct cost of corruption was 10 per cent of land lease revenues, fixed investments and government spending, which was equivalent to 3 per cent of national GDP in 2003, or $86 billion. The indirect cost of corruption is incalculable. Indirect costs include efficiency losses, waste, damage to the environment, public health and education, and loss of credibility in public institutions and the morals of civil servants.

10.3 Anti-corruption in China

In December 1978, the Communist Party of China (CPC) established the first CPC Central Commission for Discipline Inspection, which is in charge of rooting out corruption and malfeasance among CPC cadres. Since 1989 anti-corruption work has been placed high on the agenda of the Chinese government. On 15 August 1989, China's Supreme People's Court and China's Supreme People's Procuratorate (CSPP) together released a circular, which declared the central government's determination to severely punish corrupt officials.[6] It started an upsurge in the fight against corruption.

Following the example of the Independent Commission Against Corruption (ICAC) in Hong Kong, the People's Procuratorate of Guangdong Province was the first to establish an anti-corruption bureau in 1989. In 1995 CSPP established a general anti-corruption bureau, and from then on anti-corruption units were established at four levels of the procuratorate throughout the country. Except for the general bureau, anti-corruption offices are set up under the provincial people's procuratorates, municipal people's procuratorates, and county people's procuratorates. At present, there are more than 40,000 procurators from various procuratorates in China taking part in the fight against corruption. The anti-corruption offices are in charge of the investigation and preliminary hearings of cases involving corruption, bribery, misappropriation, unstated sources of large properties, disguised overseas savings deposits, illegal possession of public funds, illegal possession of confiscated properties, and so on.

During the first stage (1980–1988), ideological education was the major method for fighting corruption, which stressed the need to keep up the revolutionary traditions of the CPC and maintain sharp vigilance against hedonism (that is, pleasure seeking). Corrupt officials were given disciplinary punishment within the Party. From the second stage (after 1989), in addition to ideological education and disciplinary punishment, corrupt officials were punished according to law. The people's procurator office, in accordance with laws and relevant facts, could decide to arrest and approve the arrest of the suspect(s) in corruption cases proposed by the public security departments, state security departments or prison authorities. Then the people's procurator office instituted proceedings in the people's court against the suspects.

The anti-corruption bureau has made a contribution towards fighting corruption. As shown in Table 10.1, CSPP reported that from 1999–2010, the anti-corruption offices had investigated 450,608 corruption cases involving 528,591 persons (including 33,019 government officials with a ranking of division director or county administrator), and helped to retrieve a great amount of economic loss. In 2010 alone, the retrieved economic loss was about RMB 7.4 billion (about $1.09 billion). However, the rate of investigation is still low, according to researchers' predictions of corruption.

Recently, non-institutional contributions to anti-corruption have increased. More people at grassroots level have been involved in anti-corruption through new media platforms and *weibo*, China's Twitter-like microblog, has been represented. A number of corrupt officials were quickly sacked after they were exposed by microbloggers. New media has increased the public awareness of and participation in the anti-corruption campaign. Public pressure has speeded up the process of anti-corruption and influenced decision-making. However, new media anti-corruption efforsts have their shortcomings, such as accountability and potential abuse.

Although the Chinese government has hesitated to fight against corruption, corruption is still a serious social problem. Pei (2007) analysed three main causes of corruption in China. First, the dual-track economy (or hybrid economy in Pei's paper). After 30 years of reform towards a market economy, the state monopolized key industries, including banking, power generation and natural resources; controlled key prices such as interest rates and land prices; and regulated certain economic activities, for example real estate and infrastructure. The power of approval in these areas provides opportunities for corruption. Second, corruption is a high-return, low-risk activity because the punishment of corrupt officials is weak. The majority of corrupt officials received a warning, and only 6 per cent were criminally prosecuted and mainly received suspended sentences. The odds on a corrupt official going to jail is 3–100. Third, anti-corruption is adopted as a top-down approach. There are tough regulations with more than 1,200 laws and rules against corruption, but implementation is as ineffective at the local level as that of environmental regulations and others.

Similarly, Yao (2013) points out the causes of corruption include the current power structure, reliance on prosecution rather than the reformation of political, economic and social systems. He compares fighting corruption to a wolf chasing a herd of sheep. The investigated corrupt official is just like the straggling sheep which is caught by the wolf, that is to say, only those who fail to become members of corruption groups are vulnerable, while those who are in the corruption groups protect each other effectively to avoid being investigated and prosecuted. Therefore, to fight against corruption, political reform is needed to change how power is highly concentrated or controlled by one person or a group of people, and break up political groups with common economic interests by moving officials to different positions on a regular basis. Yao (2013) also argues that press freedom is important to prevent corruption, but this is still a no-go area.

10.4 Corruption and FDI

From the mid–1990s to the mid–2000s, the procurator's offices investigated at least 500,000 corruption cases, 64 per cent of them related to international trade and foreign enterprises (Takung Pao, 19 September 2006). Bribery of local officials by foreign investors has increased in recent years, destroying fair market competition and warping the allocation of resources.

Some investors feel that the investment environment in China is different to that of their home country. They know corruption is a widespread social problem and consider that bribery is a 'latent rule' in the Chinese economy. They give bribes to win against the competition and to avoid unfavourable regulations and policies.

China is still at a stage of transition to a market economy and government has the power to control the allocation of resources and access to certain business areas. Multinational firms may not gain market entrance just because of their advantages in capital, technology and management. In order to achieve higher profits, some multinational enterprises like to pay the cost of bribing local officials.

Seeking high profits is therefore the intrinsic motivation for foreign investors to give bribes, and the weakness in anti-corruption (anti-bribe) regulations also provides an external condition for bribery.

However, corruption does not encourage foreign investment. Most foreign investors are worried, or fearful, about corruption in local government. Pei (2007) argues that 'corruption endangers FDI because illicit behaviour by local officials could expose Western firms to potentially vast environmental, human rights and financial liabilities. Corruption creates serious obstacles for Western companies facing rivals who engage in illegal practices in order to win business in China. Corruption puts Western firms' intellectual property particularly at risk because unscrupulous local officials routinely protect Chinese counterfeiters in exchange for bribes'.[7]

Although in the short-term they could gain market entrance, or some other preferential treatment, by bribery, multinational firms would like to locate in places where the corruption level is low for long-term benefits.

10.5 Provincial anti-corruption efforts

Most corruption indices are cross-national and perception based. To investigate whether provincial differences in corruption and governance quality have an impact on FDI location choice in China, the lack of an obvious index of provincial government corruption meant we had to develop our own measure of corruption. In China, the procuratorates only report the number of registered cases under their direct investigation, which could be used to proxy provincial corruption. However, corruption is so serious in China that this measure, to a high degree, is appropriate to proxy the extent to which provincial governments fight corruption. Therefore, we modified our objective to find out whether provincial control of corruption and governance quality influences FDI inflows. We used the normalized number of registered cases related to corruption and dereliction of duty under the direct investigation of procuratorates to proxy the provincial control of corruption.

Fredriksson *et al.* (2003) used the number of convictions of public officials per 1,000 public employees to measure bureaucratic corruption. The data was from a 1987 US Department of Justice report and was used in Goel and Nelson (1998) and Fisman and Gatti (1999) to measure state-level corruption in the US.

Fredriksson *et al.* (2003) and Goel and Nelson (1998) discussed the shortcomings of this measurement of corruption. 'First, convictions are only recorded if the corrupt bureaucrats are caught and evidence of their guilt is obtained. Second, the data treat all corruption convictions homogeneously. ... Finally, the data of conviction provides no indication of when corrupt activity actually occurred. We attempt to circumvent this final problem by using the number of convictions in year $t + 1$ to proxy for corruption in year t. Despite these caveats, it remains the best available measure of corruption.'[8]

Since we lacked a subjective state-level corruption index, such a measure of corruption seemed to be the only feasible method. The Procuratorial Yearbook of China (various years) provided the annual reports of the Supreme People's Procuratorate and local people's procutatorates, which included similar data. However, while all the procuratorates reported the number of registered cases under their direct investigation, a number of provinces did not report the number of persons involved in these cases. When focusing on the provinces that provided the data, including both cases and persons, and the whole country, we found the correlation between the number of cases and number of persons was 0.99.[9] Therefore, we used registered cases under direct investigation by procurator's offices to proxy the corruption level of each province.

Registered cases include, for example, those charged with corruption, bribery, misappropriation of public funds, collective illegal possession of public funds, unstated sources of large property, abuse of power, dereliction of duty, fraudulent practices and others. Since those involved in these cases may include not only public officials but also people working in other sectors, we normalized the number of cases by the provincial population.

Another issue to note is that corruption cases under investigation could be interpreted in two different ways, real corruption level or anti-corruption effort. However, China is very different from the US; the corruption level in China is much higher than that in the US. According to the CPI score provided by TI, the average score of the US was above 7.5 in the past ten years, while that of China was around 3.5. Sucha high corruption level in China is compounded by the low investigation rate (at about 10 per cent or less as discussed in Section 10.2). Therefore, investigated corruption cases cannot reflect the real corruption level in Chinese provinces, therefore, copying the method of Fredriksson *et al.* (2003) is not ideal. However, if we assume that inherent corruption levels are equal across provinces, which could be the case if individuals were equally susceptible to temptation, then investigated corruption cases scaled by population can be considered as a good proxy for the level of effort that a province expends fighting corruption. Given the high levels of corruption and the very public fight against it in China, the number of corruption cases under investigation is a good indicator of how seriously a province takes the fight against corruption. We also noted that the CSPP treats these data as the anti-corruption achievement of supreme and local procuratorates for each year. In addition, the consistent positive coefficient on this variable in the results (see Chapter 11) suggested that this measure should be interpreted as anti-corruption effort. The difference in provincial anti-corruption efforts is reported in Table 10.3.

We observed that most provinces remained stable in terms of their number of normalized cases. The majority of provinces had higher numbers of normalized cases during 2000–2003. We observed that some provinces, on average, made more effort in anti-corruption than others, for example, Tianjin, Jilin and Heilongjiang; some had a jump in some years and returned to lower levels in the following years, such

Table 10.3 Provincial anti–corruption effort

		1998		1999		2000	
	Province	Cases/ 100,000 persons	Rank	Cases/ 100,000 persons	Rank	Cases/ 100,000 persons	Rank
1.	Beijing	2.17	25	2.77	18	3.27	15
2.	Tianjin	3.21	12	4.26	3	6.15	1
3.	Hebei	3.60	5	4.06	5	4.30	6
4.	Shanxi*	3.76	4	4.05	6	4.98	5
5.	Inner Mongolia**	2.52	20	2.41	25	3.14	19
6.	Liaoning	3.28	10	4.14	4	5.43	3
7.	Jilin*	4.53	1	5.08	1	5.40	4
8.	Heilongjiang*	4.40	2	4.60	2	5.87	2
9.	Shanghai	3.39	8	3.11	12	3.03	24
10.	Jiangsu	2.33	22	2.57	23	3.26	16
11.	Zhejiang	2.76	16	3.06	14	3.11	20
12.	Anhui*	2.00	28	2.53	24	3.11	21
13.	Fujian	3.50	6	3.51	9	3.85	8
14.	Jiangxi*	2.59	19	3.27	10	3.31	14
15.	Shandong	3.42	7	3.58	8	2.47	27
16.	Henan*	2.33	23	3.04	16	3.90	7
17.	Hubei*	3.19	13	3.23	11	3.37	11
18.	Hunan*	2.52	21	2.75	20	3.03	23
19.	Guangdong	2.08	26	2.15	28	2.20	30
20.	Guangxi**	1.82	30	2.25	27	2.78	26
21.	Hainan	3.15	14	2.74	21	3.18	17
22.	Chongqing**	2.25	24	2.76	19	3.03	25
23.	Sichuan**	1.89	29	2.30	26	3.04	22
24.	Guizhou**	2.71	17	2.69	22	3.15	18
25.	Yunnan**	2.93	15	3.06	15	3.37	12
27.[a]	Shaanxi**	3.23	11	3.02	17	3.60	9
28.	Gansu**	2.04	27	2.12	29	2.33	28
29.	Qinghai**	3.32	9	3.10	13	3.38	10
30.	Ningxia**	2.70	18	2.03	30	2.28	29
31.	Xinjiang**	4.09	3	3.82	7	3.32	13

Continued

Table 10.3 Continued

	Province	2001		2002		2003	
		Cases/ 100,000 persons	**Rank**	**Cases/ 100,000 persons**	**Rank**	**Cases/ 100,000 persons**	**Rank**
1.	Beijing	2.95	22	3.08	21	2.30	25
2.	Tianjin	7.03	1	6.88	1	5.24	2
3.	Hebei	4.27	7	4.49	7	3.74	6
4.	Shanxi*	4.50	6	3.93	8	3.56	7
5.	Inner Mongolia**	2.92	24	3.25	16	2.94	17
6.	Liaoning	5.05	4	5.41	4	4.62	4
7.	Jilin*	5.12	3	4.72	6	4.25	5
8.	Heilongjiang*	5.65	2	5.92	3	6.10	1
9.	Shanghai	3.22	17	3.00	23	2.18	27
10.	Jiangsu	3.31	15	3.30	13	3.03	14
11.	Zhejiang	3.16	18	3.12	19	2.98	15
12.	Anhui*	3.03	19	3.61	11	2.38	23
13.	Fujian	3.67	11	3.28	15	3.42	8
14.	Jiangxi*	3.85	10	4.91	5	4.82	3
15.	Shandong	4.50	5	6.09	2	3.06	13
16.	Henan*	3.86	9	3.76	10	3.34	10
17.	Hubei*	3.49	13	3.29	14	2.81	18
18.	Hunan*	2.59	28	3.11	20	2.09	28
19.	Guangdong	2.28	29	2.32	29	1.99	29
20.	Guangxi**	3.02	20	2.83	24	2.80	19
21.	Hainan	2.88	25	2.76	25	2.33	24
22.	Chongqing**	2.72	26	2.56	28	2.42	21
23.	Sichuan**	2.67	27	2.61	27	2.42	22
24.	Guizhou**	2.97	21	3.05	22	2.95	16
25.	Yunnan**	3.66	12	2.76	26	2.29	26
27.[a]	Shaanxi**	3.35	14	3.19	18	3.17	12
28.	Gansu**	2.00	30	1.74	30	1.90	30
29.	Qinghai**	3.31	16	3.31	12	3.39	9
30.	Ningxia**	2.93	23	3.79	9	2.53	20
31.	Xinjiang**	4.03	8	3.21	17	3.33	11

Continued

Table 10.3 Continued

	2004		2005		2006		2007	
Province	Cases/ 100,000 persons	Rank	Cases/ 100,000 persons	Rank	Cases/ 100,000 persons	Rank	Cases/ 100,000 persons	Rank
1. Beijing	2.39	24	1.90	29	2.03	25	1.97	28
2. Tianjin	4.83	2	5.06	1	4.11	2	3.41	6
3. Hebei	3.38	8	3.83	4	2.22	21	5.19	2
4. Shanxi*	3.45	7	3.55	7	3.82	3	2.74	14
5. Inner Mongolia**	2.77	18	2.62	19	1.96	28	3.21	10
6. Liaoning	3.73	4	3.71	6	3.73	5	4.83	3
7. Jilin*	4.31	3	4.05	3	4.37	1	6.10	1
8. Heilongjiang*	4.92	1	4.22	2	2.86	12	3.31	9
9. Shanghai	2.52	20	2.41	21	2.61	14	2.39	17
10. Jiangsu	2.44	23	2.36	23	2.33	19	2.18	22
11. Zhejiang	2.90	16	3.30	10	2.44	17	4.23	5
12. Anhui*	2.36	25	2.19	25	2.05	24	2.13	25
13. Fujian	3.26	11	3.11	12	3.04	10	3.34	7
14. Jiangxi*	3.69	5	2.38	22	2.31	20	2.23	21
15. Shandong	3.14	14	3.73	5	3.79	4	2.37	18
16. Henan*	3.34	9	3.49	8	3.22	8	3.31	8
17. Hubei*	2.73	19	2.72	16	2.73	13	2.80	13
18. Hunan*	2.45	22	2.46	20	2.49	16	2.48	16
19. Guangdong	1.60	30	1.85	30	1.81	30	2.09	26
20. Guangxi**	2.88	17	2.71	18	2.51	15	0.60	30
21. Hainan	2.52	21	2.22	24	2.12	23	2.14	24
22. Chongqing**	2.18	27	2.13	26	1.85	29	2.23	20
23. Sichuan**	2.36	26	2.71	17	2.13	22	2.70	15
24. Guizhou**	2.97	15	3.43	9	3.34	6	4.75	4
25. Yunnan**	2.08	29	2.03	28	1.99	26	1.98	27
27.[a] Shaanxi**	3.17	13	2.89	14	3.04	11	2.89	11
28. Gansu**	2.13	28	2.12	27	1.98	27	2.15	23
29. Qinghai**	3.27	10	2.84	15	2.35	18	1.18	29
30. Ningxia**	3.45	6	2.95	13	3.11	9	2.25	19
31. Xinjiang**	3.20	12	3.13	11	3.23	7	2.82	12

Notes: * indicates central provinces and ** Western provinces. [a] No. 26 is where Tibet would have been.

as Shandong, Jiangxi and Ningxia; and few provinces had a significant decrease in the value of normalized cases.

In terms of the relative rankings of provinces, the majority tended to move within a limited range of their 1998 ranking. Some provinces have always made more effort to tackle corruption, such as Tianjin, Liaoning, Jilin, Heilongjiang, Hebei, Shanxi, and Shandong; and some provinces have made less effort, such as Guangdong, Guangxi, Chongqing, Sichuan, Beijing, and Gansu. However, there were some notable changes in position, for example, Henan (23rd to 8th) and Guizhou (17th to 4th) significantly improved their ranking while Shanghai (8th to 17th), Hainan (14th to 24th) and Yunnan (15th to 27th) saw their ranking worsen. There appears to be no discernible geographic pattern.

10.6 Provincial government efficiency

Following the methodology in two papers, Tang and Tang (2004a, b), we constructed a government efficiency index to measure provincial governance quality.

Tang and Tang (2004a, b) created a system of indices to measure provincial government efficiency in China following the methodology and analysis principles of the IMD World Competitiveness Yearbook (IMD, 2013). The system contains 47 indices in four factors such as public services, public goods, government scale and national welfare. Then they calculated the standardized value (STD) of 37 indices with the help of the Standard Derivation Method according to the data from 2001. Then the aggregated STD of each province was worked out using the weighted arithmetic mean method, and hence the rank of STD value. The STD was used to measure the efficiency of 31 provincial governments in 2002. This method was adopted in Kao *et al.* (2005) to create an index measuring governance quality in each province. In this book, we follow this method and improve on Tang and Tang (2004b) and Kao *et al.* (2005) by adding more indices (from 37 to 40) and for a longer period of ten years (1998–2007) across 30 provinces. We assumed that a province with a higher level of government efficiency is an indicator that it has good local bureaucrats.

Table 10.4 lists the 47 indices in each of the four factors. The government public services factor includes four sub-factors: 1) education, science and technology, culture, and public health services (11 indices), with a weight of 0.55 for the first factor; 2) public security services (8 indices) with a weight of 0.15; 3) meteorological services (2 indices) with a weight of 0.15; and 4) social security services (3 indices) with a weight

Table 10.4 Government efficiency indices

Government Public Services (24 indices, weight = 0.4)	
Sub Factors	**Indices**
Education, Science & Technology, Culture, and Public Health Services (11 indices) (weight = 0.55)	1. Per Capita Government Budgetary Expenditures for Scientific and Technology Promotion (yuan) 2. Rate of Products with Excellent Quality (per cent) 3. Three Types of Patent (Inventions, Utility Models and Designs) Applications Granted (item/100 000 persons) 4. Per Capita Transaction value in Technical Market (yuan) 5. *Student-Teacher Ratio of Primary Schools* 6. *Student-Teacher Ratio of Secondary Schools* 7. *Illiterate and Semi-illiterate Rate (per cent)* 8. The Share of Government Appropriation for Education in GDP (per cent) 9. Institutions for Culture and Art (unit/100 000 persons) 10. Beds in Health Institutions (unit/100 000 persons)
Public Security Services (8 indices) (weight = 0.15)	11. Employed Persons in Health Institutions (person/ 100 000 persons) 12. *Three Accidents (Traffic Accidents, Fires and Pollution Accidents) (case/100 000 persons)* 13. *Losses in Three Accidents (yuan)* 14. *Legislations (New Legislations, Revised Old Legislations, Including Laws, Regulations, and so on.) (case)* 15. *First Trial Cases Accepted by Courts (case)* 16. *First Trial Cases Settled by Courts (case)* 17. *Arrests of Criminal Suspects by Procurator's Offices (person)* 18. *Criminal Cases Cracked and/or Registered in Public Security Organs (case)* 19. *Criminal Cases (case/100 000 persons)*
Meteorological Services (2 indices) (weight = 0.15)	20. Agro-Meteorological Services Stations (unit/100 000 persons) 21. Earthquake Monitoring Stations (unit/100 000 persons)
Social Security Services (3 indices) (weight = 0.15)	22. Number of Careers Service Agency at the end of year (unit/100 000 persons) 23. Number of Urban Community Welfare Facilities (unit/100 000 persons) 24. Rural Social Security Network (unit/100 000 person)

Continued

Table 10.4 Continued

Sub Factors	Indices
Government Public Services (24 indices, weight = 0.4)	
Social Infrastructure (6 indices) (weight = 0.5)	25. State Budgetary Appropriation in Capital Construction and Innovation (100 million yuan)
	26. Local –Central Government Projects Ratio of Investment in Capital Construction and Innovation (per cent)
	27. Ratio of Projects Completed and Put into Use in Capital Construction and Innovation (per cent)
	28. Treatment Efficiency of Industrial Wastewater, Waste Gas and Solid Wastes
	29. Reservoir Volume (100 million cubic metres/ 10 000 persons)
	30. Ratio of Area of Nature Reserves and Provincial Area (per cent)
City Infrastructure (5 indices) (weight = 0.5)	31. *Rate of Access to Gas (per cent)*
	32. Numbers Public Transportation Vehicles per 10 000 persons in Cities (unit)
	33. Per Capita Area of Paved Roads (sq.m)
	34. Per Capita Green Area (sq.m)
	35. Number of Public Toilet per 10 000 persons (unit)
Government Scale (5 indices, weight = 0.2)	
	36. *Ratio of Staff and Workers in Government Agencies and Total Population (person/10 000 persons)*
	37. *Ratio of Staff and Workers in Government Agencies and Total Employed Persons (per cent)*
	38. *Ratio of Government Consumption and Final Consumption (per cent)*
	39. *Ratio of Government Expenditures and GDP (per cent)*
	40. *The Share of Penalty and Confiscatory Income and Income from Administrative Fees in Total Government Revenue*
National Welfare (7 indices, weight = 0.1)	
	41. Per Capita Annual Net Income of Rural Households (yuan)
	42. Per Capita Annual Disposable Income of Urban Households (yuan)
	43. *Engle Coefficient of Rural Households (per cent)*
	44. *Engle Coefficient of Urban Households (per cent)*
	45. *Consumer price index (preceding year = 100)*
	46. GDP per capita (yuan)
	47. Ratio of Expenditure on Policy-related Subsidies and Government Expenditure (per cent)

Note: The indices in italic are inverse criteria. The indices in bold type are unavailable.

of 0.15. Government public goods factor has two sub-factors, social infrastructure (6 indices) and city infrastructure (5 indices) with equal weights. Government scale factor has five indices and national welfare factor seven indices. The weights of the four factors are 0.4, 0.3, 0.2, and 0.1 respectively, according to their importance. The indices in bold type are the seven indices that are not available.

The measure of provincial government efficiency is developed in five steps as follows:

1) *Construction of the primary measures for Chinese provinces*. The primary measures are constructed by the available data for a provincial characteristic. For example, numbers of students and teachers in specialized and regular secondary schools; total number of and losses in traffic, fire and pollution accidents; central government and local government investments in capital construction and innovation, and so on. Data are recorded in the form in which they are provided in the China Statistical Yearbook and the China Environment Yearbook.
2) *Normalization of the primary measures*. In addition to the losses from three accidents, and the state budget investment in capital construction and innovation, each of the primary measures are either in the form of a ratio (for example student/teacher ratio, local/central government projects ratio of investment in capital construction and innovation, and Engle coefficients) or normalized either by present population or by the dimension (square kilometres) of the provincial area, depending on the features of the indices (but some data are already normalized in the yearbooks). The results are in the types as: per capita green area in the city, ratio of area of nature reserves and provincial area. Definitions of the 40 indices are in Appendix 10.1.
3) *Standardization of the normalized measures*. The output of the normalization is a set of indices that are presented in different units. They are not directly comparable. Each index is standardized using the following formula.

$$STD_{i,j} = (X_{i.j} - \bar{X}_j) / S_j \tag{3.4.2}$$

where

$STD_{i,j}$ is the standardized value of index j in region i;
$X_{i,j}$ is the original value of the index j in region i;
$\bar{X}$ is the mean value of X; and
S is standard error defined as $S_j = \sqrt{\sum_{i=1}^{n} (X_{i,j} - \bar{X}_j)^2 \frac{1}{n}}$.[10]

4) *Aggregation into the sub-factors*. The arithmetic mean is used to average the STD values for each region within each sub-factor. In most cases, a higher value is better, for example, per capita income; the province with the highest standardized value is ranked first while the one with the lowest is last. However, with some criteria (in italic in Table 10.4), the lowest value is the most efficient, for example, Engle coefficients. In these cases, a reverse ranking is used: the province with the highest standardized value is ranked last and the one with the lowest is first. According to the principles of the IMD World Competitive Yearbook, in the aggregation of the statistics all missing values are replaced with a STD value equal to zero. The resulting STD value for each sub-factor is then averaged arithmetically, standardized and normalized.
5) *Aggregation of the sub-factors and four factors*. The weighted mean is then used to aggregate these sub-factors, and after that the four factors. The weight of each sub-factor and factor follows that in Tang and Tang (2004b). Finally, we get the aggregated STD values and corresponding ranks of 30 provinces for ten years. Results are provided in Table 10.5.

Table 10.5 shows that eight provinces (Beijing, Shanghai, Jiangsu, Tianjin, Zhejiang, Heilongjiang, Liaoning, and Jilin), had relatively high STD values from 1998–2007. These provinces are located in eastern regions or regions on the border, where the economy grows quickly and national welfare is high thanks to geographic advantages and favourable policies. In contrast, some inland provinces, for example, Guizhou, Guangxi, Hunan, Yunnan, Chongqing, Jiangxi, Henan, Gansu, Sichuan, and Shanxi, have relatively low or negative STD values indicating low government efficiencies. The difference in government efficiencies among Chinese provinces appears to be consistent with the disparity in regional economic development.

In terms of the trend over time, the ranks of the provinces, such as Shanxi, Inner Mongolia, Shaanxi, Qinghai, and Xinjiang, have increased. The ranks of Beijing, Shanghai, and Liaoning remain relatively stable but the STD values have increased considerably. The significant positive movers include Shaanxi (25th to 8th), Qinghai (24th to 14th), Jiangxi (28th to 20th), and Inner Mongolia (16th to 9th). Those moving in the opposite direction include Hainan (6th to 24th), Yunnan (18th to 28th), Jilin (4th to 11th), and Sichuan (20th to 26th). Our results suggest that provinces with rapid economic development have tended to retain

Table 10.5 Provincial government efficiency

Province		1998		1999		2000		2001		2002	
		STD value	Rank	STD value	Rank	STD value	Rank	STD value	Rank	STD value	Rank
1.	Beijing	0.38	2	0.40	2	0.49	1	0.62	1	0.81	1
2.	Tianjin	0.37	3	0.24	5	0.25	5	0.26	4	0.29	3
3.	Hebei	0.01	12	0.09	10	–0.01	16	0.09	9	0.15	10
4.	Shanxi*	–0.12	21	–0.24	26	–0.21	26	–0.15	19	–0.09	19
5.	Inner Mongolia**	–0.04	16	0.00	16	0.07	10	0.08	11	0.24	5
6.	Liaoning	0.15	8	0.18	7	0.17	8	0.18	6	0.23	6
7.	Jilin*	0.33	4	0.32	4	0.25	4	0.12	8	0.16	9
8.	Heilongjiang*	0.15	9	0.22	6	0.20	6	0.15	7	0.22	7
9.	Shanghai	0.48	1	0.52	1	0.41	2	0.53	2	0.55	2
10.	Jiangsu	0.32	5	0.35	3	0.25	3	0.32	3	0.25	4
11.	Zhejiang	0.21	7	0.13	9	0.17	7	0.24	5	0.21	8
12.	Anhui*	–0.02	14	–0.05	18	–0.07	20	–0.02	16	–0.06	17
13.	Fujian	–0.07	19	–0.04	17	0.03	13	0.08	10	0.01	13
14.	Jiangxi*	–0.32	28	–0.36	29	–0.33	29	–0.24	26	–0.29	27
15.	Shandong	–0.06	17	0.02	15	0.07	12	–0.03	17	–0.06	18
16.	Henan*	–0.14	22	–0.22	24	–0.20	25	–0.21	25	–0.23	24
17.	Hubei*	0.10	11	0.07	13	0.08	9	0.02	15	–0.11	20
18.	Hunan*	–0.33	29	–0.35	28	–0.31	28	–0.27	28	–0.32	28
19.	Guangdong	0.00	13	0.08	11	–0.03	18	0.07	13	0.01	12
20.	Guangxi**	–0.26	26	–0.24	25	–0.30	27	–0.31	29	–0.35	29
21.	Hainan	0.21	6	0.15	8	0.07	11	0.08	12	–0.06	16
22.	Chongqing**	–0.28	27	–0.29	27	–0.09	21	–0.21	24	–0.23	26
23.	Sichuan**	–0.10	20	–0.12	21	–0.07	19	–0.19	23	–0.22	23
24.	Guizhou**	–0.43	30	–0.43	30	–0.40	30	–0.49	30	–0.50	30
25.	Yunnan**	–0.07	18	–0.11	20	–0.18	24	–0.18	22	–0.20	22
27.[a]	Shaanxi**	–0.25	25	–0.20	23	–0.14	22	–0.04	18	–0.01	14
28.	Gansu**	–0.14	23	–0.13	22	–0.16	23	–0.25	27	–0.18	21
29.	Qinghai**	–0.16	24	–0.10	19	0.02	14	0.05	14	–0.02	15
30.	Ningxia**	–0.03	15	0.03	14	0.02	15	–0.17	21	–0.23	25
31.	Xinjiang**	0.10	10	0.08	12	–0.02	17	–0.15	20	0.05	11

Province	2003		2004		2005		2006		2007	
	STD value	Rank	STD value	Rank	STD value	Rank	STD value	Rank	STD value	Rank
1. Beijing	0.86	1	0.85	2	0.79	1	0.80	1	0.68	2
2. Tianjin	0.34	4	0.32	4	0.31	5	0.39	3	0.05	10
3. Hebei	0.02	12	0.04	14	–0.02	14	0.01	14	–0.07	17
4. Shanxi*	–0.13	20	–0.10	19	–0.14	17	–0.05	16	–0.05	16
5. Inner Mongolia**	0.28	6	0.26	6	0.15	9	0.14	9	0.13	9
6. Liaoning	0.24	8	0.23	8	0.25	7	0.24	6	0.24	5
7. Jilin*	0.19	9	0.07	11	0.08	11	0.07	11	0.05	11
8. Heilongjiang*	0.36	3	0.32	5	0.30	6	0.18	8	0.16	7
9. Shanghai	0.76	2	0.92	1	0.78	2	0.77	2	0.91	1
10. Jiangsu	0.31	5	0.25	7	0.40	4	0.34	4	0.48	3
11. Zhejiang	0.24	7	0.35	3	0.53	3	0.33	5	0.39	4
12. Anhui*	–0.13	19	–0.18	21	–0.23	22	–0.21	22	–0.15	21
13. Fujian	0.01	14	0.06	13	0.11	10	–0.05	15	–0.04	15
14. Jiangxi*	–0.25	24	–0.21	22	–0.20	19	–0.18	20	–0.14	20
15. Shandong	–0.11	18	–0.08	18	–0.06	16	0.24	7	0.18	6
16. Henan*	–0.27	25	–0.32	25	–0.27	26	–0.23	24	–0.20	22
17. Hubei*	–0.11	16	–0.07	17	–0.17	18	–0.06	17	0.00	13
18. Hunan*	–0.41	28	–0.45	29	–0.29	27	–0.22	23	–0.28	25
19. Guangdong	–0.14	21	–0.04	15	–0.01	13	–0.11	19	–0.09	19
20. Guangxi**	–0.49	29	–0.44	28	–0.36	29	–0.33	28	–0.33	27
21. Hainan	–0.11	17	–0.06	16	–0.21	20	–0.20	21	–0.22	24

Continued

Table 10.5 Continued

Province	2003		2004		2005		2006		2007	
	STD value	Rank	STD value	Rank	STD value	Rank	STD value	Rank	STD value	Rank
22. Chongqing**	–0.31	26	–0.37	26	–0.26	24	–0.30	26	–0.21	23
23. Sichuan**	–0.17	22	–0.24	23	–0.23	23	–0.25	25	–0.32	26
24. Guizhou**	–0.64	30	–0.70	30	–0.64	30	–0.61	30	–0.62	30
25. Yunnan**	–0.33	27	–0.39	27	–0.34	28	–0.42	29	–0.35	28
27.[a] Shaanxi**	0.05	11	0.06	12	0.05	12	0.03	12	0.14	8
28. Gansu**	–0.08	15	–0.14	20	–0.27	25	–0.31	27	–0.42	29
29. Qinghai**	0.01	13	0.10	10	–0.03	15	0.01	13	–0.02	14
30. Ningxia**	–0.19	23	–0.26	24	–0.21	21	–0.08	18	–0.08	18
31. Xinjiang**	0.19	10	0.21	9	0.18	8	0.09	10	0.01	12

Notes: * indicates central provinces and ** Western provinces. [a] No. 26 is where Tibet would have been.

their advantage in government efficiency and that eastern regions have generally fared better than central and Western regions.

More worrying is that the difference between the highest and the lowest scoring provinces has increased, for example, the difference between Shanghai and Guizhou has increased from 0.91 in 1998 to 1.53 in 2007. This rise in the standard deviation means that provincial inequalities are widening, which may further impact future growth and FDI prospects for laggard provinces..

10.7 Conclusions

Corruption has been openly recognized as an emerging challenge to China's economy and social reforms. Fighting corruption requires increasing transparency in government affairs and an improvement in related laws and regulations. Some legal experts suggest revising the current Anti-unfair Competition Law and drawing up an Anti-corruption Law and an Anti-commercial Bribery Law. Chinese President Hu Jintao has declared the fight against corruption a priority in government's the political agenda. On 25 October 2006 the International Association of Anti-Corruption Authorities (IAACA) was officially established in order to promote the United Nations Convention Against Corruption and Jia Chunwang, procurator-general of the CSPP, was elected as president. Increasing transparency and improving regulations cannot work well without political reform. Therefore, anti-corruption work appears to be a long-term fight. After the eigteenth Congress of the CCP in 2012, the new political leaders seem to have strengthened anti-corruption activities and, hopefully, the situation will improve.

The results of our provincial anti-corruption effort scores do not show any obvious geographical disparity, while those of government efficiency are consistent with differences in regional economic development and FDI inflows. According to the argument that corruption deters FDI, anti-corruption may have a positive impact on FDI inflows, assuming inherent corruption levels are high and equal across provinces. Similarly, FDI is attracted by efficient government. The next chapter tests these hypotheses using Chinese province-level data from 1999–2003.

Appendix 10.1 Explanations of the government efficiency indices

1. Per Capita Government Budgetary Expenditures for Scientific and Technology Promotion: refers to the expenses appropriated

from the government budget for scientific technological expenditure, including new products development expenditure, expenditure for intermediate trial and subsidies for important scientific researches.

2. Rate of Products with Excellent Quality: reflects the quality of products. Sampling data is collected from 73 main industrial cities in different regions. There are missing values for some regions.
3. Three Types of Patent Applications Granted: patent rights are granted for inventions, utility models and designs. This indicator reflects the achievements of science and technology and design with independent intellectual property.
4. Per Capita Transaction value in Technical Market: indicates the regional ability for transfer of scientific and technological achievements.
5. Student/Teacher Ratio of Primary Schools: student refers to the number of student enrolments; teacher refers to the number of teachers and staff in schools.
6. Student/Teacher Ratio of Secondary Schools: secondary schools refer to regular junior secondary schools, regular senior secondary schools, specialized secondary schools, and vocational secondary schools.
7. Illiterate and Semi-illiterate Rate: refers to the population aged 15 and over, who are unable to read or find it very difficult to read. Data obtained from the sample survey.
8. The Share of Government Appropriation for Education in GDP: education expenses refer to the expenses appropriated from the government budget for expenditure on salaries and operational expenditure for education.
9. Institutions for Culture and Art: includes art performance troupes, art performance places, cultural centres, public libraries, and museums.
10. Beds in Health Institutions: includes hospitals, health centres, clinics, centres for disease control (including epidemic prevention stationss), maternity and child care centres and other health institutions.
11. Employed Persons in Health Institutions: refers to all medical technical personnel (including doctors, assistant nurses, pharmacists, and laboratory technicians) and other employed persons working in health institutions.
12. Three Accidents: refers to the number of traffic, fire, pollution and fire and pollution accidents.

13. Losses in Three Accidents: refers to direct economic losses from three accidents converted into cash.
20. Agro-Meteorological Services Stations: includes agro-meteorological observation stations, agro-meteorological stations, and agro-meteorological information services stations.
21. Earthquake Monitoring Stations: includes fiducial stations, basic stations, provincial stations, city and county stations, and enterprise managing stations.
22. Number of Careers Service Agency.
23. Number of Urban Community Welfare Facilities: number of places, buildings and equipment used for urban community activities and services.
24. Rural Social Security Network: number of established rural social security networks.
25. State Budgetary Appropriation in Capital Construction and Innovation: investment in capital construction and innovation from state budget consists of budgetary appropriations and loans from the state budget.
26. Local/Central Government Projects Ratio of Investment in Capital Construction and Innovation: reflects the administrative relationship of fund sources in capital construction and innovation. Capital construction refers to the new construction projects or extension projects and related activities of the enterprises, institutions, or administrative units mainly for the purpose of expanding production capacity, covering only projects with a total investment of RMB 500,000 (about $60,459) and over. Innovation refers to the technological innovation of original facilities by enterprises and institutions, as well as corresponding supplementary projects for production or welfare facilities and related activities, covering only projects with a total investment of RMB 500,000 and over.
27. Ratio of Projects Completed and Put into Use in Capital Construction and Innovation: refers to the ratio of the number of projects completed and put into use in a certain period of time to the number of projects under construction in the same period.
28. Treatment Efficiency of Industrial Wastewater, Waste Gas and Solid Waste: average ratio of treated pollutants to discharged pollutants. Industrial wastewater treatment efficiency refers to the ratio of the volume of industrial wastewater up to the discharge standards to the total volume of discharged wastewater. Waste gas treatment efficiency refers to the ratio of the volume of removed waste gas to the volume of waste gas emissions; for 1998–2000, it is equal

to the ratio of the removed soot and dust plus waste gas purified to the total waste gas emission; and for 2001–2003, it is equal to the removed SO_2 to the total SO_2 emission. Solid waste treatment efficiency refers to the ratio of the volume of industrial solid waste utilized in a comprehensive way to the total solid waste produced.

30. Ratio of Area of Nature Reserves and Provincial Area: Nature reserves refer to certain areas of land, water or sea that are representative of natural ecological systems, or are natural habitats for rare or endangered wild animals or plants, or water conservation zones, or the location of important natural or historic relics, which are demarcated by law and put under special protection and management. Nature reserves are designated by the formal approval of governments at and above county level.
31. Rate of Access to Gas: refers to the ratio of the urban population with access to gas to the total urban population at the end of reference period.
32. Numbers Public Transportation Vehicles per 10,000 persons in Cities: Public transportation vehicles include bus, trolley, vehicles with tracks (metro, light railway, tram, ropeway, and cable car), taxi, and public ferry. The standardized set = Σ sets of each type of vehicle × corresponding coefficient.
33. Per Capita Area of Paved Roads: paved road refers to paved roads with a width of 3.5 meters and over (including roads in open-ended factory compounds and residential quarters) and paved surface including square bridges and tunnels connected with roads.
34. Per Capita Green Area: refers to those for public use, such as municipal, community and neighbourhood parks and roadside parks, including water within parks. Neighbourhood parks should occupy an area larger than 10,000 square meters, and roadside parks should occupy an area larger than 400 square meters, with a width of more than eight meters.
35. Number of Public Toilets per 10,000 persons.
36. Ratio of Staff and Workers in Government Agencies and Total Population: refers to the ratio of the number of persons working in government agencies, party agencies, public management, and social organizations to the number of total population.
37. Ratio of Staff and Workers in Government Agencies and Total Employed Persons.
38. Ratio of Government Consumption and Final Consumption: government consumption refers to the expenditure on the consumption of the public services provided by the government to society as a

whole and the net expenditure on the goods and services provided by the government to households free of charge or at low prices. Final consumption refers to the total expenditure of resident units on purchases of goods and services from domestic and foreign economies to meet the requirements of material, cultural and spiritual lives. The final consumption consists of household consumption and government consumption.

39. Ratio of Government Expenditures and GDP.
40. The Share of Penalty and Confiscatory Income and Income from Administrative Fees in Total Government Revenue: penalty and confiscatory income refers to the fines and converted income of confiscated properties collected by government agencies, institutions and social organizations which have the right to impose fines and confiscate in accordance with laws, rules and regulations. Administrative fees refers to funds not covered by the regular government budgetary management, which is collected by government agencies, institutions and social organizations while performing duties delegated to them or on behalf of the government in accordance with laws, rules and regulations.
41. Per Capita Annual Net Income of Rural Households: reflects the average income level of rural households in a given area. Net income refers to the total income of rural households from all sources, minus all corresponding expenses, including household operation expenses, taxes and fees, depreciation of fixed assets for production, subsidy for those participating in household surveys, and gifts to non-rural relatives. Net income is mainly used as input for reproduction and as consumption expenditure in the same year, and also used for savings and non-compulsory expenses of various forms.
42. Per Capita Annual Disposable Income of Urban Households: Disposable income refers to the actual income at the disposal of members of the household which can be used for final consumption, other non-compulsory expenditure and savings. It equals total income minus income tax, personal contribution to social security and sample household subsidy for keeping diaries.
43. Engle Coefficient of Rural Households: refers to the percentage of expenditure on food in the total consumption expenditure.
44. Engle Coefficient of Urban Households.
45. Consumer price index: reflects the trend and degree of change in prices of consumer goods and services purchased by urban and rural residents, and is a composite index derived from urban and rural consumer price indices.

46. GDP per capita.
47. Ratio of Expenditure on Policy-related Subsidies and Government Expenditure: expenditure on policy-related subsidy refers to the expenditure appropriated, with the approval of the government, from the state budget for price subsidies on such products as grain, cotton and edible oil.

11
Corruption, Governance, and FDI Locations in China: Empirical Evidence

11.1 Introduction

China's relative success in attracting FDI contrasts to the experiences of some other developing and transition countries. Global geographical disparities in the location of FDI have led researchers to return to an examination of the structural determinants of FDI inflows. One factor that has received sustained attention is the relationship between corruption and FDI. At the country level a number of studies examine the impact of corruption on cross-country patterns of FDI (see for example Wheeler and Mody, 1992; Hines, 1995; Wei, 2000; Habib and Zurawicki, 2002; Smarzynska-Javorcik and Wei, 2005). These studies use cross-country perception-based corruption indices within FDI location decision models. Whilst some earlier studies did not find a consistently negative correlation (for example Wheeler and Mody, 1992; Hines, 1995) more recent studies have reported a statistically significant negative impact of corruption on FDI (for example Wei, 2000; Smarzynska-Javorcik and Wei, 2005).

In China, the transition to a more market based economy, known as 'socialism with Chinese characteristics', has resulted in considerable changes to how firms operate within the new commercial business environment. Inevitably, when any system undergoes such rapid transition problems will arise. The huge increase in opportunities in the private sector combined with the traditional power of local and national officials has led to a proliferation of corruption at all levels of the Chinese economy. For example, although labour markets have become more market-oriented the wage premium for being a member of the

Communist Party has actually increased (Appleton *et al.*, 2009); in part, this may reflect low-level corruption. Corruption is now recognized as an emerging challenge to China's economy and to its social reforms.

As discussed in Chapter 9, corruption should not be considered in isolation as it is strongly correlated with the quality of government. Governance can therefore be considered as a broad measure of corruption where good governance promotes successful performance and hence encourages FDI by increasing the scope for profitable business activities (Globerman *et al.,* 2006).

In this chapter we examine, for the first time, the effect of both corruption and governance quality on province-level FDI inflows for China. However, due to the lack of measures for corruption, we examine the effect of anti-corruption effort and governance quality on FDI inflows into Chinese provinces. In addition to our proxies for anti-corruption and governance we include a standard set of control variables to capture provincial differences in income, labour costs and quality, infrastructure, agglomeration economies, population density and environmental regulations. Our results reveal that foreign capital prefers to locate to regions where the government has made more effort to fight corruption and where local government is considered to be more efficient.

The remainder of this chapter is organized as follows: Section 11.2 presents our econometric framework and Section 11.3 reports our main results, with conclusions in the final section.

11.2 Methodology and data

In this section we outline our empirical framework. As, to the best of our knowledge, there is no survey of province-level corruption or governance quality over time we use data from the Procuratorial Yearbook of China, China Statistical Yearbook and China Environment Yearbook. A full list of our data sources is provided in Appendix 11.2.

Our basic specification is:

$$FDI = f(Anti-Corruption, STD, X, \gamma, \eta) \tag{11.1}$$

where *FDI* is the flow of FDI into region *i* in time period *t*; *Anti-Corruption* is our measure of the level of regional anti-corruption effort; *STD* is measured as the standardized value of government efficiency index; *X* is a vector of other regional characteristics that may affect FDI; γ refers to location-invariant time effects; and η refers to time-invariant regional effects.

As in Chapter 8, FDI is measured by the total amount of actually used FDI inflows into a province during the year ,according to agreements and contracts, and includes investment from Hong Kong, Taiwan, and Macao, and investment from foreign countries. We normalized FDI by two alternative methods: provincial FDI divided by provincial GDP (*FDI/GDP*), and provincial FDI divided by the population of each province (*FDI/POP*).

In terms of our control variables in vector *X* we included: per capita gross regional product (*GRP per capita*), which captures income effects; manufacturing wages, which proxies the price of labour factor; FDI inflows in the previous year, to capture the agglomeration induced by FDI; regional gross industry product of domestic firms (*GIPd*), as a proxy of agglomeration of domestic industrial enterprises; population density, which captures the potential market size and land prices; road density, which captures the infrastructure effect; and the rate of illiteracy, which proxies labour quality.[1] Following Fan *et al*. (2007), we also included the expected real per capita GDP growth rate (*ExpGrowth*) of each province, which is the average growth rate of the past four-year's growth rates. This variable was intended to capture a province's profitable investment opportunities and its track record in gaining government support (Fan *et al*., 2007).

The final estimating equation is therefore:

$$\begin{aligned}\ln(FDI_{it}) = \alpha &+ \beta_1 \ln(AntiCorruption_{it-1}) + \beta_2 STD_{it-1} \\ &+ \beta_3 \ln(GRPperCapita_{it-1}) + \beta_4 \ln(Wage_{it-1}) \\ &+ \beta_5 \ln(FDI_{it-1}) + \beta_6 ExpGrowth + \beta_7 \ln(GIPd_{it-1}) \\ &+ \beta_8 \ln(Pop.Density_{it-1}) + \beta_9 \ln(RoadDensity_{it-1}) \\ &+ \beta_{10} \ln(IlliterateRate_{it-1}) + \gamma_t + \eta_i + \varepsilon_{it}\end{aligned} \tag{11.2}$$

where *i* refers to province and *t* refers to year. To control for possible endogeneity we lagged all independent variables by one year. Of particular concern is the potential endogeneity of corruption given the possibility that FDI, and the likely economic opportunities that it provides, may increase the likelihood of corruption taking place. Furthermore, as Fan *et al*. (2007) pointed out, investment opportunities are likely to be more abundant in locations with good institutions and lower corruption, at the same time, increased investment opportunities may provide an incentive for governments seeking FDI to improve the quality of institutions. Hence, corruption and STD cannot necessarily be considered exogenous. The options for removing such concerns are limited, as are the prospects of finding suitable and convincing instruments for corruption and STD. Instead, we lagged these variables by one year and also test the exogeneity of corruption and STD using Davidson-Mackinnon exogeneity tests. In all cases the null of exogeneity cannot be rejected, as reported in Tables 11.1 and 11.2. Returning to Equation 11.2, we did not take the natural log of STD because it is an index with positive and negative values. The expected signs of the coefficients are:

Coefficients	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}
Expected Signs	+	+	+	–	+	+	–/+	–/+	+	–

We estimated both fixed and random effects models. Hausman specification tests were performed to discover whether the random effects model was appropriate and suggest that the random effects estimator was not efficient and therefore we focused on fixed effect results. Time dummy variables are included for all estimations.

11.3 Empirical results

Table 11.1 reports the Feasible Generalised Least Square (FGLS) estimation results for our log specifications with FDI scaled by GDP as our dependent variable. Appendix 11.2 presents the Hausman specification test and autocorrelation test results. We tested AR(1) autocorrelation using the dynamic model, $\varepsilon_t = \rho\varepsilon_{t-1} + v_t, t = 2, \ldots, T$ to regressions (1) to (8) in Table 11.1 and regressions (8) to (12) in Table 11.2. The null hypothesis is H_0: ρ 0. The *t*-statistics showed that we could no reject the null hypothesis for all log specifications. Appendices 11.3 and 11.4 provide summary statistics and a correlation matrix respectively.

As our key variables of interest were anti-corruption and governance we included the other independent variables sequentially as a form of sensitivity analysis. We also included anti-corruption and STD together and individually.

From Table 11.1 we observe that the coefficient on *Anti-Corruption* is positive and statistically significant suggesting that provinces that do the most to tackle corruption attract greater levels of FDI inflows. Our full specification in column (9) shows that the marginal effect of tackling corruption is 0.43. Thus, a 10 percent increase in the effort to control corruption in a province would lead to a 4.3 percent increase in FDI inflows (relative to GDP). Assuming a province that has a population of 50 million (a little larger than Zhejiang province), with an average per capita income of RMB 4,765, tackling 150 extra corruption cases (an approximate 10 per cent increase in average anti-corruption effort),

Table 11.1 FGLS results; dependent variable: FDI/GDP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Anti-corruption$_{t-1}$ †		0.460		0.514	0.516	0.459	0.420	0.397	0.430
		(4.24)***		(4.92)***	(4.81)***	(4.19)***	(3.70)***	(3.43)***	(3.45)***
STD$_{t-1}$			0.205	0.385	0.410	0.395	0.363	0.522	0.464
			(1.02)	(2.03)**	(1.98)**	(1.91)*	(1.77)*	(2.49)**	(2.27)**
GRP per capita$_{t-1}$	1.957	2.082	1.746	1.975	2.052	2.279	2.347	1.902	2.332
	(3.63)***	(3.90)***	(3.20)***	(3.71)***	(3.21)***	(3.54)***	(3.58)***	(2.97)***	(3.63)***
Wage$_{t-1}$	–0.380	–0.971	–0.511	–1.096	–1.017	–0.835	–0.851	–0.901	–1.089
	(1.20)	(2.56)**	(1.51)	(2.66)***	(2.27)**	(1.76)*	(1.77)*	(1.89)*	(2.39)**
FDI$_{t-1}$	0.487	0.446	0.470	0.436	0.448	0.439	0.433	0.428	0.363
	(7.34)***	(6.72)***	(7.09)***	(6.69)***	(6.53)***	(6.19)***	(6.06)***	(6.00)***	(5.04)***
ExpGrowth					–0.219	0.042	0.321	1.233	0.827
					(0.16)	(0.03)	(0.24)	(0.94)	(0.65)
GIPd$_{t-1}$						–0.226	–0.231	–0.179	–0.212
						(1.92)*	(1.99)**	(1.47)	(1.89)*
Pop. density$_{t-1}$							–0.671	–0.856	–0.934
							(0.96)	(1.22)	(1.32)
Road density$_{t-1}$								0.211	0.209
								(2.61)***	(2.48)**
Illiterate rate$_{t-1}$									0.253
									(2.31)**
Constant	–11.647	–7.789	–8.554	–5.891	–7.364	–9.435	–5.367	–1.900	–3.513
	(2.67)***	(1.77)*	(1.78)*	(1.23)	(1.37)	(1.78)*	(0.80)	(0.29)	(0.53)
Observations	147	147	147	147	147	147	147	147	147
Wald χ^2	9590.23	12041.88	11121.49	11723.53	10992.73	11636.34	11765.12	11833.36	11773.22
Davidson-Mackinnon test									
Anti-corruption$_{t-1}$		0.321		1.151	1.084	1.074	1.010	1.132	1.120
		(0.573)		(0.283)	(0.298)	(0.300)	(0.315)	(0.287)	(0.290)
STD$_{t-1}$			0.874	0.837	0.692	0.462	0.446	2.603	2.306
			(0.353)	(0.360)	(0.405)	(0.497)	(0.505)	(0.107)	(0.129)

Notes: Absolute value of z-statistics in parentheses. Time dummies are included. † All the independent variables are in logs except STD; *significant at 10% level; ** significant at 5% level; *** significant at 1% level.

would lead to $70 million increase (at 2003 prices) in FDI inflows into the province (4.3 per cent increase at the average level of FDI/GDP) in the following year.[2] For example, Zhejiang province tackled 140 extra cases in 1999 (a 10 per cent increase in anti-corruption effort compared to 1998) and FDI inflows increased by over $380 million in 2000 (a 16 per cent increase in FDI/GDP); Hebei province (with a population around 67 million and GDP per capita around RMB 5,000 at 1990 prices) investigated 164 extra cases in 2002 (a 5 per cent increase in anti-corruption effort relative to 2001) and attracted $180 million extra FDI inflows in 2003 (a 6.2 per cent increase in its FDI/GDP).

The coefficient on STD is also positive and significant across nearly all specifications. The marginal effect from column (9) of 0.46 suggests that a 0.1 unit increase in the level of government efficiency is associated with a 4.75 per cent increase in FDI inflows relative to GDP.[3] Regional government efficiency is therefore a significant determinant of foreign investment location choice. In 2001, Beijing and Shanghai both increased their STD values by around 0.1 units. Beijing enhanced its government efficiency score through a significant increase in the STD values of the government public services factor and government scale factor, by improving the provision of education, technology and science, public health, and public security, and retained a relatively stable government size. Similarly, Shanghai increased its STD values in the government public goods factor and the national welfare factor, by investing more in social infrastructure, providing more city public facilities, and significantly improving household net income.

Turning to the other control variables, as expected, income has a strong positive effect on FDI inflows, indicating that the richer a province the more FDI it attracts. Manufacturing wage has a negative and significant effect on FDI flows. Lagged FDI proxies the agglomeration effects of FDI and is strongly positive and significant. Perhaps surprisingly, *GIPd*, which proxies the regional agglomeration effects of domestic firms, is negative and significant. Population density and the expected growth rate are not statistically significant, while the sign and significance of the illiteracy rate indicate that FDI is attracted by relatively low education levels.[4] When we interact illiteracy rate with manufacturing wage, we find a negative coefficient on the illiteracy rate and a positive coefficient on the interaction term, but neither is significant. The results suggest that, given the average manufacturing wage, FDI is attracted to low education provinces, as in provinces that have a relative surplus of unskilled labour. Finally, the coefficient on road density shows that FDI prefers to locate in regions with good road transportation networks.[5]

Table 11.2 FGLS results for sensitivity check; dependent variable FDI/GDP

	(10)	(11)	(12)	(13)	(14)
Anti-corruption$_{t-1}$[†]	0.430	0.331	0.346	0.467	0.370
	(3.45)***	(2.80)***	(2.85)***	(4.33)***	(3.22)***
STD$_{t-1}$	0.464				
	(2.27)**				
STD1$_{t-1}$		0.049			
		(0.23)			
STD2$_{t-1}$			–0.091		
			(0.97)		
STD3$_{t-1}$				0.300	
				(3.67)***	
STD4$_{t-1}$					0.205
					(2.44)**
GRP per capita$_{t-1}$	2.332	3.050	3.148	2.546	2.829
	(3.63)***	(4.95)***	(5.04)***	(4.59)***	(4.77)***
Wage$_{t-1}$	–1.089	–1.131	–0.989	–1.074	–1.069
	(2.39)**	(2.54)**	(2.14)**	(2.64)***	(2.53)**
FDI$_{t-1}$	0.363	0.383	0.370	0.382	0.380
	(5.04)***	(5.11)***	(5.02)***	(5.62)***	(5.25)***
ExpGrowth	0.827	–0.774	–1.150	–0.605	–0.263
	(0.65)	(0.70)	(0.90)	(0.65)	(0.23)
GIPd$_{t-1}$	–0.212	–0.292	–0.274	–0.270	–0.291
	(1.89)*	(2.33)**	(2.26)**	(2.31)**	(2.71)***
Pop. density$_{t-1}$	–0.934	–1.033	–1.001	–0.371	–1.112
	(1.32)	(1.51)	(1.44)	(0.55)	(1.68)*
Road density$_{t-1}$	0.209	0.128	0.131	0.300	0.163
	(2.48)**	(1.40)	(1.47)	(3.26)***	(1.79)*
Illiterate rate$_{t-1}$	0.253	0.311	0.275	0.278	0.311
	(2.31)**	(2.68)***	(2.34)**	(3.24)***	(2.71)***
Constant	–3.513	–7.666	–9.852	–9.143	–6.189
	(0.53)	(1.22)	(1.47)	(1.61)	(1.01)
Observations	147	147	147	147	147
Wald χ^2	11773.22	10554.98	10547.43	15907.56	11358.74
Davidson-Mackinnon test					
Anti-corruption$_{t-1}$	1.120	0.575	0.043	0.591	0.018
	(0.290)	(0.448)	(0.837)	(0.442)	(0.895)
STDj$_{t-1}$[‡]	2.306	0.784	0.721	0.837	0.280
	(0.129)	(0.376)	(0.399)	(0.360)	(0.597)

Notes: Absolute value of z-statistics in parentheses. Time dummies are included. † All the independent variables are in logs except STD. ‡ STD*j* indicates STD, STD1, STD2, STD3, and STD4 by column respectively. *significant at 10% level; ** significant at 5% level; *** significant at 1% level.

For sensitivity analysis we re-estimated Equation 11.2 using (FDI/POP) as our dependent variable. The results can be found in Appendix 11.5 and are broadly similar to those in Table 11.1. In addition, given the complex methodology required to generate our government efficiency measures, we checked the sensitivity of our results by re-estimating Equation 11.2 for the full specification, splitting the STD index into its four component parts. The results are in Table 11.2.

In Table 11.2, column (10) is a repeat of column (9) from Table 11.1. The four component parts that make up the overall STD index are STD1 (Government Public Services), STD2 (Government Public Goods), STD3 (Government Size), and STD4 (National Welfare). The results show that the STD indices remain generally positive and significant with the exception of STD2 (Government Public Goods). A positive and significant coefficient is found for STD3 (Government Size) and STD4 (National Welfare), which may suggest that foreign capital is attracted to provinces that have relatively low government size and high income. The coefficients on the other variables are largely unchanged.

11.4 Conclusions

In this chapter we have analyzed the determinants of inter-province FDI inflows for China from 1999 to 2003. To examine the relationship between province level corruption, governance and FDI we constructed indices of government efficiency and anti-corruption effort at the provincial level. The provincial data suggest that higher government efficiency tends to be associated with economic development, with the eastern and coastal provinces recording the highest levels of good governance. In contrast, our measure of corruption shows no discernible pattern between provinces even though the relative ranking across provinces remains relatively stable over our time period. The econometric results reveal that FDI is attracted to provinces that have done the most to tackle corruption and that have the most efficient local government. The policy implications are that there appears to be a strong incentive for provinces to act tough on corruption as this will encourage additional FDI and growth to their region. Likewise, efforts to improve governance systems within a province appear to pay dividends in terms of future investment.

When we compared the increases in FDI as a result of the improvement in anti-corruption effort between the top and bottom quartiles of anti-corruption effort, everything else being equal, we found that if those provinces that are currently below the average level of anti-corruption effort increased their effort to the average, for example a 10% increase in anti-corruption effort, the increase in FDI in the following year would be more than $40 million. In contrast, the increases in FDI inflows for the top quartile would be $60 million. However, if a province has already achieved a high level of anti-corruption effort it may find it more difficult to increase its effort further (for example, Tianjin), in this case a province could increase FDI through improvements in government efficiency (as measured by STD).

Similar to anti-corruption effort, for a 0.1 unit increase in the STD values, provinces in the top quartile will increase their FDI inflows by $120 million, 6.5 times as much as those provinces in the bottom quartile. Therefore, central government could increase investment in public goods, public services, government scale and national welfare in those provinces that have STD values above average, in order to improve their government efficiency and hence attract greater levels of FDI.

Appendix 11.1 Data sources

Variable	Definition/Source
Anti-Corruption	The number of registered cases under the direct investigation of people's procuratorates divided by regional population (cases per 100,000 persons). *Source*: The Procuratorial Yearbook of China; population data as FDI.
STD	The aggregate standardized value of government efficiency indices. *Source*: government efficiency indices data from China Statistical Yearbook.
STD1	The aggregate standardized value of government public services indices.
STD2	The aggregate standardized value of government public goods indices.
STD3	The aggregate standardized value of government scale indices.
STD4	The aggregate standardized value of national welfare indices.
ExpGrowth	Average value of the real per capita gross regional product (GRP) growth rate in the past four years of the region. Real per capita GRP growth rate is measured by the first difference of logged real per capita GRP. *Source*: as above.
GIPd	Regional gross industrial output value of domestic enterprises (100 million yuan at 1990 price). *Source*: as above.

Table A11.1.1 Hausman tests for FDI/GDP

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9 & 10)**	**(11)**	**(12)**	**(13)**	**(14)**
Hausman Chi-2	17.01	22.80	26.09	14.60	29.54	30.84	22.58	20.03	26.71	29.72	26.26	30.04	33.37
p-value	0.017	0.004	0.001	0.103	0.001	0.001	0.032	0.094	0.020	0.008	0.024	0.008	0.003

Table A11.1.2 Autocorrelation tests for FDI/GDP

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9 & 10)**	**(11)**	**(12)**	**(13)**	**(14)**
ρ	0.026	0.015	0.016	0.004	0.004	−0.011	−0.018	−0.039	−0.020	−0.011	−0.007	−0.058	−0.018
	(0.17)	(0.12)	(0.11)	(0.03)	(0.03)	(−0.08)	(−0.14)	(−0.31)	(−0.16)	(−0.09)	(−0.05)	(−0.47)	(−0.15)
R^2	0.002	0.002	0.002	0.001	0.001	0.002	0.002	0.003	0.002	0.002	0.002	0.005	0.002

Note: Robust t-statistic in parentheses.

Table A11.1.3 Hausman tests for FDI/POP

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9 & 10)**	**(11)**	**(12)**	**(13)**	**(14)**
Hausman Chi-2	13.11	167.27	14.25	17.23	30.27	32.70	25.49	28.00	31.97	30.22	26.52	29.74	27.47
p-value	0.070	0.000	0.076	0.045	0.001	0.001	0.013	0.009	0.004	0.007	0.022	0.008	0.017

Table A11.1.4 Autocorrelation tests for FDI/POP

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9 & 10)**	**(11)**	**(12)**	**(13)**	**(14)**
ρ	0.010	−0.0004	−0.002	−0.015	−0.015	−0.031	−0.036	−0.056	−0.037	−0.023	−0.018	−0.068	−0.031
	(0.07)	(−0.00)	(−0.01)	(−0.12)	(−0.11)	(−0.24)	(−0.27)	(−0.44)	(−0.29)	(−0.18)	(−0.15)	(−0.55)	(−0.25)
R^2	0.002	0.002	0.001	0.002	0.002	0.003	0.003	0.005	0.003	0.002	0.002	0.007	0.002

Note: Robust *t*-statistic in parentheses.

Appendix 11.2 Hausman specification test and autocorrelation test

We undertook the Hausman specification test to find out whether GLS estimator was BLUE, consistent and asymptotically efficient under the null hypothesis H_0: $E(\varepsilon_{it}|X_{it}) = 0$. The results below show that the GLS estimator does not always produce efficient results. Therefore we focused on fixed effect models.

We applied the dynamic model, $\varepsilon_{it} = \rho\varepsilon_{it-1} + \nu_{it}, t = 2,\ldots,T$ to all specifications. The null hypothesis is H_0: $\rho = 0$. The *t*-statistics show that we rejected the null hypothesis for all specifications. Therefore AR(1) autocorrelation exists within panels in our specifications.

Appendix 11.3 Descriptive statistics of the variables

Variable	Obs.	Mean	Std. Dev.	Min.	Medium	Max.
FDI/GDP (FDI in RMB yuan per 10,000 RMB yuan GDP)	149	256.80	271.11	6.76	140.66	1140.13
FDI/POP (FDI in RMB yuan per capita)	149	188.62	276.04	3.19	42.89	1395.25
FDI/GDP$_{t-1}$ (FDI in RMB yuan per 10,000 RMB yuan GDP)	148	295.71	314.44	9.83	152.65	1352.72
FDI/POP$_{t-1}$ (FDI in RMB yuan per capita)	148	190.57	277.44	3.19	46.37	1180.71
Anti-Corruption$_{t-1}$ (cases/100,000 persons)	150	3.37	1.01	1.74	3.16	7.03
STD$_{t-1}$	150	0.00	0.24	–0.50	0.02	0.81
GRP per capita$_{t-1}$ (RMB yuan)	150	4765.65	3591.10	1255.09	3376.21	21876.21
Wage$_{t-1}$ (RMB yuan at 1990 price)	150	4720.76	1549.53	2614.68	4399.02	11885.36
ExpGrowth	150	0.085	0.019	0.014	0.085	0.124
GIPd$_{t-1}$ (100 million RMB yuan at 1990 price)	150	1556.23	1713.53	79.41	912.00	8815.18
Pop. density$_{t-1}$ (persons per km^2)	150	376.11	460.55	6.99	251.56	2700.00
Rail Density$_{t-1}$ (km/10,000 km^2)	150	151.39	145.08	8.38	109.65	690.83
Road Density$_{t-1}$ (km/10,000 km^2)	150	3341.10	2110.37	204.76	3053.05	10138.71
Illiteracy Rate$_{t-1}$ (%)	150	13.13	6.46	4.36	12.11	42.92

Appendix 11.4 Correlations of the variables

	FDI/ GDP	**FDI/ POP**	**FDI/ GDP_{t-1}**	**FDI/ POP_{t-1}**	**Anti-$Corruption_{t-1}$**	**STD_{t-1}**	**GRP per $capita_{t-1}$**	**$Wage_{t-1}$**	**ExpGrowth**	**$GIPd_{t-1}$**	**Pop. $density_{t-1}$**	**Road $density_{t-1}$**	**Illiterate $rate_{t-1}$**
FDI/GDP	1.00												
FDI/POP	0.86	1.00											
FDI/GDP_{t-1}	0.95	0.79	1.00										
FDI/POP_{t-1}	0.85	0.96	0.86	1.00									
Anti-$Corruption_{t-1}$	0.03	0.08	0.00	0.06	1.00								
STD_{t-1}	0.52	0.66	0.49	0.65	0.26	1.00							
GRP per $capita_{t-1}$	0.62	0.90	0.56	0.87	0.17	0.76	1.00						
$Wage_{t-1}$	0.51	0.78	0.46	0.74	0.04	0.56	0.86	1.00					
ExpGrowth	0.19	0.34	0.13	0.31	0.05	0.34	0.40	0.13	1.00				
$GIPd_{t-1}$	0.39	0.43	0.32	0.38	0.17	0.39	0.44	0.29	0.25	1.00			
Pop. $density_{t-1}$	0.50	0.81	0.44	0.76	0.02	0.53	0.86	0.67	0.37	0.44	1.00		
Road $density_{t-1}$	0.69	0.80	0.66	0.79	0.12	0.49	0.77	0.69	0.19	0.37	0.73	1.00	
Illiterate $rate_{t-1}$	−0.31	−0.36	−0.29	−0.35	−0.45	−0.39	−0.43	−0.34	−0.01	−0.28	−0.27	−0.41	1.00

Appendix 11.5 FGLS results; dependent variable, FDI/POP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9 & 10)	(11)	(12)	(13)	(14)
Anti-Corruption $_{-1}$ †		0.451		0.512	0.503	0.424	0.415	0.375	0.408	0.304	0.328	0.488	0.351
		(4.00)***		(4.72)***	(4.51)***	(3.68)***	(3.48)***	(3.11)***	(3.12)***	(2.45)**	(2.52)**	(4.30)***	(2.89)***
STD$_{t-1}$			0.334	0.451	0.444	0.421	0.407	0.621	0.567				
			(1.65)*	(2.37)**	(2.10)**	(1.99)**	(1.92)*	(2.92)***	(2.70)***				
STD1$_{t-1}$										0.024			
										(0.11)			
STD2$_{t-1}$											–0.028		
											(0.28)		
STD3$_{t-1}$												0.310	
												(3.79)***	
STD4$_{t-1}$													0.220
													(2.50)**
GRP per capita$_{t-1}$	2.421	2.598	2.084	2.546	2.732	2.961	2.978	2.427	2.863	3.603	3.630	3.031	3.402
	(4.36)***	(4.70)***	(3.81)***	(4.57)***	(4.07)***	(4.40)***	(4.34)***	(3.75)***	(4.36)***	(5.65)***	(5.54)***	(5.59)***	(5.56)***
Wage$_{t-1}$	–0.391	–0.964	–0.568	–1.284	–1.231	–0.875	–0.873	–0.949	–1.115	–1.105	–0.994	–1.053	–1.048
	(1.14)	(2.60)***	(1.69)*	(3.18)***	(2.67)***	(1.81)*	(1.79)*	(1.98)**	(2.39)**	(2.47)**	(2.07)**	(2.67)***	(2.41)**
FDI$_{t-1}$	0.487	0.437	0.461	0.414	0.420	0.415	0.413	0.403	0.342	0.365	0.349	0.373	0.349
	(7.25)***	(6.41)***	(6.95)***	(6.12)***	(5.90)***	(5.74)***	(5.63)***	(5.62)***	(4.66)***	(4.78)***	(4.59)***	(5.50)***	(4.72)***
ExpGrowth					–0.472	–0.188	–0.120	0.941	0.384	–1.422	–1.311	–1.429	–0.882

					(0.34)	(0.14)	(0.09)	(0.73)	(0.31)	(1.33)	(1.00)	(1.59)	(0.79)
GIPd$_{t-1}$						–0.287	–0.289	–0.230	–0.261	–0.336	–0.327	–0.305	-0.340
						(2.28)**	(2.31)**	(1.83)*	(2.17)**	(2.50)**	(2.50)**	(2.43)**	(2.91)***
Pop. Density$_{t-1}$							–0.160	–0.488	-0.524	–0.620	–0.665	0.196	–0.713
							(0.22)	(0.67)	(0.71)	(0.88)	(0.91)	(0.28)	(1.03)
Road Density$_{t-1}$								0.231	0.227	0.122	0.135	0.296	0.166
								(3.07)***	(2.83)***	(1.34)	(1.55)	(3.17)***	(1.84)*
Illiterate Rate$_{t-1}$									0.214	0.276	0.224	0.298	0.279
									(2.10)**	(2.44)**	(1.93)*	(3.87)***	(2.51)**
Constant	–15.837	–12.545	–11.178	–9.421	–11.577	–14.789	–13.859	–8.472	–10.549	–15.110	–15.964	–17.202	–13.709
	(3.44)***	(2.84)***	(2.35)**	(1.95)*	(2.13)**	(2.74)***	(2.05)**	(1.31)	(1.60)	(2.38)**	(2.32)**	(2.95)***	(2.24)**
Observations	147	147	147	147	147	147	147	147	147	147	147	147	147
Wald χ^2	13859.01	17367.84	16076.69	17004.56	15860.57	16965.16	16990.52	22886.52	20381.72	16455.92	16939.08	23054.03	17539.49
Davidson-Mackinnon Test													
Anti-		0.353		1.280	1.027	1.202	1.125	1.248	1.238	0.536	0.114	0.660	0.018
Corruption$_{t-1}$		(0.554)		(0.258)	(0.272)	(0.273)	(0.289)	(0.264)	(0.266)	(0.464)	(0.736)	(0.417)	(0.893)
STDj$_{t-1}$‡			0.959	0.869	0.718	0.458	0.410	2.446	2.204	0.526	0.479	0.864	0.278
			(0.331)	(0.351)	(0.397)	(0.499)	(0.522)	(0.118)	(0.138)	(0.468)	(0.489)	(0.353)	(0.598)

Notes: Absolute value of z-statistics in parentheses. Time dummies are included. † All the independent variables are in logs except STD. ‡ STD*j* indicates STD, STD1, STD2, STD3, and STD4. *significant at 10% level; ** significant at 5% level; *** significant at 1% level.

12
Corruption, FDI, and Environmental Regulations

12.1 Introduction

Part II of this book reviewed previous literature on the pollution haven hypothesis. The results are mixed in that there is a not consistent finding on whether FDI is attracted by weak environmental regulations. A common limitation in these studies is that they only consider the impact of environmental regulations on FDI and none have considered the endogeneity of environmental regulations. In Chapter 8, we addressed the endogeneity of environmental regulations by making a one year lag for the three regulatory variables. In this chapter we re-consider the endogeneity of environmental stringency that may be influenced by both local government behaviour (for example corruption) and the level of FDI.

Local authorities sometimes tolerate environmental violations, driven by the need to boost economic growth. For example, in 2006 two serious pollution incidents in Gansu and Hunan provinces were both caused by the negligence and malpractice of the local government and environmental departments, which ignored people's health in favour of economic growth.[1] The relationship between polluting industries and local officials may weaken the level of environmental enforcement. Government failure to fulfil their environmental responsibilities and interference in environmental law enforcement are the main reasons for some of China's persistent environmental problems. High polluting firms, including foreign firms, are incentivised to bargain with or offer bribes to the local authority to be lax in enforcing environmental regulations, and local authorities may tolerate these violators in order to stimulate industrial output and GDP growth, as well as to gain more tax income. However, in regions where the government has made great efforts to fight against corruption, the above phenomenon is less likely to happen. Therefore, both government behaviour and FDI have an impact on environmental regulations and the impact of FDI may be conditional on the degree of corruption/anti-corruption effort.

In this chapter, we use similar datasets to previous chapters and examine whether FDI and anti-corruption impact on provincial environmental regulations in China. The findings suggest that FDI has a negative impact on environmental regulations, which again confirms the existence of pollution havens in China. Such negative impacts can be mitigated when the degree of tackling corruption is high enough.

This chapter is organized as follows. Section 12.2 reviews the literature on endogenous environmental regulations and Section 12.3 describes the methodology and data. Section 12.4 reports the empirical results, with conclusions in the final section.

12.2 Endogenous environmental regulations

Brunnermeier and Levinson (2004) summarized two issues that complicate empirical tests of the pollution haven hypothesis: unobserved heterogeneity and endogeneity. The first issue has been addressed in Chapter 8 by using panel data and incorporating regional fixed effects. The second issue is that both environmental regulations and FDI may be endogenous. On the one hand, Henderson and Millimet (2007) argued that regulatory stringency may be related to bureaucratic corruption (Fredriksson *et al.*, 2003), political climate, or the presence of industry subsidies used to offset the costs of pollution abatement (Eliste and Fredriksson, 2002). On the other hand, there are causal relationships between FDI and environmental regulations running in both directions, that is environmental regulations could be a function of FDI (Brunnermeier and Levinson, 2004).[2] The solution for the second issue is to employ an instrumental variable approach to account for the endogeneity of environmental stringency.

Within the pollution haven literature some studies focusing on trade and environmental regulations have found more robust evidence of a moderate pollution haven effect, for instance, Ederington and Minier (2003) and Levinson and Taylor (2008). They find that pollution abatement costs and expenditures (PACE) have no impact on US exports when the PACE are treated as exogenous, but have a significant impact when PACE are treated as endogenous.

Evidence is also provided by empirical studies focusing on FDI and environmental stringency. Xing and Kolstad (2002) was the first study to take into account the endogeneity of environmental regulations. Due to a lack of regulation data, the stringency of environmental regulations was expressed as an inverse function of pollution emissions (SO_2), that is environmental stringency was determined by SO_2 emissions and other variables. Then they substituted this function for environmental regulations in the FDI model. They employed instruments for SO_2 emissions and investigated outbound US FDI to 22 countries in six manufacturing sectors. The cross-section estimation suggested positive significant coefficients on SO_2 emissions only for the two most pollution intensive industries, chemicals and primary metals, that is, FDI is an increasing function of lax environmental regulations in these two sectors. In general, the results indicated that lax environmental policy in a foreign host country tends to attract more FDI from the US for pollution intensive industries.

Another paper that considered the endogeniety of environmental policy was Fredriksson *et al.* (2003) when examining the intra-country pollution haven effects of US inbound FDI. In this paper, they also allowed for the impact of differences in regional corruption levels. In a model of international capital flows, capital flows had a positive relationship with pollution emission levels, which meant capital flows were reduced by stringent environmental standards. When considering the effect of corruption, the model suggested that corruption influenced capital flows through two channels. First, corruption influenced the level of capital stock through its effect on environmental policy, and this effect was positive (negative) if an increase in corruption resulted in greater capital inflows (outflows). Second, corruption influenced capital flows through its impact on public goods, and this effect was negative because the theft of public funds reduced the expenditure on productivity, enhancing public goods and thus lowering the productivity of capital. Therefore, conditional on environmental regulation and public goods, corruption had no measurable effect on FDI inflows.

Fredriksson *et al.* (2003) used state-level panel data from 1977 to 1987 to test the predictions of their model. The first stage results confirmed their theory that corruption has a significant effect on environmental stringency and the supply of public goods. From the second stage results, they found public expenditure and environmental stringency to have an impact upon FDI in some sectors; while conditional on environmental policy and supply of public goods, they did not find a remaining influence of corruption on FDI inflows. Additionally, the effects of environmental stringency were found to be sensitive to the exogeneity assumption, which explains the significant effect of environmental regulations compared with previous literature.

The majority of theoretical and empirical papers in this area investigated the effects of differences in the stringency of environmental regulations on FDI. The influence of FDI on environmental policy was ignored. Cole *et al.* (2006) first addressed this weakness and developed a political economy model of local environmental policymaking. The model assumes an imperfectly competitive local goods market containing both local and foreign firms, which jointly lobby the local government for a favourable pollution tax. The net impact comes from two main effects. First, an increase in foreign firms will lead to more output in the local markets and hence more bribes offered by the lobby group for lax environmental regulations. This is called the 'bribery effect' of FDI by Cole *et al.* (2006). Second, the increased number of foreign firms led to higher levels of competition and hence reduced the government's incentive to lower pollution tax in order to stimulate output and consumer surplus. This is denoted as the 'welfare effect' of FDI. When the degree of corruptibility is high, the bribery effect dominates and FDI leads to less stringent environmental policy. When the degree of corruptibility is low, the welfare effect dominates and FDI leads to more stringent environmental policies. Therefore, the impact of FDI on environmental stringency is conditional on the government's degree of corruptibility. Using panel data containing 33 developed and developing countries from 1982 to 1992, their empirical results were consistent with the predictions of the model. The results also suggested that the overall effect of corruption on environmental stringency is negative at the mean level of FDI stock, but positive at the mean level of FDI flows.

In this chapter, we follow Cole *et al.* (2006) in examining the impact of FDI on provincial environmental regulations. Due to the lack of a reliable index to measure regional government corruption levels, we examined the role government anti-corruption played in the FDI and environmental regulation relationship.

12.3 Data and methodology

We use data from 29 provinces over the period of 1999–2005.[3] Data sources are similar to those in previous chapters, including China Statistical Yearbook, China Environment Yearbook, China Compendium of Statistics 1949–2004, and China Procuratorial Yearbook.

If it is true that high (low) corruptibility will contribute to (mitigate) the creation of pollution havens (Cole *et al.,* 2006), high levels of anti-corruption effort will alleviate FDI's pollution haven effect in developing countries. Therefore, we test the following hypothesis: the increase of FDI leads to less stringent environmental regulations (that is pollution havens exist), but the impact will be mitigated by local anti-corruption effort.[4]

The empirical model is equation 12.1.

$$
\begin{aligned}
ER_{it} = \alpha_i + \gamma_t + \beta_1 FDI_{it-1} + \beta_2 Anti-Corruption_{it-1} \\
+ \beta_3 (FDI \times Anti-Corruption)_{it-1} + \phi' X + \varepsilon_{it}
\end{aligned}
\tag{12.1}
$$

where *ER* measures environmental regulatory stringency in region *i* in time period *t*; *FDI* is the amount of FDI inflow; *Anti-Corruption* is the regional effort on tackling corruption; *FDI* × *Anti-Corruption* captures the effect that FDI's effect is conditional on regional anti-corruption effort; *X* is the set of other regional characteristics that may affect *ER*; α is a time-invariant regional effect; γ is a location-invariant time-fixed effect; and ε is the idiosyncratic error term.

We tested the hypothesis that an intra-country pollution haven effect exists in China and that this effect can be lessened by increased regional fighting against corruption, therefore we expected a negative estimated coefficient on *FDI* but a positive coefficient on its interaction with *Anti-Corruption*.

Similar to Chapter 8, three proxies of environmental regulations are used in the estimation. However, the results using *Punish* as a dependent variable are generally not statistically significant, we therefore only report those estimated on *EI3* and *Charge*. *EI3* denotes environmental investment in industrial pollution treatment projects normalized by total investment in fixed assets, while *Charge* is the pollution emission charge divided by the number of organizations.[5]

We still employ two different measures of FDI: FDI scaled by regional GDP (*FDI/GDP*) and FDI normalized by regional population (*FDI/POP*). The anti-corruption index constructed in Chapter 10 is used to measure the extent to which corruption is being fought at province level.

Similar to Cole *et al.* (2006) we included a number of control variables. Income effect on environmental regulations is captured by per capita GDP (*GDP*), assuming that the demand for environmental quality increases with income. Urban population share (*URBANPOPsh*) controls greater political pressure on regulatory stringency in more urbanized regions because more citizens are exposed to pollution.

Thus, we expected positive signs of the estimated coefficient on both *GDP* and *URBANPOPsh* variables. However, according to the Environmental Kuznets Curve theory (EKC), the impacts of both variables may be non-linear.[6] Therefore their quadratic terms are included in the regression.

We included industrial output to GDP (*INDOUTPUTsh*) to capture the impact of industrial sectors on environmental policy and this impact is twofold. One the one hand, more industrial output leads to lower regulatory stringency because lobby groups would like to protect jobs and remain competitiveness. On the other hand, if there are a lot of pollution intensive industries in the economy, such industrial structure would lead to more stringent regulations. This non-monotonic impact is consistent with the ambiguous structure effect of economic development on the environment as discussed in EKC. Therefore, a quadratic term of *INDOUTPUTsh* is also added to the model.

$$
\begin{aligned}
ER_{it} = {} & \alpha_i + \gamma_t + \beta_1 FDI_{it-1} + \beta_2 Anti - Corruption_{it-1} \\
& + \beta_3 (FDI \times Anti - Corruption)_{it-1} \\
& + \beta_4 GDP_{it-1} + \beta_5 GDP^2_{it-1} + \beta_6 URBANPOPsh_{it-1} \\
& + \beta_7 URBANPOPsh^2_{it-1} + \beta_8 INDOUTPUTsh_{it-1} \\
& + \beta_9 INDOUTPUTsh^2_{it-1} + \varepsilon_{it}
\end{aligned}
\tag{12.2}
$$

We still took one year lags of all the explanatory variables, partly because the impact of these variables on environmental regulations is unlikely to be immediate; and partly because taking lags help to minimize any potential causality links from *ER* to all the control variables. Taking lags for all the independent variables was used in Cole *et al.* (2006).

Previous literature on pollution haven effects assumes that FDI is affected by environmental regulations. To allow for the potential endogeneity of FDI, we applied an instrumental variable approach using two-stage-least squares (2SLS) estimator. The main econometric problem is to find appropriate instruments for FDI in the first stage regression. To be suitable for use as an instrument, the variable must be correlated with FDI, yet has no correlation with environmental regulatory stringency. We employed two instruments that proxy the regional differences in infrastructure: one is road density, as used in Chapter 8; and the other is the number of telephone main lines and mobile phones per 100 persons. We also took a one year lag for these two instruments to minimize the possible causality moving from FDI to public infrastructure.

Other exogenous variables in Equation 11.2 were all used to instrument FDI. Since these variables wereed lagged in the second-stage regression, they also enter the first-stage regression in lagged form. Appendix 12.1 provides variable definitions and data sources and Appendix 12.2 a table of the descriptive statistics.

Since the model treats FDI as over-identified, we provide results of a Sargan test of the over-identifying restrictions to assess the validity of our instruments. The tests suggested that both instruments are valid and the reported F-tests suggest joint instrument significance. However, results from Durbin-Wu-Hausman and Davidson-MacKinnon tests both suggest that the lagged FDI is exogenous. Therefore, it is not necessary to report 2SLS results in the main text and we focus on OLS results, which are consistent. Results of 2SLS are reported in Appendix 12.3 and their first stage results in Appendix 12.4.

Next, we chose the estimator between fixed effects and random effects. Hausman specification test cannot reject the null hypothesis that there is a systematic difference between these two estimators, hence individual effects and time effects could be adequately modelled by random effects models. Hausman test results are reported in Appendix 12.5. For a sensitivity check, we reported results from both fixed effects and random effects models. Finally, there is no evidence of first-order autocorrelations.

12.4 Empirical results

Table 12.1 provides both fixed effects (FE) and random effects (RE) results using two measures of FDI (*FDI/GDP* and *FDI/POP*). The dependent variable is *EI3* in columns 1, 3, 5, and 7 and *Charge* in columns 2, 4, 6, and 8.

The empirical findings in Table 12.1 confirm the existence of intra-country pollution havens in China and support our hypothesis that the impact of FDI on environmental regulations is conditional on regional anti-corruption effort. FDI has negative and statistically significant coefficients on two measures of environmental regulations in all models. Increased FDI inflows lower the stringency of environmental regulations in Chinese provinces. The interaction term between FDI and Anti-Corruption is positive in all models, with statistical significance in six of them (except Models 2 and 6), indicating that the negative effect of FDI on environmental regulations can be mitigated by regional attempts at fighting corruption. The F-test on two FDI variables is significant in six models indicating their coefficients are not equal to zero.

Table 12.1 Fixed and random effects results for FDI/GDP and FDI/POP; dependent variables: EI3 and charge

	1	2	3	4	5	6	7	8
	FDI/GDP, EI3 FE	**FDI/GDP, Charge FE**	**FDI/POP, EI3 FE**	**FDI/POP, Charge FE**	**FDI/GDP, EI3 RE**	**FDI/GDP, Charge RE**	**FDI/POP, EI3 RE**	**FDI/POP, Charge RE**
*FDI*t_1	–1.351	–1.093	–0.156	–0.211	–1.133	–0.895	–0.145	–0.188
	(0.002)***	(0.083)*	(0.004)***	(0.007)***	(0.001)***	(0.051)*	(0.001)***	(0.001)***
Anti-Corruption $_{t-1}$	–0.154	0.006	–0.122	–0.028	–0.051	–0.003	–0.032	–0.033
	(0.014)**	(0.946)	(0.028)**	(0.732)	(0.258)	(0.962)	(0.424)	(0.537)
*(FDI*Anti-Corruption)* $_{t-1}$	0.321	0.212	0.034	0.044	0.252	0.196	0.029	0.039
	(0.005)***	(0.205)	(0.006)***	(0.015)**	(0.005)***	(0.113)	(0.002)***	(0.003)***
GDP_{t-1}	0.627	2.086	0.068	1.557	–0.679	0.208	–0.833	0.096
	(0.466)	(0.106)	(0.937)	(0.218)	(0.046)**	(0.653)	(0.016)**	(0.836)
$GDP2_{t-1}$	0.121	–0.126	0.311	0.140	0.296	0.217	0.438	0.411
	(0.556)	(0.680)	(0.160)	(0.665)	(0.027)**	(0.251)	(0.001)***	(0.030)**
UrbanPopsh $_{t-1}$	0.517	–0.515	0.538	–0.464	0.268	–0.117	0.249	–0.090
	(0.009)***	(0.077)*	(0.006)***	(0.105)	(0.018)**	(0.447)	(0.026)**	(0.550)
UrbanPopsh$^2_{t-1}$	–0.055	0.059	–0.057	0.053	–0.025	0.012	–0.023	0.010
	(0.006)***	(0.049)**	(0.004)***	(0.069)*	(0.021)**	(0.403)	(0.033)**	(0.477)
IndOutputsh $_{t-1}$	0.256	0.243	0.220	0.206	0.206	0.171	0.213	0.192
	(0.004)***	(0.066)*	(0.014)**	(0.112)	(0.000)***	(0.024)**	(0.000)***	(0.010)**
IndOutputsh$^2_{t-1}$	–0.012	–0.014	–0.009	–0.011	–0.008	–0.008	–0.008	–0.009
	(0.009)***	(0.045)**	(0.045)**	(0.101)	(0.006)***	(0.048)**	(0.006)***	(0.027)**
Constant	–0.976	–0.385	–0.872	–0.131	–0.304	–0.182	–0.367	–0.237
	(0.148)	(0.701)	(0.202)	(0.896)	(0.366)	(0.685)	(0.267)	(0.590)
Observations	174	174	174	174	174	174	174	174
R^2	0.431	0.403	0.427	0.421	0.412	0.496	0.422	0.515
F-test FDI (*p*-value)	5.20	1.77	4.61	3.82	11.91	3.97	11.93	11.06
	(0.007)	(0.175)	(0.012)	(0.024)	(0.003)	(0.138)	(0.003)	(0.004)
$\partial ER/\partial FDI$	–0.276	–0.383	–0.042	–0.064	–0.289	–0.238	–0.048	–0.057
$(\partial ER/\partial FDI)\times s.d.$	–0.072	–0.100	–0.112	–0.169	–0.075	–0.062	–0.127	–0.152

Note: p-value of t-statistics in parentheses. Time dummies are included. *significant at 10 per cent level; ** significant at 5 per cent level; *** significant at 1 per cent level. Marginal effects are calculated at the sample means of Anti-Corruption; s.d. = standard deviation. FE denotes fixed effects and RE denotes random effects.

To investigate the economic and environmental significance of FDI, at the bottom of Table 12.1 we also report the estimated marginal effect of *FDI* on *ER* at the mean level of *Anti-Corruption*. *∂ER/∂FDI* shows the changes in environmental regulations (*EI3* or *Charge*) associated with a one unit increase in *FDI/GDP* or *FDI/POP* at the mean of *Anti-Corruption*, while (∂ER/∂FDI) × *s.d.* shows the changes in *ER* associated with a one standard deviation increase in FDI variables. All these marginal effects are negative, suggesting that at the mean level of Anti-Corruption, the impact of FDI on environmental regulation stringency is negative across Chinese provinces. For example, in Model 5, a unit increase in FDI/GDP *reduces* EI3 by 0.289 (= –1.133 + 0.252 × 3.35), equivalent to a decline of RMB 289 yuan environmental investment in pollution treatment projects per billion yuan investment in total fixed assets, evaluated at the mean of Anti-Corruption.[7] This effect is economically and environmentally significant because it is a reduction of more than half of the mean of *EI3* (RMB 540 yuan per billion yuan in fixed assets) or seven times the value of the minimum *EI3* (RMB 40 yuan per billion yuan in fixed assets) within the sample over the observed period.

The story is different at higher levels of Anti-Corruption. For example, at two standard deviation above the mean of Anti-Corruption, a one unit increase in *FDI/GDP raises EI3* by 0.225 (= –1.133 + 0.252 × (3.35 + 2 × 1.02)), equivalent to an increase of RMB 225 yuan environmental investment per billion yuan investment in fixed assets. Therefore, when Anti-Corruption effort is high enough, FDI inflows benefit the stringency of environmental regulations or, as discussed in Cole *et al.* (2006), that the welfare effect of FDI dominates the bribery effect.

Model 5 also suggests that a one standard deviation increase in *FDI/GDP* reduces *EI3* by 0.075, equivalent to a reduction of RMB 75 yuan per billion yuan investment in fixed assets. This reduction in *EI3* is equivalent to a decline of a 0.2 of its standard deviation.

In terms of *FDI/POP* in Models 7 and 8, the marginal effect of FDI indicates a unit increase in FDI results in a decline of RMB 42 yuan investment in environmental protection per billion yuan investment in fixed assets, or a decline of RMB 640 yuan pollution charge paid by each enterprise. A one standard deviation increase in *FDI/POP* results in a decline of RMB 127 yuan environmental investment per billion yuan in fixed assets expenditure, equivalent to a reduction of a 0.35 of its standard deviation. A one standard deviation increase in *FDI/POP* results in a decline of RMB 152 yuan pollution charge paid by each enterprise, equivalent to a reduction of a 0.30 of its standard deviation.

Figures 12.1 and 12.2 respectively demonstrate the marginal effect of two measures of FDI variables on environmental regulations at different levels of *Anti-Corruption* for the six regressions in Table 12.1. With a stronger anti-corruption effort, there is more positive impact of FDI on *ER*. Given that the Anti-Corruption score is between 1.60 (minimum)

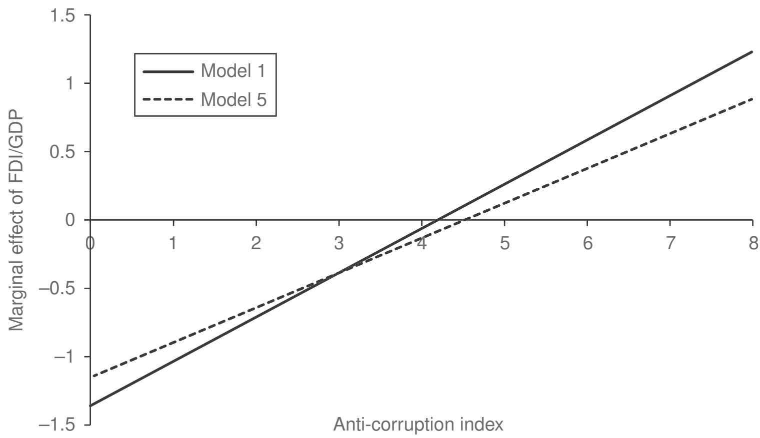

Figure 12.1 The marginal effect of FDI/GDP on ER conditional on anti-corruption

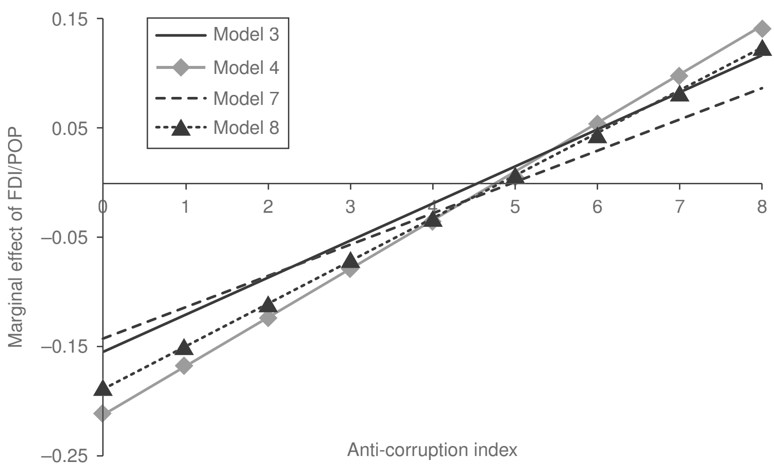

Figure 12.2 The marginal effect of FDI/POP on ER conditional on anti-corruption

and 7.03 (maximum) in the sample, these two figures suggest that the marginal effect of FDI on environmental regulations becomes positive at within-sample levels of Anti-Corruption scores between 4.2 to 5.0. To make it clearer in context, the average level of Anti-Corruption over 1999–2005 was 2.1 in Guangdong, 2.8 in Beijing and Shanghai, 3.0 in Jiangsu and Zhejiang, 3.5 in Fujian, 3.8 in Shandong, 4.0 in Hebei, and 5.7 in Tianjin. These nine provinces have attracted more than 80 per cent of national FDI. Therefore, the results in Table 12.1 illustrate that FDI weakened environmental regulations in most of these regions. In the whole sample, only Tianjin, Heilongjiang, Jilin, Liaoning and Shandong had an Anti-Corruption score over 5.0 in certain years. Therefore, for most Chinese provinces their anti-corruption effort is too low to lessen the negative impact of FDI on regulatory stringency. This finding is consistent with the current situation in China that many of the environmental accidents/problems that have been exposed are associated with corruption or dereliction of duty by governmental officials.

In Models 5–8, none of the coefficients on *Anti-Corruption* is statistically significant. The positive and significant coefficient on *FDI* × *Anti-Corruption* indicates that the overall effect of *Anti-Corruption* on *ER* is positive at the mean of FDI. For example, at the mean level of *FDI/POP*, a unit increase in *Anti-Corruption* raises environmental investment by RMB 53 yuan per billion yuan investment in fixed assets (Model 7), or adds RMB 710 yuan charge paid by each polluting enterprise. The effect of *Anti-Corruption* is negative in Models 1 and 3 at the mean levels of FDI. The effect of *Anti-Corruption* becomes positive when *FDI/GDP* is at or above 0.48 (= 0.154/0.321) in Model 1, equivalent to a 0.85 standard deviation above the mean level of *FDI/GDP*.[8] Similarly in Model 5, the effect of *Anti-Corruption* is positive when *FDI/POP* is above 3.59 (= 0.122/0.034), or at two thirds of a standard deviation above the mean of *FDI/POP*.[9]

In terms of the control variables, the results of per capita GDP are not consistent across models. A U shaped relationship is found between per capita GDP and environmental regulation stringency in two random effects regressions when using *EI3* as a dependent variable. The minimum turning points are at 1.15 (RMB 11,5000 yuan) and 0.95 (RMB 9,500 yuan) in Models 5 and 7. In our sample, only four regions (Beijing, Shanghai, Tianjin and Zhejiang), had per capita income more than RMB 9,500 yuan in recent years. Therefore, income is generally negatively correlated with *ER*, which is consistent with the findings in Chapter 5 that at current income levels, economic growth leads to weaker environmental regulations and lower environmental quality. No significant effect of per capita GDP is found in other models.

The results of *URBANPOPsh* are mixed. The impact of urban population share on *EI3* is inverted-U shaped and the maximum turning point is between 47 per cent and 54 per cent, roughly equivalent to the levels in Jilin and Zhejiang. In 2005, about 75 per cent of Chinese regions had an urban population share less than 54 per cent, indicating that urbanization in the majority of Chinese regions pushes more environmental investment into pollution treatment projects. However, when *URBANPOPsh* is above 54 per cent, the impact on *EI3* tends to be negative. A possible explanation is that when urban population share is sufficiently high, there is more investment in fixed assets, such as construction and equipment, to accommodate the large urban population, as well as to provide job opportunities and services. Therefore, the share of investment in environmental protection declines. The impact of *URBANPOPsh* on *Charge* is U shaped in Model 2. The minimum turning point is 43.6 per cent, roughly above the median of *URBANPOPsh*, indicating that for half the regions in the sample, pollution charges increase with urban population share.

The results of *INDOUTPUTsh* are consistent across models. *INDOUTPUTsh* is positively associated with *ERs*, although decreasing at the margin. The maximum turning point level of *INDOUTPUTsh* is between 8.9 and 13.3, where the latter is broadly equivalent to the level of Zhejiang in 2005. Over the observed period, more than 50 per cent of the regions with an *INDOUTPUTsh* level less than 13.3 or more than half less than 8.9. Therefore, for many regions in the sample, environmental regulations increase with industrial output.

12.5 Conclusions

Although a number of studies examine the effects of environmental regulations on FDI location choice and some studies look at the impact of FDI on the environment, only a few investigate the effects of FDI on environmental regulations and none focus on China. This chapter is the first study to fill that gap in the literature.

Using Chinese provincial-level data from 1999 to 2005, we tested the hypothesis that FDI has a negative impact on environmental regulations and that this impact could be mitigated when the degree of anti-corruption effort is high. The results confirmed that FDI inflows lower regional environmental investment in pollution treatment projects and the pollution emission charge paid by violating firms, which again supports the existence of pollution havens in China. The impact of FDI is conditional on the government's degree of tackling corruption. The negative impact of FDI would become positive when more effort is put into fighting corruption. However, China's current average anti-corruption effort is too low to compensate for the negative impact of FDI.

The findings again warn of the negative impact of FDI on the environment in China, given that corruption has become a common social problem that has spread to many areas. FDI contributes to the creating of pollution havens in China. The findings provide a solution to diminishing the negative impact of FDI on the environment, which is to encourage efforts to fight corruption. Anti-corruption efforts not only increase the quantity of FDI but also improves its quality. Anti-corruption is important in attracting more environmentally friendly FDI which will result in improved environmental quality in China. Therefore, political reform is needed to reduce corruption at all levels.

Appendix 12.1 Variable definitions and data sources

Variable	Definition/Source
EI3	Investment in industrial pollution treatment project divided by total investment in fixed assets (yuan per million yuan). *Source*: China Environment Yearbook; Innovation investment data as FDI.
CHARGE	Pollution emission charge divided by the number of organizations paid the charge (10 000 yuan per enterprise, at 1990 price). *Source*: China Environment Yearbook.
FDI/GDP	FDI divided by regional GDP (yuan per 1000 yuan). *Source*: China Statistical Yearbook.
FDI/POP	FDI divided by regional population (yuan per 100 people at 1990 price). *Source*: as above; GDP deflator data from Econ Stats, http://www.econstats.com
ANTI-CORRUPTION	Anti-corruption index: registered cases under the direct investigation by procurator's offices normalized by regional population. *Source*: as Chapter 11.
GDP	Regional GDP per capita (10 000 yuan at 1990 price). *Source*: as FDI.
URBANPOPsh	Share of the population living in urban areas (per 10 persons). *Source*: China Compendium of Statistics, 1949–2004.
INDOUTPUTsh	Regional gross industrial output value normalized by regional GDP (yuan per 10 yuan). *Source*: as above.
ROAD	Regional highway density (km per 10000 km^2). *Source*: as above.
PHONE	Telephone mainlines and mobile phones (per 100 people). *Source*: China Compendium of Statistics, 1949–2004.

Appendix 12.2 Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.
EI3	0.54	0.36	0.04	1.85
CHARGE	0.61	0.52	0.14	3.87
FDI/GDP	0.26	0.26	0.01	1.14
FDI/Population	1.82	2.65	0.03	13.51
ANTI-CORRUPTION	3.35	1.02	1.60	7.03
GDP	0.52	0.40	0.13	2.49
UrbanPopsh	4.64	1.95	2.20	9.94
IndOutputsh	8.14	3.25	3.82	16.69
ROAD	0.38	0.23	0.02	1.26
PHONE	32.18	24.76	3.70	155.60

Appendix 12.3 2SLS results of fixed and random effects models

	1	2	3	4	5	6	7	8
	FDI/GDP, EI3 FE, IV	**FDI/GDP, Charge FE, IV**	**FDI/POP, EI3 FE, IV**	**FDI/POP, Charge FE, IV**	**FDI/GDP, EI3 RE, IV**	**FDI/GDP, Charge RE, IV**	**FDI/POP, EI3 RE, IV**	**FDI/POP, Charge RE, IV**
FDI_{t-1}	–0.093	–0.172	–0.389	–0.700	–0.146	–0.431	–0.178	–0.541
	(0.302)	(0.192)	(0.013)**	(0.002)***	(0.055)*	(0.000)***	(0.101)	(0.000)***
Anti-Corruption $_{t-1}$	–0.042	–0.017	–0.131	–0.232	–0.072	–0.193	–0.027	–0.119
	(0.616)	(0.887)	(0.077)*	(0.028)**	(0.219)	(0.014)**	(0.547)	(0.041)**
*(FDI*Anti-Corruption)* $_{t-1}$	–0.002	0.032	0.042	0.152	0.036	0.080	0.030	0.074
	(0.952)	(0.382)	(0.153)	(0.000)***	(0.013)**	(0.000)***	(0.017)**	(0.000)***
GDP_{t-1}	0.275	1.649	0.026	0.106	–0.773	1.026	–0.630	1.198
	(0.760)	(0.213)	(0.979)	(0.937)	(0.107)	(0.109)	(0.268)	(0.110)
$GDP^2{}_{t-1}$	0.128	–0.032	0.543	0.814	0.330	0.101	0.404	0.451
	(0.571)	(0.922)	(0.059)*	(0.045)**	(0.044)**	(0.643)	(0.005)***	(0.017)**
UrbanPopsh t_1	0.492	–0.489	0.513	–0.399	0.223	–0.099	0.207	–0.153
	(0.014)**	(0.094)*	(0.010)**	(0.153)	(0.045)**	(0.502)	(0.078)*	(0.322)
$UrbanPopsh^2{}_{t-1}$	–0.052	0.056	–0.054	0.047	–0.020	0.013	–0.018	0.019
	(0.011)**	(0.059)*	(0.008)***	(0.097)*	(0.058)*	(0.346)	(0.108)	(0.212)
IndOutputsh $_{t-1}$	0.219	0.193	0.200	0.127	0.208	0.168	0.207	0.179
	(0.017)**	(0.148)	(0.029)**	(0.322)	(0.000)***	(0.024)**	(0.000)***	(0.017)**
$IndOutputsh^2{}_{t-1}$	–0.010	–0.011	–0.009	–0.007	–0.008	–0.008	–0.008	–0.007
	(0.027)**	(0.089)*	(0.066)*	(0.306)	(0.005)***	(0.040)**	(0.018)**	(0.110)

Constant	–0.809	0.088	–0.422	1.320	–0.138	0.421	–0.323	–0.038
	(0.303)	(0.939)	(0.585)	(0.227)	(0.690)	(0.362)	(0.334)	(0.931)
Observations	174	174	174	174	174	174	174	174
R^2	0.402	0.395	0.415	0.449	0.425	0.510	0.418	0.518
F-test FDI (*p*-value)	1.71	0.91	3.19	7.41	6.33	20.90	5.86	23.02
	(0.184)	(0.406)	(0.044)	(0.001)	(0.043)	(0.000)	(0.054)	(0.000)
F-test on IVs (*p*-value)	3.46	3.46	1.28	1.28	15.88	15.88	11.59	11.59
	(0.034)	(0.034)	(0.280)	(0.280)	(0.000)	(0.000)	(0.003)	(0.003)
Sargan test (*p*-value)	0.703	0.581	0.090	0.406	0.703	0.581	0.090	0.406
	(0.402)	(0.445)	(0.764)	(0. 524)	(0.402)	(0.445)	(0.764)	(0. 524)
DWH endogeneity test	4.772	3.252	3.000	4.326	6.49	3.41	6.42	4.16
(*p*-value)	(0.029)	(0.073)	(0.085)	(0.039)	(0.011)	(0.067)	(0.011)	(0.043)
$\partial ER/\partial FDI$	–0.100	–0.065	–0.248	–0.191	–0.025	–0.163	–0.078	–0.293
$(\partial ER/\partial FDI)\times$ *s.d.*	–0.026	–0.017	–0.658	–0.506	–0.007	–0.042	–0.205	–0.777

Note: *p*-value of t-statistics in parentheses. Time dummies are included. *significant at 10 per cent level; ** significant at 5 per cent level; *** significant at 1 per cent level. Marginal effects are calculated at the sample means of Anti-Corruption; s.d. = standard deviation. FE denotes fixed effects and RE denotes random effects. IV means instrumental variable approach. DWH endogeneity test indicates Durbin-Wu-Hausman test of endogeneity with the null hypothesis that lagged FDI is endogeneous.

Appendix 12.4 First stage results of 2SLS

	Models 1 & 2	Models 3 & 4	Models 5 & 6	Models 7 & 8
	FDI/GDP FE	**FDI/POP FE**	**FDI/GDP RE**	**FDI/POP RE**
$Road_{t-1}$	0.380	0.992	3.834	1.949
	(0.860)	(0.462)	(0.002)***	(0.003)***
$phone_{t-1}$	–0.039	–0.011	–0.021	–0.008
	(0.018)**	(0.287)	(0.070)*	(0.237)
$Anti\text{-}Corruption_{t-1}$	0.360	0.168	0.113	0.009
	(0.064)*	(0.167)	(0.479)	(0.917)
GDP_{t-1}	8.329	5.890	7.497	5.219
	(0.083)*	(0.051)*	(0.001)***	(0.000)***
$GDP^2{}_{t-1}$	–1.501	0.054	–2.371	–0.374
	(0.178)	(0.938)	(0.000)***	(0.331)
$UrbanPopsh_{t-1}$	–0.797	–0.558	0.335	–0.275
	(0.333)	(0.279)	(0.548)	(0.373)
$UrbanPopsh^2{}_{t-1}$	0.099	0.065	–0.016	0.037
	(0.238)	(0.213)	(0.767)	(0.220)
$IndOutputsh_{t-1}$	–0.130	–0.041	–0.181	–0.175
	(0.729)	(0.863)	(0.518)	(0.256)
$IndOutputsh^2{}_{t-1}$	–0.009	–0.002	0.010	0.017
	(0.658)	(0.868)	(0.514)	(0.038)**
Constant	1.471	–0.311	–1.586	–0.526
	(0.627)	(0.869)	(0.367)	(0.587)
Observations	174	174	174	174
R^2	0.262	0.403	0.666	0.927
F-test on IVs (*p*-value)	3.46	1.28	15.88	11.59
	(0.034)	(0.280)	(0.000)	(0.003)
Sargan test (*p*-value)	0.703	0.581	0.090	0.406
	(0.402)	(0.445)	(0.764)	(0. 524)

Note: *p*-value of t-statistics in parentheses. Time dummies are included. *significant at 10 per cent level; ** significant at 5 per cent level; *** significant at 1 per cent level. FE denotes fixed effects and RE denotes random effects. These first-stage equations were used to estimate the corresponding models in Appendix 12.3.

Appendix 12.5 Hausman tests in Table 12.1

Model	**(1) & (5)**	**(2) & (6)**	**(3) & (7)**	**(4) & (8)**
Hausman Chi-2	19.78	11.11	21.18	8.90
p-value	0.137	0.678	0.097	0.780

13
Conclusions

13.1 Introduction

This book reviews China's rapid economic growth and the development of FDI from 1978 and links them with two common, serious problems: corruption and the environment. Over thirty years of rapid economic growth, China has become the second largest economy in the world. Along with deepening economic reform and opening up to the rest of world, China is also one of the largest recipients of foreign capital and the top destination preferred by foreign investors. As the most populous country in the world, China offers relatively cheap labour, low cost of raw materials and rent, and huge market potential. These have led to a huge number of foreign investors pouring into China to find business opportunities (Tian, 2007). However, both economic growth and FDI inflows are geographically unbalanced, with eastern provinces better off than inland provinces.

The economic structure has been highly energy inefficient, posing a big threat to sustainable growth. FDI has also been concentrated in the manufacturing sector, producing low-quality and low value-added products for export. A serious by-product of such a growth path is environmental degradation and increasing pollution. Evidence suggests that at current income levels China has not yet passed the turning point of the Environmental Kuznets Curve. However, the existence of EKC does not mean that environmental problems will solve themselves by simply emphasizing economic growth. Early and active environmental protection is needed. Although China has a comprehensive environmental policy framework, its implementation is weak and varies across regions. Lax environmental stringency has caused China to offer a comparative advantage in producing dirty goods. Some regions, which still give priority to economic growth, may lower their environmental standards (or ignore environmental impact) to attract investment and hence become pollution havens. At the same time, rampant corruption encourages pollution intensive firms to bribe government officials for laxer environmental regulations. Therefore, the negative relationship between FDI and environmental regulations indicate that FDI is not always beneficial to China's economy. To avoid becoming a pollution haven, reforms are needed to improve the legal force of Chinese environmental regulations. In addition, evidence suggests that encouraging anti-corruption not only attracts FDI inflows but also helps to mitigate the negative impact of FDI on environmental regulations.

In this chapter, we first provide a brief summary of the key findings in this book, followed by the challenges and policy suggestions. Finally, we point out the issues that have not been discussed in this book which may provide areas for further research.

13.1 Summary of key findings

The book includes three parts. The first part examines the effects of economic growth and FDI on water and air pollution in Chinese cities. Chapters 2 and 3 provide background information about China's economic growth, FDI and environmental quality. Chapter 4 critically reviews the literature on EKC as well as the effect of FDI on the environment. Previous studies and China's current economic and environmental situation motivate us to investigate the impacts of economic growth and foreign investment on environmental quality using a panel of 112 Chinese major cities from 2001 to 2004. A range of industrial pollution emissions are considered, including four water pollutants and four air pollutants. In order to find out the environmental effects of foreign firms, we split the total industrial output into three groups according to ownership: domestic firms, firms funded by Hong Kong, Taiwan and Macao, and firms invested in by other foreign economies. We address many limitations of previous EKC literature, and report the log linear and quadratic fixed effects estimation results. On balance, the results suggest that economic development has negative effects on environmental quality at current income levels in China. Total industrial output generally has a positive effect on industrial pollution emissions and domestic firms have the strongest effect among the three groups. Firms invested in by Hong Kong, Taiwan, and Macao have moderate positive effects on one water pollutant; while foreign invested firms have significant and positive influences on the emissions of petroleum-like matter, waste gas, and SO_2.

Chapter 5 makes two major contributions to the current literature. First, it considers the effects of economic growth on various environmental indicators using Chinese city-level data, and the results are broadly robust across pollutants. Second, it reveals differences in the effects of firms by ownership.

In Part II we explore the impact of environmental regulations on FDI location choice across Chinese provinces. Chapter 6 analyses China's environmental regulations and the reasons for weak implementation. We find that the environmental protection effort varies across provinces. Chapter 7 reviews the theories and empirical studies on pollution haven hypothesis and points out weaknesses in the literature. To fill this gap Chapter 8 tests the intra-country pollution haven effect within China using a panel of 30 regions from 1999 to 2003; in other words, we examine whether differences in environmental stringency affect the location choice of foreign investors in China. We use two measures of FDI, FDI per unit of GDP and FDI per capita. Distinct from abatement cost based or 0–3 type measures employed in previous empirical PHH studies, we employ three measures of environmental regulation: industrial pollution treatment investment, administrative punishment cases related to environmental issues, and pollution emission charges, which respectively reflect local government effort on environmental protection, enforcement of regional environmental legislation, and implementation of the regional pollution levy system. We employ a FGLS estimator and address certain methodological weaknesses in the previous literature. The results suggest that, everything else being equal, FDI is attracted by weak environmental regulations. Therefore, to a certain extent, the findings support the existence of intra-country pollution havens within China. In terms of other control variables, we find that FDI prefers to locate in those regions with high income, good infrastructure, and low labour costs. These findings are consistent with previous empirical studies. However, we also find that FDI is attracted to regions with low population density and low education levels.

Chapter 8 is the first study that uses Chinese provincial data to examine the existence intra-country pollution havens. We address a number of limitations in previous PHH empirical studies. However, we do not include another structural determinant of FDI, the impact of corruption and/or bureaucracy, due to the unavailability of existing data. This problem is addressed in Part III by constructing two indices to measure government characteristics.

Part III firstly looks at the differences in regional government characteristics in China, and then investigates their role in attracting FDI and the mitigating pollution haven effects of FDI inflows.

Chapter 9 reviews the literature on corruption and FDI, as well as governance and FDI, to explain why we consider these institutional variables in this book. Chapter 10 introduces China's problems related to corruption and the fight against corruption. It analyses the causes of corruption and the implications of corruption to foreign investment. Since we cannot find any established indices that proxy regional government corruption and governance, we construct indices using the available objective data. According to the quality and properties of the data, and the corruption situation in China, we develop a variable that proxies the effort of the local government fight against corruption, and an index that measures local government efficiency. The empirical evidence in Chapter 11 suggests that FDI is attracted to regions that have done the most to tackle corruption and that have the most efficient local government.

Chapter 12 re-examines PHH from a different direction by moving the causality from FDI to environmental regulations. It also examines the effect of anti-corruption in this FDI–environment nexus. The evidence supports our hypothesis that FDI has a negative impact on environmental regulations and that this impact can be mitigated when the degree of anti-corruption effort is high.

13.2 Challenges and policy implications

The findings in this book provide important policy implications for both central and local governments in China.

Current economic growth in China is found to have a negative effect on environmental quality. The existence of EKC does not mean that environmental problems can be solved automatically without special attention being given to the environment. To alleviate the pressure on the natural environment, the government has to enforce environmental protection at an earlier stage of development, through the improvement of environmental regulations at every administrative level. Reforms are needed to improve the efficiency of environmental protection and enhance the legal force of environmental laws.

The first suggested reform is the independence of environmental protection authorities (Wang, 2006–2007). A central environmental protection agency has been promoted at cabinet ministry level; however, many local environmental protection departments are still subject to local administration. Each local environmental protection authority has to be granted the power to determine their personnel and, more importantly, be given a separate financial budget. Environmental protection departments need enhanced enforcement powers over violators. In that case, environmental protection departments would be able to act freely to protect the environment.

The second suggested reform is to find a practicable system to calculate 'green GDP', to replace traditional GDP as a measure of true economic growth and as a measure of assessing the performance of local government officials.

Third, China should encourage the participation and supervision of the public, as well as environmental NGOs. This need reforms of political and judicial systems and therefore involve lots of difficulties and obstacles.

In addition to political and judicial reforms, economic reforms are needed to promote a structural change in Chinese industry, in order to reduce industrial pollution emissions. China's current growth path is not sustainable. In 2011 the growth of the six most energy consuming industrial sectors was been faster than that of others.[1] Similarly, electricity output in 2011 reached 4.8 trillion kWh, up by 11.7 per cent, or 2.5 percentage points higher than GDP growth. More than 80 per cent of electricity was generated by coal. As electricity output grew much faster than GDP, there should have been an oversupply, rather than a shortage, of electricity, had energy efficiency not deteriorated. However, there were widespread electricity shortages across the country in 2011, with a 30 billion Watts generating capacity gap during peak time. Such a strange situation suggested that China's economic structure was highly energy inefficient, posing a big threat to sustainable growth (Yao *et al.*, 2012).

The need for industrial restructuring and upgrading has been recognized by the government for more than a decade but it has been difficult to implement any effective policies. Firstly, China's economic success has relied on cheap labour and exports of low-tech manufacturing products without an adequate capacity for innovation and ability to produce high value-added products. Secondly, the competition has become increasingly intensive for exports of cheap, energy-intensive and low-tech manufacturing goods. However, China's over-dependency on exports of these goods cannot be maintained forever because of labour shortages, population aging and rising prices of key commodities, such as iron ore, oil, soybeans, copper and others. Third, state monopoly through large state-owned enterprises and banks created inefficiency and a waste of investments, social tension and damaging effects on the development of small and medium sized enterprises. The banking system and stock markets are highly inefficient, presenting further challenges to China's ability to sustain its fast economic growth and prosperity without radical reform.

FDI has played an important role in China's economic growth. It is regarded as an engine for economic growth, and a carrier of advanced technologies. This book suggests that FDI is not always a blessing. Certain types of FDI from certain sources in certain sectors may seek to locate in pollution havens where environmental regulation is weak. FDI also lowers environmental regulations in Chinese provinces, particularly where the anti-corruption level is low.

Recently, rising labour costs in the east have driven many low-end, labour intensive and low-tech factories of foreign affiliates to relocate to inland regions where labour is relatively cheaper. These regions are usually vulnerable in terms of their natural environment and ecosystem. The government has to rethink the location, sector and types of foreign direct investment. It is recommended that the government put an emphasis on the quality rather than the quantity of FDI; that it encourages more environmentally friendly and human capital intensive FDI and controls FDI in high energy consumption and high pollution sectors. These have been written about in the 2007 *Catalogue for the Guidance of Foreign Investment Industries*. However, the implementation of environment-related FDI polices is uncertain. The negative effect of environmental stringency on FDI can be offset by the improvement of some factors that are attractive to FDI, for example the quality of infrastructure, the enforcement of anti-corruption, and the improvement of government efficiency. Fighting corruption has been illustrated as an important method to increase the quantity and improve the quality of FDI.

Corruption has been a social pollution in China. The power of approval in many areas of economic activities leads the head officials of various departments to become the targets of lobby groups offering bribes in order to get low efficiency, low-tech and high polluting projects approved. However, once these projects have resulted in negative consequences, such as pollution and production accidents, the responsibility is rarely taken by the officials who approved the projects. The lack of accountability and light punishments have made corruption a high-return but low-risk activity. To fight against corruption, such power structures need to be changed. First, it is necessary to reduce the number of items that need to be approved. Second, officials have to be accountable for their actions. Since 2006 environmental accountability has been carried out in Shanxi Province, one of the most air polluted provinces in China. All officials responsible for acts of omission in environmental protection could not be promoted and would be investigated. Thus far, over a hundred local officials have been called to account over environmental pollution, which has helped to alleviate the environmental problem, but pollution is still serious in Shanxi. Third, China lacks an efficient oversight mechanism in many fields, including environmental protection, food security and others. To fight against corruption, radical political reform is necessary. Similar to enforcement of the legal system, there are many obstacles because of upsetting the interests of corrupt groups.

Lopez and Mitra (2000) suggest that at any level of per capita income the pollution levels corresponding to corruption behaviour are always above the social optimal level and that the turning point of the EKC takes place at income and pollution levels above those corresponding to the social optimum. Therefore, anti-corruption not only strengthens environmental regulation stringency and lowers pollution levels but will also help China pass the turning point of the EKC at lower income levels, everything else being equal.

Finally, it is also recommended that local government promote environmental technology transfer from foreign to domestic firms, and increase the absorptive capacity of local firms by increasing the investment in, for example, R&D and education.

13.3 Further research

A further improvement from Chapter 5 is to develop a simultaneous equation model in which pollution emissions are determined by regulations, technology and industrial composition. Then it would be possible to estimate the scale effects, technique effects, and composition effects caused by economic growth and foreign investment. Therefore, a major task is to find valid measurements for regulations and technology at city level. In addition, more years of data could be add to the dataset. Then we would be able to check whether there are similar turning points for wastewater and petroleum-like matter emissions, to show whether cities that had passed the turning point during the observed period did continue to reduce their emissions. With a longer time period, an EKC relationship may exist for other pollution emissions.

One limitation in Chapter 8 is that the data do not allow us to disaggregate FDI from different sources and/or into different industry sectors. Therefore, we cannot examine whether certain types of FDI from certain countries in certain industrial sectors prefers to locate in regions with weak environmental regulations.

In terms of new research based on this book, the following three topics can be considered as noteworthy in the area of economic growth, FDI, governance, and the environment.

This book considers the relationship between FDI and the environment from a regional perspective. Further research could be applied to industry-level data. This has not been considered in any previous studies. The research questions could be: (1) whether FDI is attracted to the industrial sectors that have low environmental regulations; (2) whether FDI is attracted to heavy pollution-intensive industries; and (3) whether FDI has a negative effect on pollution emissions across industrial sectors. Recently released industrial FDI data make this research possible. Similar methodology to that used in this book could be employed.

Another improvement is to investigate some interesting questions relating to the environment using Chinese firm-level data rather than aggregated regional data. A problem we faced was that the current, widely used, firm-level databases do not provide any environmental information. Recently, the non-governmental Institute of Public and Environmental Affairs has reported the names of enterprises that have emitted excessive water and air pollutants above national standards in recent years and are forced to make changes within a certain period. Firm-level datasets can also be acquired through a grant funded survey. With firm-level information, it is possible to employ a Probit model to examine the factors that may affect the differences in environmental performance, including endogenous drivers such as firm size and ownership, and exogenous drivers such as industry, market and regulatory forces.

Finally, anti-corruption and government efficiency indices could be used in a wider range of topics. Such bureaucracy characteristics could be used as factors that influence regional differences in economic growth and income inequality.

Notes

1 Introduction

1. Data source: http://data.worldbank.org/country/china. Poverty is defined as the number of people living at < $1.25/day measured by purchasing power parity.
2. According to the World Bank GDP in the United States and Japan in 2010 was $14.42 trillion and $5.49 trillion respectively. RMB is the abbreviation for the Chinese currency, the renminbi, also known as the yuan. In this book 1 trillion = 1,000 billion = 1,000,000 million.
3. Sustainable development refers to development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs', which is defined in the UN Report of the World Commission on Environment and Development (1987) (http://www.un.org /documents/ga/res/42/ares42–187.htm).

2 Economic Growth and FDI in China

1. China's share of world GDP increased from 4.1 per cent to 8.6 per cent and its share in international trade rose from 3.3 per cent to 7.8 per cent. Data source: World Development Indicators, the World Bank.
2. Actually used FDI refers to the amount which has actually been used according to the agreements and contracts, that is, the realized FDI.
3. This is the production approach in calculating a country's GDP. Another two methods of calculation are income approach and expenditure approach.
4. Guangdong and Fujian are both coastal provinces in the south east of China. The four SEZs are Shenzhen, Zhuhai, Shantou in Guangdong, and Xiamen in Fujian.
5. Deng's visit in the spring of 1992 pushed China's overall economic reform process forward and emphasized China's commitment to the open door policy and market-oriented economic reform. It gave greater confidence to foreign investors in China. From then on, China adopted a new approach, which pushed a more nationwide implementation of open policies to encourage FDI inflows.
6. From 2004, the China Statistical Yearbook no longer reported actually utilized FDI by region, and instead reported registration status of foreign funded enterprises by region at the year end, including number of enterprises, total investment, and registered capital.
7. Cumulative FDI from 1979 to 2003 is not reported here due to the different classification in tertiary sectors. From 1979–2003, about 67 per cent of FDI flowed into secondary industries, with 63.66 per cent to the manufacturing sector and 2.57 per cent to construction; 31.08 per cent to tertiary industry, with the proportion of real estate accounting for about 20 per cent. Primary industry attracted less than 2 per cent of total FDI inflows.

8. In 2011, Foxconn was entangled in the 'Poison Apple' scandal when Chinese environmental groups claimed that many of Apple's product part suppliers were violating environmental regulations, releasing toxic gases, heavy metal sludge and other pollutants.

3 Environmental Quality in China

1. Climate change has been an important issue in China. In the last decade, extreme events such as heat waves, intense precipitation, drought, floods and storms have occurred more frequently in China. There is evidence of a rise in sea level and a reduction in glaciers in the mountains of western China, which have threatened China's access to water, food, health, the use of land and the environment. In addition, as a rising power, China's climate policy has been paid increasing attention by the rest of the world. Climate change, as a global issue, is not only an environmental problem, but also a problem of science, economics, politics and international relations. Climate policies for reducing the emission of CO_2 are still under negotiation among countries. China stands to uphold the principle of 'common but differentiated responsibilities' to tackle climate change as a developing country. It insists that, considering their historic responsibilities and current capabilities, developed countries should take the lead in reducing carbon emissions and in helping developing countries mitigate for and adapt to climate change. For developing countries, economic growth and improving living standards take top priority, but efforts should be made to pursue sustainable development according to national conditions. Since climate change is all-encompassing problem with a global effect, this book focuses on those environmental problems, such as air, water and solid waste pollution, which are more urgent for China at a local and regional level. Emissions of CO_2 and other greenhouse gases are not emphasized.
2. *Mu* is the Chinese unit of area, 1 mu = 666.67 m^2 or 0.0667 hectares.
3. Erosion is the displacement of solids (soil, mud, rock and other particles) by the agents of wind, water or ice, by downward or down-slope movement in response to gravity or by living organisms (in the case of bioerosion, among which water and wind are the main agents).
4. State Forestry Administration, 2010, 'The Main Results of the Seventh National Survey on Forest Resources 2004–2008' [in Chinese], http://www.forestry.gov.cn/portal/main/s/65/content-326341.html [Accessed on 1 May 2012].
5. In 2010, the volume of water resources was 3,090.6 billion cubic metres, the water resources per capita were 2,310.4 cubic metres. The average rainfall was 695.4 mm, equivalent to a total rainfall of 6,585.0 billion cubic metres. The total amount of water supply was 602.2 billion cubic metres, with 81 per cent from surface water and 18.4 per cent from groundwater, 61 per cent of the water was used in agriculture and 24 per cent in industry. The water use per capita was 450.2 cubic metres.
6. Flood Control and Drought Relief in China, Ministry of Water Resources, http://www.mwr.gov.cn/english/fcdrc.html [Accessed 10 November 2012].

7. Bulletin of Flood and Drought Disasters in China 2010, Ministry of Water Resources, http://www.mwr.gov.cn/zwzc/hygb/zgshzhgb/201110/P020111013356349751920.pdf [Accessed 1 December 2012]
8. According to data from 409 monitored sections in 204 rivers, the proportions of Grade I–III, IV–V and worse than V were respectively 59.9 per cent, 23.7 per cent, and 16.4 per cent. The data concludes that the seven river systems were lightly polluted in general, among which the Yangtze and Pearl were reasonably clean, Songhua and Huai lightly polluted, Yellow and Liao moderately polluted, and Hai was heavily polluted.
9. According to the results, groundwater quality of 418 stations (10.2 per cent) was excellent, 1135 (27.6 per cent) was good, 206 (5.0 per cent) was satisfactory, 1662 (40.4 per cent) was poor, and 689 (16.8 per cent) was very poor.
10. China has been the world leader in wind and solar power industries. In 2009, its newly installed wind power capacity achieved 13.8 GW, ranked first in the world. In 2010, one out of three newly installed wind turbines were in China. The country also has the largest global share in the solar photovoltaic (PV) industry. In 2009, it produced 37 per cent of the world's solar cells (2,570 MW) and provided 88 per cent of the world's on-grid building-mounted segments. However, 95 per cent of China's PV products have been exported to other countries, such as Switzerland, Germany, and the US. The domestic demand for PV installation in China was only 228 MW in 2009, although this was an impressive 552 per cent increase on 2008 (see more details in Fu and Zhang, 2011).
11. China Vehicle Emission Control Report 2010 (in Chinese), Ministry of Environmental Protection, http://wfs.mep.gov.cn/dq/jdc/zh/201011/P020101110336607260005.pdf [Accessed 10 October 2012].
12. Serious SO_2 pollution means that the annual concentration of SO_2 does not achieve the national standard II (0.06 mg/cubic metres).
13. Eastern regions produced 40.3 per cent of the total volume of solid wastes, while central and western regions generated 29.1 per cent and 30.6 per cent, respectively. However, the utilize rate of solid waste in eastern regions (78 per cent on average) are much higher than the other two regions (70.8 per cent and 55.2 per cent). Therefore, the discharged volume of solid waste is low is eastern regions.
14. China.org.cn (2012), 'UK Firm Punished for Illegal Waste Exports' published on 24 February 2012, http://www.china.org.cn/environment/2012–02/24/content_24718178.htm [Accessed 20 November 2012].
15. Deng F. (2009) 'Cancer Villages in China', Phoenix Weekly, 324. The list of the villages is available at Deng Fei's blog at http://jushuixitian.blog.163.com/blog/static/19578601200946013062 6/, and a map at http://maps.google.com/maps/ms?ie=UTF8&oe=UTF8&msa=0&msid=104340755978441088496.000469611a28a0d8a22dd.
16. The Economist (2004), 'A Great Wall of Waste: China is Slowly Starting to Tackle Its Huge Pollution Problems', 19 August 2004, http://www.economist.com/node/3104453 [Accessed 01 August 2005].
17. The World Bank and The Government of the People's Republic of China (2007), 'Cost of Pollution in China: Economic Estimates of Physical Damages'. http://siteresources.worldbank.org/INTEAPREGTOPENVIRONMENT/Resources/China_Cost_of_Pollution.pdf [Accessed 01 February 2012].

18. Latest news of environmental and economic accounting reports can be found at the website of MEP's Chinese Academy for Environmental Planning: http://www.caep.org.cn/type.asp?typeid=24.
19. Converted at current prices according to the annual average exchange rates of RMB yuan against the US dollar in 2004 and 2009, one US dollar was equivalent to 8.2768 RMB yuan and 6.8310 RMB yuan, respectively.

4 Literature Review on EKC and the Effects of FDI on the Environment

1. Panayotou (2003), p. 2.
2. Nahman and Antrobus (2005), p. 112
3. Grossman and Krueger (1995), p. 372.
4. Nahman and Antrobus (2005), p. 110.
5. The pollution haven hypothesis studies related to trade include: Tobey (1990), Birdsall and Wheeler (1993), Jaffe *et al.* (1995), Rothman (1998), Antweiler *et al.* (2001), Ederington and Miner (2003), and Levinson and Taylor (2008). Those related to foreign direct investment include Levinson (1996a, 1996b), Xing and Kolstad (2002), Eskeland and Harrison (2003), Fredriksson *et al.* (2003), and Smarzynska-Javorcik and Wei (2005). Some studies avoid the issue of environmental regulations, for example, Cole (2004) examines the pollution intensity of trade inflows between developed and developing counties. Other studies examine the relationship between consumption, rather than production, of pollution intensive goods and economic growth.
6. Cole (2003), p. 561.
7. op. cit. p. 562.
8. Zarsky (1999), p. 3.
9. Grossman and Krueger (1991), p. 4.
10. 'In general, the theory of foreign investment dependence asserts that the accumulated stocks of foreign investment make a less developed country more vulnerable to different global political-economic conditions, often leading to negative consequences for domestic populations within investment dependent nations. These structural process and outcome are partly maintained and reproduced by the stratified interstate system' (Jorgenson, 2007c, p. 138).

5 Growth, FDI, and the Environment: Evidence from Chinese Cities

1. Most county-level cities were created in the 1980s and 1990s, by replacing counties. This process was halted in 1997.
2. For example, the poorest city, Xining (in Table 5.1), would need 24 years to catch up to the income level of the richest city, Zhuhai, if they remain on their current income growth paths (ln(7848/1025)/ln[(100+12.37)/(100+3.32)] = 24).
3. The index is calculated from $P = \sum_{i=1}^{n} P_i = \sum_{i=1}^{n} \frac{C_i}{C_{io}}$ where *C*i is the concentration of pollutant *i*, and *C*io is the limit value of *C*i. The limit value is the annual average concentration level according to the national ambient air quality

standard II. The annual average limit values for SO_2, NO_2, and PM_{10} are respectively 0.06, 0.08, and 0.10 (mg/m^3).

4. Note that the EU SO_2 standard is not to be exceeded when averaged over any 24 hour period and the US PM_{10} standard applies to a 1 hour period. The US used to have an annual PM_{10} standard of 0.05 mg/m^3 but no longer reports this because of a lack of evidence of a link between long-term exposure to PM_{10} and poor health. All other standards reported above are annual standards.
5. The particulates discharged from the power station are counted in industrial soot.
6. As an alternative solution we tried including the capital labour ratio as an attempt to proxy the pollution intensity of the composition of industry within the city. Previous studies have found a clear positive correlation between an industry's capital intensity and its pollution intensity (Antweiler et al., 2001; Cole and Elliott, 2005). However, the capital-labour ratio was not statistically significant and its inclusion did not alter the significance of the other explanatory variables. We therefore opted to report results in which this variable was omitted.
7. Firms within each city are selected for inclusion in the sample by local environmental bureaus but there appears to be no explicit criteria for inclusion. While selection bias therefore remains a possibility, the direction of such bias is unclear. On the one hand the environmental bureaus may be more familiar with 'dirty' firms, suggesting firms in the sample may be more pollution intensive than average. On the other hand, the environmental bureaus are more likely to deal with large firms who are typically *less* pollution intensive than average (Cole *et al.*, 2008).
8. For example, Selden and Song (1994) find that the turning point for city-level concentrations is at lower income levels than for national emissions because the reduction of concentration within a city is reasonably easy to achieve.
9. After taking logs, the positive skewness of all the dependent and independent variables is significantly reduced.
10. The between estimator is obtained by using OLS to estimate the models which use the time-averages for both dependent and independent variables and then runs a cross sectional regression (Wooldridge, 2000, chapter 14, 442). GLS estimators produce more efficient results than between estimators because they use both the within and between information.
11. Grossman and Krueger (1991 and 1995) argue that the random effects estimator is more appropriate than the fixed effects estimator for studies that use unit-specific data. In the model with fixed effects, all unit-specific characteristics that are constant over time are absorbed in the constant term, ☒. Thus, we cannot discriminate between the effects of some variables, such as the province dummies of the city, which may influence pollution. If we add these variables as additional regressors, these individual-specific effects cannot be estimated in the fixed effects model due to perfect collinearity. To account for this, we estimated Equations 5.1 and 5.2 by Generalized Least Square (GLS). We added province-level dummy variables to capture province-specific characteristics which are assumed to be constant over time, such as, geographical location, climate, resource endowments, corruptibility

of government. In this case, the error term is the sum of two components, the random component and an idiosyncratic error component. In order to check the efficiency of the random effects estimator, a Hausman specification test was employed to examine whether or not there was some correlation between the explanatory variables and the error terms (the strictly exogeniety assumption of the random effects model). The results generally indicated that the random effects specification was consistent and efficient for some of the models. Since the random effects results are similar to those of fixed effects, we only report results using the fixed effects estimator, which are always consistent.

12. For random effects models, AR(1) presented in CrVI logged models; while for fixed effects models, AR(1) presented in wastewater level models, SO_2 logged models and soot logged models. We used the Stata command *xtreg* with the *robust* option to remove the heteroskedasticity and the Stata command *xtregar* to correct the autocorrelation. However, *xtregar* does not allow a *robust* option to be applied. Therefore, we employed a heteroskedasticity test for the *xtregar* results. For example, we plotted the squared residuals and the fitted values of logged CrVI, and did not find a significant relationship between them for our random effects models, suggesting homoskedasticity in the residuals.
13. The Davidson-MacKinnon test results suggest the exogeniety of current income. The autocorrelation test also suggests no correlation within panels.
14. Annual average exchange rate is $1 = RMB 4.78 in 1990. RMB 35,235 is equal to about RMB 70,763 at 2004 prices, which is approximately $8,546 at the 2004 exchange rate ($1 = RMB 8.28). We note that the confidence interval around these estimated turning points is likely to be large.
15. Although significant coefficients are found on all income terms in cubic specifications, the function increases monotonically, that is, no turning point is found.
16. Shen (2006) finds a U-relationship between per capita income and per capita emissions, and the turning point is RMB 3,000–5,000, indicating that at least 50 per cent of the provinces are on the increasing side of the curve.
17. The elasticity in Liang (2006) is -0.6 to -0.7, and that in He (2006) is 0.098.
18. Shanghai Securities News, 03 August 2007, in Chinese, http://paper.cnstock.com/paper_new/html/2007–08/03/content_58400546.htm

6 Environmental Regulations in China

1. The 1982 Constitution included important provisions on environmental protection. Article 9 states that 'the state ensures the rational use of natural resources and protects rare animals and plants. The appropriation or damage of natural resources by any organization or individual by whatever means is prohibited.' Article 26 provides that 'the state protects and improves the living environment and the ecological environment, and prevents and controls pollution and other public hazards. The state organizes and encourages afforestation and the protection of forests.' The full text of the Constitution is http://english.people.com.cn/constitution/constitution.html [Accessed 01 December 2012].

2. The full text of the Environmental Protection Law of the People's Republic of China is http://www.china.org.cn/english/environment/34356.htm [Accessed 01 December 2012].
3. The full paper of Environment Protection in China, 1996–2005, is available online at: http://news.xinhuanet.com/english/2006–06/05/content_4647221.htm [Accessed 01 July 2007]. MEP homepage: http://english.mep.gov.cn.
4. Since 2000, MEP has released detailed data for all categories of investment in the treatment of environmental pollution; before that MEP only reported data on investment in industrial pollution treatment.

7 Theoretical and Empirical Studies on FDI and Environmental Regulations

1. Aliyu (2005) summarizes three dimensions of the pollution haven hypothesis. The first is the relocation of heavily polluting industries from developed countries with stringent environmental regulations to developing countries without or with lax or unenforced regulations. The second dimension is the dumping of hazardous waste generated from developed countries in developing countries. The third is the unrestrained extraction of non-renewable natural resources in developing countries by multinational firms.
2. Esty and Gentry (1997) and Aliyu (2005) outline four types of FDI: market seeking, production platform seeking, resource seeking and low cost seeking. Environmental policy cost has less impact on the categories of market seeking and production platform seeking, but certainly has an effect on resource seeking and/or low cost seeking FDI.
3. Xing and Kolstad (2002) found that there is a negative linear relationship between FDI of the US chemical industry and the stringency of environmental regulation in a foreign host country. A lax environmental policy tends to attract more capital inflows from the US for pollution intensive industries; while tough environmental regulations tend to impede or discourage FDI from these industries.
4. Pearson (1987), p. 124.
5. Smarzynska-Javorcik and Wei (2001), p. 2.
6. op. cit., p. 3.

8 Do Intra-Country Pollution Havens Exist?

1. Tibet is not included in our estimating sample due to the lack of data on FDI inflows.
2. The enterprises are all state-owned and non-state-owned enterprises above a designated size, which is an annual sales income of over RMB 5 million (about $0.60 million).
3. Gross industrial product is the total volume of final industrial products produced and industrial services provided during a given period. It measures the total achievement and overall scale of industrial production during a given period.

Industrial enterprise is used as the basic accounting unit. Double counting does not exist within the same enterprise, but may exist between enterprises.

4. After taking logs, the positive skewness of all the variables is significantly reduced.
5. Because all independent variable are one year lagged, the value of the two dependent variables, FDI_1 and FDI_2 are the values for 2003.
6. An alternative measure of inflation is the consumer price index. However, the GDP deflator is a better measure of overall inflation than the consumer price index because it is based on a broader market basket, including every item in the GDP.
7. The between estimator is obtained by using OLS to estimate the models which use the time-averages for both dependent and independent variables and then run a cross-sectional regression (Wooldridge, 2000, chapter 14, p. 442). GLS estimators produce more efficient results than between estimators because they use both the within and between information.
8. Here *X* it proxies all the independent variables in the estimated model. Since we take a one-year lag for all independent variables, the hypothesis is to test whether $E(\varepsilon_{it} | X_{it-1}) = 0$.
9. David Greenberg, who is an expert in Stata at New York University, states on the Stata Listserver that FGLS is feasible when the number of panels is larger than time period. Clive Nicholas from Newcastle University agrees Greenberg's point of view and specifies that FGLS is efficient when the degree of freedom is larger than 25, which is the case in our model (see Greenberg, 26 January 2004; and Nicholas, 10 August 2004).
10. The major syntaxes include *xtreg* with *fe* and *re*, and *xtgls*.
11. Regional-specific effects and time effects are not reported in all the tables in the main text and appendices.
12. exp[6.49/(0.04×2)] = 3,336. RMB 3,336 at 1990 prices is equivalent to $698 at the 1990 average exchange rate that $1=RMB 4.78.
13. We also estimate our regressions using the numbers of enterprises as a proxy of agglomeration. These enterprises include all state-owned and non-state-owned industrial enterprises with an annual sales income of over RMB 5 million yuan. Our main results are unaffected.
14. The average railway density for a province in China is 0.0077 km/km^2 in 2003. The 10 provinces with the lowest railway density are Tibet, Qinghai, Xinjiang, Gansu, Inner Mongolia, Yunnan, Sichuan, Hainan, Chongqing, and Guizhou. These provinces all have geographical restrictions on building railways. Tibet and Qinghai are located on Qinghai-Tibet Plateau; Xinjiang and Gansu both have large areas of Gobi desert; Inner Mongolia has the largest area of grassland; Yunan, Sichuan, Chongqing and Guizhou are in mountainous regions; and Hainan is an island province. Apart from Hainan, the other nine regions are all located in western China.
15. We also estimate our regressions including railway density and road density separately but the results were very similar. We also estimated the regressions respectively including numbers of ports in each province and dummy variable for coastal provinces. Both coefficients are positive but not significant.

9 Literature Review

1. Wei (2000), p. 1.
2. Wei (2000), p. 1, cited in Transition, 7(9–10), p. 9, September/October 1996.
3. Picci (2005), p. 3.
4. Golden and Picci (2005) argue that for countries where information from all surveys is available, the scoring is likely to be more reliable than for countries scored on the basis of a minimum number of available surveys. It also generates systematic biases in the dataset, making the index more reliable for developed than for less developed countries.
5. World Bank, Corruption and Governance, Available online: http://lnweb18.worldbank.org/eca/eca.nsf/ Sectors/ECSPE/ E9AC26BAE82D37D685256A940073F4E9?OpenDocument [Accessed 15 August 2006].
6. The construction of the government efficiency variable is discussed later in Section 9.4.

10 Corruption, Anti-corruption, and Governance in China

1. A dual-track economy involves the co-existence of central planning with a market mechanism for the allocation of resources. Local officials play a critical role in coordinating production and exchange.
2. From 1989 was the era of the *third generation* political leaders. The new Chinese leaders gave priority to anti-corruption work and which meant that corruption was controlled effectively by the 1990s.
3. *Large case* refers to cases involving bribery of over RMB 50,000, or a misappropriation of over RMB 100,000, or cases involving RMB 500,000. *Key case* refers to actions committed by government officials with the rank of division director or county administrator.
4. Xinhua Net, 2011, ‘Life in Prison or Above for Eleven High-profile Corruption Officials in 2010’ on 27 January 2011, available online at:- http://news.xinhuanet.com/2011–01/27/c_121032566.htm [Accessed 10 December 2012].
5. Exchange rate in this chapter (if not specified) is the average rate of RMB yuan against US Dollars in 2003: $1= RMB 8.277.
6. The Circular announced that criminals related to corruption, bribe, fraudulent buying and selling, and so on, must surrender themselves to the police or judicial department within a fixed time.
7. Pei (2007), p. 6.
8. Fredriksson *et al.* (2003), footnote 12, 1416.
9. One case corresponds to at least one person.
10. *n* is the number of provincial governments.

11 Corruption, Governance, and FDI Locations in China: Empirical Evidence

1. These two measures of agglomeration follow Head and Ries (1996). We also employ an alternative measure of *GIPd*, that is, the number of domestic enterprises as the results are similar to those of *GIPd*.

2. The formula used to calculated the FDI inflows is: (0.043 × mean of FDI/GDP × average GDP per capita × population × GDP deflator) ÷ exchange rate, where population equals the assumed 50 million; GDP deflator equals 1.896 which is the GDP deflator in 2003 setting 1990 equal to 1; and exchange rate equals that in 2003, that is $1 = RMB 8.28.
3. 4.75% = [exp (0.464 × 0.1)–1] × 100.
4. We included the percentage of enrolment in different levels of education to substitute for the rate of illiteracy. We found that the percentage of population that received primary school education and above has a negative effect on FDI inflows. We found negative and insignificant coefficients on the enrolment of education at junior school and above, as well as that at senior school and above. The impact of enrolment at college and above was positive but not significant. We also constructed an index to measure the average education level of the population aged 15 and above. The results suggest a negative and significant relationship between FDI inflows and average education level, which is consistent with the results for the illiteracy rate.
5. As part of a sensitivity analysis we included railway density (with and without road density). The coefficient was negative. We believe this is due to the relatively low railway densities in some provinces. For example, Guangdong attracted the largest FDI inflows yet the railway length is 2,112.5 km with a density of 0.01 km/km^2, which is only slightly higher than the average level for the country.

12 Corruption, FDI, and Environmental Regulations

1. Huixian County Non-Ferrous Metal Smelter Co Ltd, which produced about 5,000 tons of lead a year, had never operated anti-pollution equipment, despite being upgraded in 2004, and had been guilty of illegal waste discharge ever since it began operations in 1996. The factory continued to operate secretly after being told to stop production in early 2006. Consequent lead poisoning in Huixian county in Gansu province resulted in the hospitalization of 250 children under the age of 14 and left hundreds of others with excessive amounts of lead in the blood. The chairman of the polluting smelter, and another 19 officials (mostly at county-level and from city environmental authorities) received various punishments for their role in this lead contamination scandal. The other serious pollution incident was caused by two factories in Yueyang county in Hunan Province that released wastewater with high concentrations of an arsenic compound into the Xinqiang River, affecting the water supply for 80,000 residents in the lower reaches. The head and a deputy head of the local environmental protection bureau were fired and another five officials were given warnings and other penalties. The two plants were closed and the managers of the two companies were arrested to face criminal charges and prosecution (China View, 2006a, b, 2007).
2. For example, if higher FDI leads to higher income, and higher income leads to greater demand for environmental quality, then environmental regulations could be a function of FDI (Brunnermeier and Levinson, 2004).
3. Tibet and Qinghai are excluded due to lack of data.

4. We also tested whether government efficiency would have any impact on environmental regulations and whether FDI???s impact on environmental regulations is conditional on government efficiency STD scores. However, the results are not statistically significant. Therefore, we only consider anti-corruption efforts in this chapter.
5. We use EI3 rather than EI1 here because investment in innovation is not reported in the China Statistical Yearbook after 2003.
6. According to EKC, environmental quality declines at the initial stage of economic development due to scale effect but the demand for environmental quality increases when income reaches a certain level. Similarly, the stringency of environmental regulation may diminish at the early stage of urbanization but when more urban citizens are exposed to industrial pollution greater political pressure is added to regulatory stringency.
7. In Model 1, a unit increase in FDI/GDP results in a decline of RMB 276 yuan environmental investment in pollution treatment projects per million investments in total fixed assets, evaluated at the mean of Anti-Corruption.
8. 0.0004 = – 0.154 + 0.321 × (0.26 + 0.26 ?? 0.85).
9. 0.0000 = – 0.122 + 0.034 × (1.82 + (2.65 ?? 2/3)).

13 Conclusions

1. The six highly energy-consuming industries include manufacturing of raw chemical materials and chemical products, manufacturing of non-metallic mineral products, smelting and pressing of ferrous metals, smelting and pressing of non-ferrous metals, oil processing, coking, and nuclear fuel processing, and production and supply of electricity and heat.

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