DEVELOPMENT AND THE ENVIRONMENT IN CHINA: A MULTILEVEL ANALYSIS 2004-2013

by

Jianmei Hao

A dissertation submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Department of Sociology

The University of Utah

May 2018

The University of Utah Graduate School

STATEMENT OF DISSERTATION APPROVAL

The dissertation of **Jianmei Hao**

has been approved by the following supervisory committee members:

		Date Approved
Ming Wen	, Cochair	**11/28/2017**
Michael F. Timberlake	, Cochair	**12/01/2017**
Andrew K. Jorgenson	, Member	**12/13/2017**
Brett Clark	, Member	**11/30/2017**
Yehua Dennis Wei	, Member	**12/01/2017**

and by **Ming Wen**, Chair/Dean of

the Department/College/School of **Sociology**

and by David B. Kieda, Dean of The Graduate School.

ABSTRACT

This dissertation theoretically and empirically explores how development impacts the environment in the largest developing country in the world from the perspective of the sociology of development, and environmental and urban sociology. This dissertation focuses on the context of China, reviews the development trajectories adopted during the past more than 6 decades, and presents the spatial and temporal pattern of environmental degradation across regions and over time. This dissertation also empirically examines the relationship between development and environmental degradation answering the following questions: (1) whether economic development level is positively or negatively associated with air and water pollution; (2) whether industrialization, urbanization, and globalization (international trade and Foreign Direct Investment inflows) are positively or negatively associated with air and water pollution; (3) how the impact has changed across regions and over time; and (4) how the sources of foreign capital have differentially affected environmental pollution across cities and over time. The dissertation presents how economic development level (GDP per capita as the indicator), globalization, industrialization, and urbanization have an impact on air and water pollution, respectively, across regions and over time, and examines whether globalization, industrialization, and urbanization serve as the pathways in the association between development and environmental pollution in such a rapidly growing economy with the largest population in the world. Multilevel modeling is used to analyze the longitudinal data at the city level from 2004 to2013. The findings confirm that there is an inverted U-shape only between economic development and SO_2 emission (not for dust emission or water pollution), indicating whether the Environmental Kuznets Curve (EKC) holds depending on the specific indicators of environmental degradation analyzed. More importantly, the results show that industrialization and urbanization are more likely to positively impact air pollution, while there is no strong evidence supporting that globalization has impact on air pollution. Meanwhile, industrialization and globalization are more likely to positively impact water pollution, while population density is negatively associated with water pollution.

To My Beloved Family, the Source of Unconditional Love

To My Advisors, the Source of Intelligence

TABLE OF CONTENTS

Appendices

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

Six years ago, when I was excited to accept the offer to enter the PhD program at the University of Utah, one of my best friends firmly believed I had chosen a tough road at the best age of my life. At that time, I totally had no idea about the future of my life in the following years. I was dreaming of being an intellectual, as I wrote in my personal statement when applying for the PhD program, who embraces both a " pure spiritually enlightened soul and smart logically intellectual brain."

During the first 4 years, to learn enough knowledge, I took as many courses as I could in sociology and other disciplines (from geography, to urban studies in architecture college, to organization studies in business school) and greatly appreciated what the University of Utah and the Sociology department provided for me. During the last 2 years, to have a big picture of American culture and society, I've participated in various social activities and traveled around the whole country and surrounding areas, and then almost finished a book focusing on an introductory comparative study of the social structure between United States and China. I also presented papers almost each year in various national and international conferences and really cherished the experiences I got from the conferences that are invaluable for my future research and career. Frankly, this is a long, quiet, and lonely journey to explore a different culture as well as the unknown world academically and practically. As an international student, it's not easy, but very worthwhile. I am greatly indebted to so many people who ever helped, comforted, and supported me during the past years.

First and foremost, I would like to express my sincere gratitude to my Master and PhD committee Co-Chairs Professors Ming Wen and Mike Timberlake, who are so brilliant, considerate, and supportive. I'm very lucky to have Professors Wen and Timberlake as my advisors, who are the best and most helpful teachers I met during the past 20 years of my student life. This dissertation would not have been possible without their mentorship, guidance, and support. I'm enormously grateful to Professor Wen. When I applied for the PhD program, she served as the director of graduate studies, and greatly helped me to coordinate with the China Government scholarship awarded to me by the China Scholarship Council. During the first year, she was my mentor to help me to adjust to the new environment. I've benefited not only from her insights of sociological study, but also her useful suggestions and continuous support throughout my graduate life. The topic of this dissertation was originally inspired by her intellectual inquiry about development, environment, and health in contemporary China. She's also always there to support and care about me even when I felt deeply depressed due to my personal issues.

Meanwhile, I have accumulated a huge debt of gratitude to Professor Mike Timberlake who helped me a lot in both research and life. Every time, when I face difficulties in life or study, he's always very supportive. The dissertation would not be finished without the guidance of Professor Timberlake. I'll remember for my whole life how much time Professor Timberlake spent on my dissertation. I'm so impressed and moved by his detailed instructions and for reading my dissertation sentence by sentence and word by word. I'm so grateful for his patience and insightful comments.

I would like to thank my other Committee members, Professors Andrew Jorgenson, Brett Clark, and Dennis Wei. The dissertation proposal was greatly reshaped by their comments and suggestions. I am really grateful to Professor Jorgenson for his sharp comments and critiques. I thank Professor Brett Clark for his invaluable advice. I thank Professor Dennis Wei for being always available and approachable. Thanks so much to them for taking time to read my manuscripts and share their critical views.

Then I would like to thank University of Utah and China Scholarship Council, both of which awarded me the scholarship to sponsor my study. Thanks to all of the faculty members, staffs and graduate students of sociology department who's are so friendly and willing to help. Especially, I've learned so much from different courses taught by and the papers published by Professor Jeffrey Kentor, Wade Cole, Kim Korinek, Rebezza Utz and Claudia Geist. I would like to show my gratitude towards Angela Midgley and Joanna Straughn, who provided generous assistance and help I greatly appreciate during my stay in the United States.

The great appreciations go to the University of Utah Library where I almost do the research every day and the staff at the Interlibrary Loan who helped me located for the materials I needed for the research.

Lastly, I would like to especially thank my beloved family, including my parents, my older brother Jianxun Hao and younger brother Jiantao Hao, whose love, care and support always accompanied me during the journey. In particular, thanks to my little niece Zihan Hao whose lovely smile and cute questions helped to relieve the stress of long hours of data analysis. Moreover, I would like to thank my beloved boyfriend, who provided love, care, and understanding during the past years when I prepared for the dissertation. I would like to express my gratitude to my soul mate and best friends who gave me trust, care and emotional support during the past years. I also greatly appreciate the help and understanding of many best friends, especially Yiqing Yang's patient care and Han Li's technical support for the GIS analysis.

In addition, I would like to thank the school of sociology of Central China Normal University, especially my former advisor Professor Yuzhen Xia, teachers like Professor Lihua Jiang and Xiaojun Xu, and friends including Professor Ping Fu and Editor Dr. Dian Yang who provided me a lot of guidance and suggestions on the revisions of the dissertation.

CHAPTER 1

INTRODUCTION

In December 2015, a historic and ambitious agreement to combat climate change was approved by 196 parties in Paris (United Nations, 2015). For the first time in history, all nations in the world reached consensus to reduce emissions to limit the increase of the world's average temperature to two degree Celsius. According to the United Nations, the Paris Agreement, as a dynamic and universal agreement, provides a mechanism for all countries to address global climate change predominately caused by human activities. In particular, China has promised that it will reduce its carbon dioxide emissions per unit of GDP by 40-45% from the 2005 level and annual carbon dioxide emissions from coal-fired power generation by 180m tons by the year 2020. Given the fact that China is the world's largest emitter of greenhouse gases, the commitment China made to reduce its carbon dioxide emissions and improve energy efficiency is critically important for the goals towards a low-carbon sustainable future for human beings.

------ 2015 Paris Climate Conference

In China, the ongoing deterioration of the environment is of great concern to the public and policymakers, who expect academic research to offer evidence-based solutions. Hence, academic research on environmental issues is urgently needed to systematically explore causes and consequences of environmental degradation. Beginning in the early 2000s, there has been a burgeoning debate about development and the environment from researchers in response to the increasing frequency and severity of environmental degradation (He et al., 2012, 2014; He & Pan, 2013; Huang et al., 2015; Kahn, 2004, 2009; Kuby & He, 2011). According to Kuhn (1962), doing research is essentially "like solving a puzzle" with different disciplines offering different paradigms to direct their inquiries (Kuhn, 1962). Regarding environmental-related research, different disciplines have very distinct views of how environmental studies can be conducted. Research in environmental science and environmental engineering extensively examine the environmental systems, focusing on scientific inquiry and technological feasibility, respectively. For example, environmental scientists examine the emission sources based on the spatial patterns of air pollution across different industry sectors (Lei et al., 2011) and across regions (Rohde & Muller, 2015; Zhang et al., 2011).

By contrast, social scientists study the environment with different perspectives than natural scientists and engineers. Environmental sociologists are more concerned with socioeconomic systems. In particular, they emphasize that environmental-related issues are profoundly social in addition to being technical/scientific. Environmental history argues that to study the modern ecological history of the planet, the socioeconomic history of humanity should be explored together (Mcneill, 2000). A report from the World Bank and United Nation Environment Program (UNEP) largely focuses on the environmental regulation and enforcement, including pollution charges, environmental subsidies, ownership structure, and the bargaining power of polluters (Dasgupta et al., 2001; VanRooij, 2012; Van Rooij & Lo, 2010).

Most existing studies on the relationship between development and the environment in the context of China are conducted using theoretical frameworks in ecological economics and economic geography (He & Pan, 2013; Huang et al., 2015; Kahn, 2004, 2009; Kuby & He, 2011). Studies in ecological economics investigate how economic growth impacts the environment across provinces in China based on the framework of the Environmental Kuznets Curve (EKC), overlooking the institutional and structural context (Shen, 2006; Song et al., 2008). These studies particularly focus on the effects of industrialization and industrial structure (Wang et al., 2011) and globalization (e.g., international trade and foreign direct investment) (He, 2006) on environmental quality. Studies in economic geography analyze the environmental impact based on the triple process of marketization, decentralization, and globalization, including sulfer dioxide (SO_2) emissions (He et al., 2012) and land use expansion (Huang et al., 2015). Urbanization processes, especially the spatial shift of the population from rural to urban areas, is seriously considered under the triple structure of the transition process. Crudely put, integration of these theoretical frameworks will provide much more comprehensive explanations for the dynamics of development and environmental degradation in China than would be provided by any one perspective alone.

The main purpose of this dissertation is to provide a comparative framework for understanding the socioeconomic determinants and the underlying mechanisms of environmental degradation in China using longitudinal data at the prefecture-city level from 2004 to 2013. This is a break from conventional analyses of cross-national comparative sociology, which takes China, as a whole, as the unit of analysis to compare with other countries in one or more time periods. Geographically, China is vast and diverse with a huge population. Accordingly, the environmental destruction in the country, along with its economic development, has varied significantly at the regional, provincial, and city level. To my knowledge, this study is the first to develop a systematic theoretical framework to examine how the dynamics of development in China have impacted the environment across cities in different regions and over time. Given the institutional and structural context of China, results from this study demonstrate that exploring the complex dynamics of development (especially economic development level, globalization, industrialization, and urbanization) are critical in addressing environmental challenges (e.g., air and water pollution) for developing countries. In addition, this study also contributes to a broad literature on changing dynamics of human-nature relationship, providing insight into the debate surrounding the interdisciplinary study of how manufacturing industrial structure, population density, international trade, and foreign direct investment (FDI) have impacted the quality of the natural environment.

The Context of China

As the world's most populous country and largest developing country, China is currently undergoing remarkable economic growth and dramatic social change through globalization, industrialization, and urbanization (Wei & Ye, 2014). Meanwhile, as the new engine of global growth and the manufacturing hub of the world, China has become the largest contributor to carbon dioxide emissions since 2007, and accounting for 29% of the world's total emissions in 2013, higher than such emissions from the United States and the European Union combined. In short, explosive economic development has posed serious environmental challenges at an unprecedented scale within the country, even spilling across its borders (Bao et al., 2012; Chen et al., 2011; Zhu et al., 2014). Purportedly, the rapid economic growth in China has consumed a large proportion of global raw materials (e.g., 54% of aluminum, 48% of copper, 50% of nickel, 45% of all steel, and 60% of concrete). According to the most recent waste report from the World Bank, China was the world's largest waste generator in 2016, producing about 189 million tons of waste annually (World Bank, 2016). Hence, environmental degradation in

China has a planetary effect, and pollution in China is not just simply China's problem since pollution knows no political boundary (Liu & Beattie, 2016, p. 1). Thus global climate change challenges could not be adequately addressed without the cooperation of China. Given the planetary scale effects, understanding the environmental consequences of China's development trajectories takes on tremendous significance for humanity in general. In particular, special attention should be devoted to the more specific questions about how the development of China has, and will, impact the environment within the country and even within the world. These questions are the core of my dissertation.

Theoretical Perspectives

Theoretically, two opposing views have dominated the intersection of development and the environment in environmental sociology and ecological economics. One is the Treadmill of the Production Theory and the other is Ecological Modernization Theory (Dietz, Rosam, & York, 2012; Gould, Pellow, & Schnaiberg, 2004; Jorgenson & Clark, 2012; Mol, Spaargaren, & Sonnenfeld, 2009; Schnaiberg, 1980).

Treadmill of Production Theory

The Treadmill of Production Theory (TPT) developed a sociological understanding of why environmental degradation has increased rapidly in the U.S. TPT provides a political economic approach for addressing growth dynamics of both capitalism and Soviet-style socialism (Foster, 2005; Schnaiberg, 1980). According to Foster (2007), capitalism itself is an ecologically destructive means of production, and more importantly, the process of producing and consuming goods generates ecological disorganization. For instance, using a societal-environmental dialectic, Schnaiberg presents an explanatory model of how the organization of social production (also called the treadmill of production) transformed and even disorganized the ecosystem by depletion (withdrawals) and pollution (additions).

TPT describes the dialectic dimensions of development and environmental impacts given that there are political-economic alternatives to the environmental impact of an accelerating treadmill (Gould et al., 2004, p. 304). More importantly, the theory works to disentangle the role of the agents of this production/destruction dynamic, such as producers, the state, consumers, and environmentalists (Schnaiberg et al., 2002). TPT identifies the state, capital, and labor as the significant actors that impact the treadmill (Spapens et al., 2016).

The belief is widely held that the most pressing environmental problems can be ameliorated by technological “fixes.” However, TPT posits that the treadmill of production is partly built upon expanded technological capacity (Schnaiberg & Gould, 1994, p. 70). Inevitably, the technological advances increase the volume of natural resource extraction (depletion) and waste (pollution). The socioeconomic production of human beings has maintained an increasingly damaging negative environmental impact across the globe (Gould & Lewis, 2009; Schnaiberg, 1980; Schnaiberg & Gould, 1994). Thus, the treadmill of production continually disrupts ecosystems at both local and global levels. Following the trajectory of expanding production, the faster the machines run, the more energy consumed, and the more the ecological disruption would occur, quantitatively and qualitatively. Essentially, environmental disruption is an inherent part of development and is deeply rooted within the socioeconomic system (Schnaiberg &

Gould, 1994). According to Jorgenson and Clark (2012), the environmental impact of economic development at the national level should remain stable or increase in magnitude over time in both developed and developing countries.

In Buttel's (2004) view, however, it would be too superficial and simplistic to apply the Treadmill of Production Theory as a linear model since some scholars note that the treadmill is expanding exponentially rather than linearly. Most of the research indicates that the theory underestimates the environmental outcome due to the constraints of available data, whereas for others, the theory overestimates the negative environmental impact of economic activities (Pellow & Brehm, 2013). In addition, TPT provides a theoretical framework that explores the causes and consequences of environmental degradation. However, in terms of influencing policy, this perspective is far from viable given economic expansion is of central importance to policymakers in most developing countries (Gould et al., 2004).

Ecological Modernization Theory

In contrast to the pessimism of Treadmill of Production Theory, Ecological Modernization Theory (EMT) provides a more optimistic perspective. Specifically, unlike the widespread yet general concept of sustainability, EMT gives primary emphasis on how to conceptualize environmental improvement. Essentially, EMT identifies factors such as technology (e.g., technological advances), policies (e.g., the state), affluence (e.g., economic development level), and culture (e.g., environmental consciousness and consumption style changing) as the keys to improving environmental quality (Buttel, 2000; Mol, 2002; Mol & Spaargaren, 2000; Sonnenfeld & Rock, 2009). Specifically, EMT is understood as a technology-based and innovation-oriented approach to achieve environmental sustainability (Janicke, 2008). In terms of the diffusion of environmental innovation, the state plays a crucial role in creating environmental governance and developing effective strategies. Moreover, proponents of EMT hypothesize that the most serious and challenging environmental problems have been caused by modernization and industrialization, and can ultimately be solved through further “super modernization and industrialization” (Liang, 2012). In brief, EMT argues that economic development and environmental improvement can be compatible and reconcilable. Put differently, a coherent set of hypotheses can be generated from EMT, from how the competition among capitalists would effectively lead to beneficial environmental outcomes, to recognizing the institutional capacity to improve eco-efficiency in the production and consumption processes. As Buttel (2000) noted, the rising visibility and influence of EMT is not only due to the clarity of its theoretical arguments, but primarily because it provides a positive response to the growing global environmental challenges.

Research Objectives

Air/water pollution accompanying economic expansion has attracted considerable attention from the general public, policymakers, and researchers who examine the key determinants of environmental degradation in China. The most important objective of the dissertation is to present how environmental degradation has changed across cities and through time, and provide a systematic exploratory study of development and the environment, focusing on globalization, industrialization, and urbanization.

The dissertation will examine the intersections of development and the environment in a rapidly developing social setting using nationally representative longitudinal data for the time period 2004-2013. The dissertation will investigate several key questions, including (1) whether economic development level (GDP per capita) is positively or negatively associated with air and water pollution, net of other variables; (2) whether globalization (international trade and FDI inflows), industrialization, and urbanization are positively or negatively associated with air and water pollution, net of other variables; (3) how the impact has changed across regions and over time; and (4) how the sources of foreign capital have *differentially* affected the environment across cities and over time. More importantly, the study will examine the joint effects of economic development (GDP per capita) and other driving forces (e.g., globalization, industrialization, and urbanization) on environmental degradation across 287 cities from 2004 to 2013. To my knowledge, this is the first multilevel study designed to exam the relationship between development and the environment within China from the perspectives of development, and urban and environmental sociology using the data at the city level. Compared to the analysis of the cross-sectional data, using longitudinal data to explore these issues will improve our understanding of the complex dynamic relationship between development and the environment over time.

Significance and Innovation of the Dissertation

Although previous research has made valuable contributions, this dissertation advances the literature in several ways. First, it will provide a detailed analysis of variation within one particular country--China, the world's most populous nation with world's most dynamic developing economy. Most of the literature on the relationship between development and the environment mainly focused on the West (within the United States, within Europe, or between United States and Europe), adopting social theories or analytical framework deeply rooted in the Western society (Liang, 2012). In spite of some scholars who have started to assess the appropriateness of the existing findings as a way of explaining environmental degradation in China (Mol, 2006), the historical and institutional context of China's development trajectories has rarely been systematically studied in comparative development-environment research. This dissertation attempts to examine how China adopted different development trajectories during different periods, and describes the spatio-temporal patterns of environmental degradation across different regions within the country.

Second, the most recent longitudinal data available are used. Prior research takes China as a whole or provinces within China as unit of analysis. Studying environmental degradation (either air pollution or water pollution) across nationally representative Chinese cities has not before been conducted. This bias is particularly evident in smaller scale studies with very limited diversity. Empirically, this dissertation is a comprehensive comparative sociological analysis of the relationship between development and the environment using the data from 287 prefecture-level cities from 2004-2013.

Third, the joint effect of a series of major factors is tested. I incorporate economic development level, globalization, industrialization, and urbanization, whereas previous studies mostly examine the effect of such factors separately. This dissertation will also extend prior research by highlighting air and water pollution, both of which are important specific types of environmental degradation.

Last, but most importantly, this dissertation will contribute to the literature by examining the independent role of the factors that have not been studied previously within China: the source of foreign direct investment, domestic investment, and population density. For instance, this dissertation extensively focuses on the relationship between globalization and the environment in the most populous developing country. In particular, it has strong policy implications for examining how the sources of foreign capital have differentially affected the environment. This dissertation will provide evidences on whether foreign capital is beneficial or detrimental to the environment, depending on the source and the type of environmental degradation. Moreover, this dissertation is sensitive to the intersection between population density and environmental degradation, and finds that higher population density is significantly positively correlated with air pollution.

In addition, this dissertation has several implications for policymakers and practitioners. For instance, this dissertation has significant implications in addressing economic disparities and environmental degradation in terms of regional development strategies. This dissertation also presents the relationship between industrialization and environmental degradation, suggesting aside effect of the spatial shift of manufacturing industries across regions.

Organization of the Dissertation

This dissertation is organized into five chapters. Following this introductory chapter, there are three chapters that describe and explain environmental degradation patterns across China from 2004-2013. Following these chapters, the dissertation briefly concludes with a discussion of the theoretical and policy implications of the findings.

Chapter 2, “Development Trajectory and Spatio-temporal Patterns of Environmental Degradation in China,” provides a big picture of how the development trajectory and the patterns of air and water pollution have changed across regions and over time. This chapter focuses on the context of China and extensively reviews the institutional changes in the transition from the planned economy to a market economy. Spatial and temporal patterns of environmental degradation are illustrated in detail.

Chapter 3, “The Dynamics of Development and Air Pollution,” presents the first empirical multilevel analysis to examine the dynamics of development on air pollution in China using longitudinal data at the prefecture-city level from 2004 to 2013. The focus is on the pathways in which major factors such as economic development level, globalization, industrialization, and urbanization have impacted air pollution across regions and over time. The chapter provides a snapshot of how the dynamics of development influences air pollution during the past 10 years, and examines whether globalization, industrialization, and urbanization serve as the pathways and underlying mechanisms in the association between development and air pollution in China.

Chapter 4, “The Dynamics of Development and Water Pollution,” empirically demonstrates the dynamics of development on water pollution in China using longitudinal data at the city level from 2004 to 2013. This chapter will consist of a literature review, description of the methodology used, and empirical analyses, showing how the trends of water pollution changed and how development affected water quality. Especially, more attention has been devoted to analyze how the major driving forces of development (such as economic development level, globalization, industrialization, and urbanization) have impacted water quality across regions and over time.

Chapter 5, “Conclusions and Implications,” will briefly sum up the contributions of these analyses to the field of environmental and urban sociology, and the broader literature on development and the environment in ecological economics and urban geography. The most significant findings are addressed in terms of their implications regarding development and environmental policies.

CHAPTER 2

DEVELOPMENT TRAJECTORY AND SPATIO-TEMPORAL PATTERNS OF ENVIONMENTAL DEGRADATION IN CHINA

The interplay between development and the environment has been recognized as a fundamental question with highly controversial debates in environmental sociology and ecological economics (Jorgenson, 2014; Jorgenson & Clark, 2012). Theoretically, it is well established that development and the environment are interdependent worldwide. However, in practice, giving top priority to development over the environment in national and regional policy is pervasive. Substantial evidence shows that rapid economic growth has been, and continues to be, pursued at the cost of environmental degradation, particularly in most developing countries (Dinda, 2004; Jorgenson, 2006). Moreover, within the developing countries, it is worth noting nation-specific institutional contexts matter when studying the environmental implications of development at different stages (Jorgenson & Clark, 2012; United Nations Development Programme, 2015). Therefore, exploring the intersection between development and the environment in a specific country is particularly significant and worthwhile to the researchers of and decision-makers in developing countries.

As the most populous and the largest developing country, China is a particularly important and interesting case for studying the intersection between development and the environment. First, sustainable development of China is of global interest given its size and unique institutional and structural characteristics. Secondly, the development mode and trajectories China adopted during the past 6 decades were paradoxically different, originally from a centrally planned economy and then transformed towards a market economy. Third, the landscape and ecosystem of China have been significantly transformed by the large-scale industrialization, urbanization, and globalization. Although many scholars in economics have systematically studied how China developed and reformed (Chow, 2004), we still know little about the environmental implications of different development strategies. In particular, within the discipline of development and environmental sociology, comparative analysis on the development trajectory and environmental degradation in China has rarely been undertaken. Hence, examining the case of China under a systematical theoretical framework will provide valuable insight into understanding environmental degradation and contributing theoretically to the scholarly literature on the relationship between development and environment problems.

How shall we best understand and elaborate the relationship between development and the environment across China from a comparative environmental sociology perspective? What are the determinants of environmental degradation in different regions of this rapidly growing economy? These questions will be explored in this chapter. To provide a snapshot of how China has developed and how environmental conditions have changed, I will first briefly review the development trajectories that China has followed since the founding of the People's Republic of China (PRC) in 1949. Following this, I will present the spatial and temporal patterns of environmental degradation across regions during the 10 years, 2004-2013, in China.

China's Development Trajectory

When the Communist Party took power in 1949, China had been backward in terms of economic development for more than 100 years. Catching up with the economic development level of developed countries is the aspiration for political leaders and social elites in backward economies, and China has been no exception. According to the United Nations (2015), the central government of China has made concerted efforts in directing national economic strategies (UNDP, 2015). Broadly, the development trajectory of China during the past more than 6 decades can be divided into two phases: the planned economy (1949-1977) and the mixed economy (1978-present) combining planned and market economy.

Soviet-Style Development Strategy Under the Planned Economy

During the prereform period (1949-1977), China was a planned economy that was closed to foreign trade and investment (Chow, 2006). Since the first 5-year plan in the 1950s, soviet-style development strategies, with emphasis on industrial development in urban areas and collectivization of agriculture in rural areas, respectively, have been adopted in China. It is widely recognized that the country's economic development strategy during 1952-1977 was characterized by a "high rate of capital accumulation at the expense of consumption and the promotion of industry at the expense of agriculture" (Chow, 1993, p. 809). As a result, in spite of its economic backwardness, giving priority to the development of heavy industry "yielded an accumulation rate over 15% of the national income," and led to a relatively comprehensive industrial system in China (Lin et al., 2003, p. 69). Accordingly, the industrial structure of Gross Domestic Product (GDP) changed greatly throughout 1949-1977 (see Figure 2.1). More strikingly, the contribution of industrial production dramatically rose from 21% in 1949 to 47% in 1977.

Meanwhile, in terms of economic efficiency and environmental impact, the cost of implementing heavy industry-oriented development strategy was extremely high. Based on the assessment of environmental problems under the Mao era, Shapiro (2001) concluded that contemporary environmental problems in China should not be attributed solely to the postreform period of remarkable economic development and industrial growth. As Shapiro (2001) noted, the rapid development of heavy industry started "the path" of environmental degradation in the 1950s when the negative effects of industrialization on the environment had been largely ignored. For example, to achieve national transformation through rapid industrialization of the rural areas, the central government in 1958 attempted to accomplish catch-up development through "the adoption of a leap-forward strategy" ignoring other development stages (Lin et al., 2003, p. 103).The share of industry in GDP rapidly increased at a much higher speed than expected, from 27% from 1957 to 44% in 1960 (see Figure 2.1). Consequently, the Great Leap Forward in 1958-1960 brought a dramatic increase in the number of factories (such as steel industries) along with pollution and more deforestation (Shapiro, 2001).

Moreover, some environmental historians argued that the environmental problems since the 1950s in China could not be understood without references to preceding development regimes (Elvin, 2012). Prior to the impact of the modern West in the 19th century, traditional Chinese society slightly changed. Although traditional China depended upon the natural environment for thousands of years, it rarely worked explicitly against nature. For instance, Pomeranz (2000) pointed out that in China, traditional agricultural practices attempted but failed to radically change nature due to low productivity in the absence of mechanization. According to Murphey (1967), traditional China was as an agrarian society in which nature was grander than man and admired by man. The traditional Chinese ideal of *Tianrenheyi* (unity of heaven and humanity) posited man as an integral part of nature, stressing the harmony between man and nature. Thus, the harmonious cooperation between man and nature became one of the central parts of Chinese philosophy. The orientation towards the natural environment that the traditional Chinese carefully cultivated and preserved was fundamentally different from that of the West (Murphey, 1967). However, such traditional notions of compromise and harmony were specifically attacked, and then replaced by *Rendingshengtian* (man must conquer nature). Following such an ideal, man was viewed as opposed to the nature, and more importantly, played the dominant role in transforming nature. Under the materialist policies of the Mao era, environmental exploitation, especially massive deforestation, overgrazing, and soil erosion, accelerated considerably in the pursuit of ambitious development projects (Edmonds, 1998; Murphey, 1967).

China was largely rural and markedly underurbanized when the West experienced the industrial and urban transformation during past centuries (Glaeser, 2011). In 1949, industry only accounted for 12.6% of national income and 10.6% of the total population lived in the city (Li & An, 2009). The growth of industrial cities such as Philadelphia in the world proved that industrial development and urban growth always proceed side by side and reinforce each other (Pred,1980). The rise of heavy industries (coal, steel, iron, and oil, etc.) in China had largely contributed to the urban expansion across the nation. According to Gu (1992), there were almost 40 prefecture-level new industrial cities established during the period of 1949-1977 across the nation, mostly in central and western regions (see Figure 2.2).

According to the World Development Report 2009, the national policies on urbanization in China have alternated between facilitating city growth to restricting it during 1949-1977. Accordingly, the patterns of population mobility were shifting from rural-urban migration in 1950s to urban-rural migration during the Cultural Revolution (1966-1976). At the beginning of the Mao era from 1949-1957, urban population increased rapidly. It is estimated the urban population in China grew by 34 million (Bernstein, 1977; Rosen, 1982). However, the growth rate of the urban population grew much faster than the job opportunities in the industrial sector (Rene, 2013). To cope with the population flows into urban areas, the government began to take stringent measures to restrict rural out-migration (Chan & Xu, 1985; Wu, 2004). In 1958, the National People's Congress officially issued the regulation of household registration system (HRS, also called the *hukou* system) to control population mobility. Since then, the freedom of residence and migration within the country were severely controlled and all internal migration was subject to approval by the relevant local government (Chan, 2010). According to HRS, each citizen is required to register with a *hukou* (registration status), categorized either as "agricultural" or "nonagricultural" by a specific administrative unit. Under this system, peasants were confined to the rural areas and entitled to many fewer rights and benefits, compared to the urban residents who had housing, educational opportunities, permanent employment, medical insurance, and pensions, etc. Arguably, the social divide between the urban and the rural that was institutionalized by the *hukou* system has become the most prominent structural feature of Chinese society (Wu, 2004).

Regarding why the government adopted such a policy to restrict population mobility, the dominate view in the literature is that the massive inflows of rural migrants into the cities earlier in 1950 greatly exceeded the growth of industrial employment in the urban areas (Chen, 1972). Therefore, the unemployment of rural-urban migrants had become a serious burden for many cities. The adoption of the Great Leap strategy and communization of agriculture also attempted to solve the problem of the massive underutilization of labor in the countryside (Chen, 1972, p. 372). Unlike Chen's statement, Chan (2010) provided an alternative explanation from the perspective of social control mechanisms. Given the scarce capital in agrarian economy, heavy industry-oriented development strategy required the extraction of agricultural surplus from the peasantry. Similar to the unequal exchange between developed and developing countries, to speed up industrialization, the government had to artificially create unequal exchange between agricultural and industrial sectors to accumulate capital. He further argued that under the Soviet-style planned economy, the government "took up the responsibility of providing food, jobs and related welfare for all urban residents" in the industrial sector, while leaving the rest of the population largely outside state support (Chan & Zhang, 1999, p. 821). The economic system needed an effective mechanism to prevent a rural exodus.

Although the rapid industrialization in cities promoted the recruitment of labor from the rural areas in 1958-60, such high rates of rural-urban migration were not sustained due to the disastrous famine of 1958-1961(Kung & Lin, 2003), which in turn enabled the government to set up the full *hukou* system in 1960. Figure 2.3 presents the percentage of urban population and nonagricultural population from 1949-1977 and clearly shows that year 1960 is a significant turning point. After 1960, the percentage of nonagricultural population became lower than the urban population share, indicating the government policies of controlling rural-urban migration including the *hukou* system took effect. The rate of the urban population sharply declined from 19.75% in 1960 to 16.84% in 1963, and then started to rise again in 1964. Meanwhile, besides the *hukou* system controlling rural-urban migration, according to Rene (2013), rustication (sending urban youth to rural areas) had become a fundamental part of the national reeducation program in 1962. Although rustication was officially designed for reeducation in line with the rationale for the Cultural Revolution, it had multiple purposes. One of the important objectives of the initiation of rustication was that the government could not provide enough employment opportunities in the cities for the new incoming graduates. Rustication was viewed as a means to reduce the urban unemployment (Bernstein, 1977; Chen, 1972; Rosen, 1982). It was estimated that there were about 17 million urban youths and intellectuals resettled from cities to the countryside from 1962-1977 (Rene, 2013). In short, the government severely controlled rural-urban migration under the *hukou* system and promoted urban-rural migration through rustication on the other hand. The percentage share of the urban population in China sharply decreased after the 1960s and the rate of urbanization lagged behind industrialization during the prereform era 1949-1977 (see Figure 2.4). This is in sharp contrast to the close correlation found in the relationship between industrialization and urbanization cross-nationally.

Export-Oriented Development Strategy During the Transition

After nearly 2 decades of experience in the planned and command economy, China began to reform the planned, centralized, and inefficient economic system. Learning from the model of the "East Asian Miracle," China adopted a comparative advantage strategy to promote regional and national economic growth (World Bank, 1993). Compared to Eastern Europe, the transition in China has been a gradual process, consisting of small, step-by-step changes preceded by trial and error (Shi, 1998). Noticeable structural change in economic sectors and institutions under these steady and experimental policies has brought rapid economic growth across the country. During the transition from a highly centralized planned economy to the market economy, a series of policy reforms have been effectively implemented nationwide.

Household responsibility system. One of the most fundamental policy reforms that moved China towards a market-oriented economy, the Household Responsibility System (HRS) was adopted in the rural areas. In Kochin's (1996) view, collectivization of agriculture in 1950s aimed to extract resources from the agricultural sector to finance industrialization. In the reform era, land was decollectivized, rather than privatized, in the form of independent family production. The implementation of HRS facilitated the decollectivization of agricultural production by replacing production team system as the unit of production and income distribution (Nolan, 1983). This institutional change has brought remarkable development for rural China, including increasing agricultural yields, production efficiency, and higher peasant income (Friedman & Lee, 2010; Wallace, 2014). The decollectivization not only increased the efficiency of labor usage, but also revealed the existence of a massive labor surplus prior to the HRS in the countryside

(Wallace, 2014). More importantly, it undermined the capacity of the government to prevent population mobility to cities. To effectively "soak up" the surplus rural labor force, the policy of rural industrialization, commonly expressed as *litubulixiang* (leaving the land but not leaving the villages), had been advocated in the 1980s and then the Township and Village Enterprises (TVEs) took off (Oi, 1999; Wallace, 2014). In sum, the rapidly growing surplus labor after the decollectivization and the implementation of HRS facilitated the transition from heavy industry-oriented development strategy in a capital-scarce economy to a comparative advantage strategy in a labor-intensive economy (Cai et al., 2003; Lin et al.,1993).

Household registration system. In essence, The Household Registration System (also called the *hukou* system) in China is both the basis and product of the authoritarian command economy (Chan, 2010). During the collective era, the *hukou* system integrated with other social and economic mechanisms, restricting population mobility from the rural to urban areas. Under the reform, the *hukou* system was challenged when the distributions of daily necessities were no longer monopolized by the state and job opportunities were available in nonstate sectors. Therefore, the *hukou* system, on the premise of a command system with a strong state and static population, became increasingly incompatible with a more marketized economy (Chan, 2010).

Specifically, along with the reform of the planned economy, the *hukou* system, functioning effectively in a closed economy, required reform to accommodate the rural-urban migration under the new circumstances since the late 1970s. The reform of the system has been very complicated, involving a series of flexible policies. The basic principle of population mobility under the *hukou* system is to control formal migration from rural to urban areas, while the flows in the opposite direction are allowed. For instance, the migration from the countryside to cities, from towns to cities, and from small cities to big cities is severely controlled. By contrast, the migration from cities to the countryside, from cities to towns, and from big cities to small cities is not limited.

There are two main parts of *hukou* registration: the place of *hukou* registration and the status of *hukou* registration (agricultural or nonagricultural status). The reform of *hukou* system in 1980s and 1990s focuses on the status of *hukou* registration. Chan and Zhang (1999) extensively investigated the specific measures of relaxing policies for *hukou* system, including loosening control policies for formal rural-urban migration (*nongzhuanfei,* converting the *hukou* status from agricultural to nonagricultural), issuing temporary resident certificates, issuing citizen identity cards, and sales of urban *hukou*, etc. In 2014, the national resident registration system (*jumin hukou*) for both rural and urban populations was set up, although the essential features of the *hukou* system were not abolished.

The massive internal migration, including both *hukou* and non-*hukou* migrants, has been remarkable since the 1980s (Cheng & Selden, 1994). The non-*hukou* migrants are also called the "floating population," mainly moving from rural to urban areas, and geographically from central/western regions to eastern regions. During the reform period (1978-present), given that the One-Child policy was more strictly enforced in urban areas, urban growth and expansion are primarily the result of rural-urban migration (Gu et al., 1989; Zhou & Ma, 2003). The underlying cause for rural-urban migration is the shift of labor force and employment from agricultural to nonagricultural sectors. As the World Bank (2014) observed, the spatial transformation of population in China from the countryside to cities reflects the sectoral transformation of the economic structure from agriculture to manufacturing and service industries in urban areas. Until 1978, only 18% of the total population lived in the cities, which is considerably less than the average low-income country (Naughton, 2007). Therefore, some scholars believed China was underurbanized in the prereform era (1949-1977) (Chan & Xu, 1985).

The urbanization of China in the reform era has greatly accelerated with the size of urban population relative to the total population, increasing to 53.73% in 2013, representing a growth rate that is three times the global average during this period (United Nations, 2014). The urban transformation has spread across the country. Figure 2.5 presents the trends of industrialization and urbanization from 1952 to 2014, indicating the level of urbanization has increased rapidly since 1977. At the national level, in 2012, over 680 million people lived in the cities, of which over 200 million are the rural migrants. According to the National New-type Urbanization Plan (2014-2020), over 100 million people are expected to move from the countryside to the cities by 2020. At the city level, taking the large cities, Beijing and Shanghai as examples, the primary and secondary labor market is not only attracting interregional migration from the hinterland to the developed coastal regions, but also from rural to urban areas. According to the data from Beijing and Shanghai Municipal Bureau of Statistics, the floating population in Beijing increased from 2.50 million in 2000 to 7.58 million in 2013, and it increased from 2.87 million in 2000 to 9.90 million in 2013 in Shanghai.

<u>Stated-owned enterprises.</u> Stated-owned enterprises (SOEs) were reformed in urban areas. SOEs, playing a leading role in industrialization of China, have dominated the key sectors of the national economy, and have been the main force behind national

rapid economic growth for decades. During the transition to the market economy, institutional reform of SOEs became an urgent priority when incentive incompatibility and information asymmetry increased inefficacies and decreased their profitability (Lin et al., 2003). The institutional arrangements via corporatization, rather than privatization, substantially improved the enterprise performance by addressing inefficiencies, uncompetitiveness, and weak transparency (Mcnally, 2002; Zhu & Nyland, 2004). However, the environmental impact of SOEs is highly controversial. In particular, the SOEs centered on heavy industry served as the basis of many resource-based industrial cities. Figure 2.6 shows that there had been 128 prefecture-level industrial cities until 2013, indicating that nearly 45% of the cities nationwide is heavily based on a single industry and is highly unsustainable in the long term (the State Council of RPC, 2013).

Additionally, studies note that the heavy manufacturing companies, especially SOEs in China, are significantly more pollution-intensive than their counterparts in the United States and Europe (Dasgupta et al., 2001). Shi and Zhang (2006) noted that the state-dominated system of industrial pollution control has fallen short in mitigating the environmental impacts of rapid industrialization. Wang and Jin (2006) provided empirical evidence that the environmental performance of SOEs was worse than POEs (privately-owned enterprises), COEs (collectively-owned enterprises), and FOEs (foreign-owned enterprises), given that SOEs had lower efficiency in implementing environmental policies and stronger bargaining position to avoid compliance with the local environmental authorities. Nevertheless, other studies argue that SMEs (small and medium enterprises), as crucial for the early stages of industrialization, tend to have worse environmental performance due to having less environmental awareness and limited investment in environmental protection (United Nations, 2011).

According to the Chinese Research Academy of Environmental Sciences (CRAES), industrial pollution has been identified as the source of approximately 70% of China’s total environmental pollution. Coal, as a major source of fuel, supplied nearly 66% of national total energy consumption in 2012 and is identified as the biggest source of air pollution in China (Energy Information Administration,2015). The report from the World Energy Council confirmed that China is ranked as the world’s top coal producer, and accounts for almost half of global coal consumption, an important factor in world energy-related carbon dioxide emissions (EIA, 2015) (see Table 2.1).

The report from the U.S. Energy Information Administration (EIA) showed that the unprecedented large-scale industrialization trajectory helped China become the world’s largest power generator in 2011, surpassing the United States as the world’s largest net importer of petroleum in 2013. According to the Center for International Climate and Environmental Research in Norway, China became the world’s largest total carbon dioxide emitter in 2007 and per capita carbon dioxide emitter for the first time in 2014. However, the most recent study conducted by Harvard scientists argues China’s carbon dioxide emission may have been overestimated (Liu et al., 2015).

Foreign direct investment and foreign-owned enterprises. The foreign direct investment (FDI) and foreign-owned enterprises (FOEs) are attracted through low taxes and loose environmental regulations. Then products are exported into the world market through international trade. Essentially, attracting FDI and exporting products via international trade are the main features of the export-oriented comparative advantage strategy China adopted, which also results in the consumption of vast natural resources, the production of considerable pollution, and increases in occupational illness and diseases related to working in and living near to hazardous industries.

Since the policies of opening up adopted in China, a series of regional development policies were implemented in the coastal areas (Chai, 1996; Goodman & Segal, 1994). For example, the Sixth Five Year Plan 1981-1985 clearly highlighted efficiency, rather than equity, as the chief priority. In order to achieve efficiency, uneven regional economic development policy was effectively implemented following the guidelines that required inland areas to provide energy and raw materials to support economic development in coastal areas. Then, the Seventh Five Year Plan 1986-1990 for the first time divided the inland areas into central and western regions (Yang, 1990).

More specifically, the blueprint of China's regional development was generally based on the statement to speed up the development of the coastal region, to put the emphasis on energy and raw materials construction in the central region, and to actively make preparations for the further development of the western region in the plan. The cities close to waterways with access to international waters, which were designated as Special Economic Zones and Open Coastal Cities, became more specialized (see Figure 2.7). Gradually, China has become a global economic powerhouse and the world's factory. One of the externalities of the comparative advantage strategy is exporting globally and polluting locally.

<u>China's economic development boom and globalization.</u> How may we understand China's economic development and its environmental impacts in relation to globalization? First, I take China as a developing country that is actively integrated into processes of economic globalization dominated by developed countries. China, once a

marginal player in global trade, emerged as the world's largest trading nation in 2013 in the era of globalization. Conventional theories of modernization optimistically implied that development for all nations worldwide is a linear, evolutionary process, and developing countries would become modern if they followed the pathways that most developed countries passed through in the past (Bernstein, 1977; Harrison, 1988; Lerner, 1958; Rostow, 1960). For instance, as a representative of classic modernization theory, Lewis contended that the international flow of capital facilitated economic development by creating industries, transferring technology, increasing productivity, and raising living standards (Kentor, 1998; Lewis, 1948). However, dependency theory, as a critique of modernization theory, focusing on the uneven development in the world economy, argued that the pathways to national development cannot be well explained without taking into account this country's position in the international division of labor (e.g., in the context of international trade and geopolitical power relations) (Amin, 1976; Bornschier & Chase-Dunn, 1985). A large number of cross-national comparative studies showed that national economic growth is positively associated with trade openness, human capital, education, lower fertility rates, lower share of government consumption, institutions (e.g., law, and regulations), and political stability (Barro & Lee, 2001; Bosworth & Collins, 2003). Moore (2002) argued that China's remarkable economic record is "not fathomable without consideration of its relation to the world market" (Moore, 2002, p. 2). Economic openness (especially attracting foreign direct investment and trade) has been conducive to the increasing economic prosperity in China during the past 3 decades.

Secondly, globalization is a transformative process involving international integration and interaction. The accelerating pace, scope, and scale of globalization have exerted profound influence on the flows of goods and services, capital and people, ideas and information, as well as on the natural environment (Christmann & Taylor, 2001; Smith, 2006). The literature on the environmental impact of globalization is confounding theoretically and empirically, and the findings are highly contentious (Christmann & Taylor, 2002). Specifically, globalization itself is "a complex process that has both positive and negative environmental potentials" (Paehlke, 2001, p. 1). Globalization proponents argue that lower barriers to international trade and foreign investment encourage firms to transfer advanced environmental technologies from developed countries with strict environmental standards to developing countries.

Moreover, the global process can also increase self-regulation pressures on firms. In contrast, globalization opponents contend that increasing international trade and FDI encourage governments to lower production costs within their jurisdiction by neglecting to enact the laws to protect the environment (Christmann & Taylor, 2001). In China, alongside an abundant labor force and low labor costs, attracting foreign capital by offering various concessions in taxes, land use fees, and environmental regulations has become one of the important strategies for the central and local governments. By studying changing patterns of environmental degradation, we can better understand whether globalization is detrimental or beneficial to the environment and, more specifically, how global processes have impacts on the environment, positively or negatively, across and within the country.

Conceptual Framework for the Case of China

To summarize, Table 2.2 outlines the development trajectories China adopted during the two developmental phases. During the prereform era (1949-1977), China was a closed, planned economy in which the central state played the dominant role. This Soviet-style development strategy centered on heavy industry was adopted across the nation, where industrialization was maximized and urbanization was severely minimized. During the reform era (1978-present), China began to open up and reform the command system. The state began allowing market forces to play an important role in the economy and also relaxed the policies in regulating rural-urban migration. An export-oriented development strategy emphasizing comparative advantage was gradually implemented. Overall, by introducing reform towards a market economy, China is experiencing remarkable economic growth and dramatic social changes through industrialization, urbanization, and globalization. In terms of the relationship between development and the environment, I argue that there are two different types during the two phases. Development without consideration for the environment was the main feature under the Mao era when environmental degradation was largely ignored by policymakers. During the reform era, development versus the environment is the key theme since a mix of laws, regulations, and industrial policies have been formulated since the 1980s to steer the country towards a sustainable development.

Following the above review, my research question is how shall we best understand, theoretically and empirically, the relationship between development and the environment during the reform era? In Table 2.2, the triple process of industrialization, urbanization, and globalization represents the driving forces of development. Most existing literature in environmental and urban sociology has examined the environmental impacts of development from the perspective of globalization or urbanization separately, neglecting the multifaceted nature of a country's economic development (Chase-Dunn & Jorgenson, 2003).

For the case of China, given its unique context, scholars have found that the country's experience is difficult to understand in terms of Western perspectives dominant in the literature (Wei & Ye, 2014). For example, when studying the economic transition towards a market economy, Wei (2001) observed that the relationship between central and local states, between plan and market, and between domestic and international forces, has been substantially reconstructed in the economic reform (Wei, 2001, p.7). Therefore, based on Nee's market transition theory (1989) and Oi's decentralization theory (1990), Wei (2001) proposed that the transition in China could be conceptualized as a gradual transformation driven by the triple process of decentralization, marketization, and globalization. Inspired by Wei's triple framework, I suggest that the development in China can be understood as a gradual triple process of industrialization, urbanization, and globalization as articulated in Chapter 1 (see Figure 2.8).

Methodologically, conventional analyses of cross-national comparative sociology always take China, as a whole, as the unit of analysis. However, China is a nation with a large and diverse geographical area. Disparities across regions have always been the most striking features of China's socioeconomic landscape (see Figure 2.9). Coastal areas were much more developed than interior areas even prior to the founding of the PRC in 1949 (Shabad, 1972). Regional disparities typically result from the physical geographic and topographic diversity of the country. Earlier studies on regional disparities claimed that the larger the geographical size of the national unit, the larger the scope for wide regional variations, whether due to differential natural resource endowments, to the nation with a large and diverse geographical area, to the weaker economic and cultural linkages between regions, or to the greater incidence of localism (Williamson, 1965). As a result, the disparities of development have impacted the environmental degradation at a regional, provincial, and even city level. In light of the geographical complexity of China, a considerable number of studies of regional disparities devoted special attention to a series of regional development policies launched by the state government, finding that since 1979, unbalanced regional policies emphasized regional specialization according to comparative advantages (Fan, 1995; Fleisher & Chen, 1997; Fujita & Hu, 2001; Wei, 2001) (see Figure 2.10).

Spatial and Temporal Pattern of Environmental Degradation

In retrospect, as He et al. (2002) observed, black smoke stacks became the main feature of Chinese industrial cities during the 1970s. Acid deposition was recognized as a potential environmental problem in 1980s, and many southwestern cities such as Chongqing and Guiyang and central cities such as Nanchang suffered serious acid rain pollution (Larssen et al., 2006). In the 1990s, acid rain pollution extended from hinterland areas (western and central regions) to coastal areas (southeast coastal cities including Xiamen and Shanghai and northeast coastal cities such as Qingdao and Shenyang). Since the late 1980s, air pollution was rapidly emerging as the major environmental issue and the air quality in many cities had deteriorated due to sulfur dioxide (SO_2), nitrous oxides (NOx), carbon monoxide (CO), and photochemical smog, which are typical of industrial and vehicle emissions, respectively. In 2000, according to the Report on the State of the Environment in China, the air pollution levels in more than 40 cities were far exceeding the residential area air quality standard set by the World Health Organization.

This section will provide a snapshot of how spatio-temporal patterns of air and water pollution have changed across provinces over the time period from 2004-2013 (see maps in Figures 2.11-2.13). First and foremost, air and water pollution in China is unevenly distributed across regions. For instance, according to the data from the Ministry of Environmental Protection (2013), 7 of the top 10 most polluted cities in China are located in Hebei province, which surrounds the capital Beijing geographically. Here, I use three measures of environmental degradation: two for air pollution (total SO_2 emissions and total dust emissions), and one for water pollution (total wastewater discharge). These indicators of air and water pollution are generally used to compare nations' degree of environmental degradation, but they are equally suited for making comparisons across regions within a country. The following maps were generated in ArcGIS based on the data of the China City Statistical Yearbook 2004-2013. The colors of the maps represent different levels of pollution. There are three types of colors based on the annual volume of air and water pollution. The darker the color, the higher the level of pollution is. For air pollution, provinces in the central and eastern regions are much more polluted than the provinces in the western region. As for water pollution, the eastern regions are much more polluted than the provinces in the central and western regions.

Air Pollution

SO_2 emission. One of the indicators of air pollution is "Total SO_2 Emission" which is measured by the annual volume of industrial sulfur dioxide emission (10 thousand tons per year) in total. Generally, the major source of sulfur dioxide (SO_2) is combustion of sulfur containing fossil fuels (coal and oil). Sulfur dioxide (SO_2) emissions have not only environmental effects such as sulfuric/nitric acid, which corrodes metals, harms textiles, impairs visibility, and stunts plant growth, but also lead to respiratory disease. Specifically, like carbon monoxide (CO) and nitrogen dioxide (NO_2), sulfur dioxide (SO_2) is also a gaseous air pollutant, causing a range of harmful effects on the lungs, including increasing inflammation of the airways, worsening cough and wheezing, reducing lung function, and increasing asthma attacks (Delfino et al., 2003; Gent et al., 2003). The estimates of total SO_2 emission are taken from the China City Statistical Yearbook. In the dataset, sulfur dioxide (SO_2) emission is the only indicator available. Its levels vary across provinces, ranging from 104 (10 thousand tons per year) in Hainan province in 2011 to 1,703,378 (10 thousand tons per year) in Shandong province in 2006.

Figure 2.11 shows how the spatial pattern of SO_2 emission changed during the period 2004-2013. The most polluted provinces measured by SO_2 emission in 2004 were located in the eastern (Hebei, Shandong, and Jiangsu), central region (Shanxi, and Henan), and western region (Sichuan). The least polluted provinces were located in the eastern region (Beijing, Tianjin, Shanghai, Fujian, and Hainan), central Region (Jilin and Heilongjiang), and western region (Ningxia, Qinghai, Tibet and Xinjiang). In 2005, there were two more highly polluted provinces; one was Guangdong in the eastern region and the other was Sichuan in the western region. Meanwhile, the province Liaoning became less polluted than in the previous year. Although there were few changes in 2006, the SO_2 emission in Shandong province reached 1,703,378 (10 thousand tons), which is the highest in the nation during the previous 10 years 2004-2013. In 2007, there were three more low-polluted provinces, including Anhui in the central region and Guizhou and Yunnan in the western region. Guangxi in the eastern region became one of the most polluted areas in 2008, 2009, and 2011, while Shaanxi in the western region for the first time became one of the worst polluted areas in 2011.The SO_2 emission in Sichuan decreased in 2012 and 2013, and became one of the moderate polluted areas in 2004 and 2007. In short, in terms of SO_2 emission, seven provinces (Liaoning, Hebei, Shandong, and Jiangsu in eastern regions and Inner Mongolia, Shanxi, and Henan in the central region) remained as the worst polluted areas throughout the period 2004-2013.

Dust emission. The other indicator of air pollution in my study is “Total Dust Emission,” which is measured by the annual volume of industrial dust emission (10 thousand tons per year) in total. Industrial dust emission primarily consists of particulate matter (PM) that refers to a mixture of solid and liquid particles suspended in the air. Dust is one of solid particles. The existing literature shows that PM_{10} and $PM_{2.5}$ (particulate matter less than 10 and 2.5 micrometers in aerodynamic diameter) are consistently linked with reduced visibility, chronic respiratory impairments, exacerbation of asthma symptoms, and lower life expectancy (Kunzli et al., 2005; Wen & Gu, 2012). In terms of the level of $PM_{2.5}$, Yale’s Environmental Performance Index has ranked China as one of the worst performers internationally since 2006. Given that the annual data for PM_{10} and $PM_{2.5}$ are unavailable at the city level during the past 10 years, here total dust emission is used instead. The data of total dust emission are also taken from the

China City Statistical Yearbook. In the dataset, the total dust emission is unevenly distributed across provinces ranging from 176 (10 thousand tons) in Hainan province in 2010 to 5,951,819 (10 thousand tons) in Shanxi province in 2013.

Figure 2.12 shows how the spatial patterns of dust emission have changed during the period 2004-2013. The worst polluted provinces measured by dust emission in 2004 were spread across three regions: Hebei in the eastern region, Shanxi and Henan in the central region, and Sichuan in the western region. The least polluted provinces were mostly located in the eastern region and the western region (Beijing, Tianjin, Shanghai, Zhejiang, Fujian, Guangdong, and Hainan in the eastern region and Ningxia, Gansu, Qinghai, Xinjiang, Chongqing, Guizhou and Yunnan in the western region). In 2005, Hebei became less polluted and the least polluted areas expanded to central regions such as Anhui and Hubei. In 2006, the most polluted areas expanded to include Shandong and Liaoning in the eastern region, Inner Mongolia in the central region, and Guangxi in the western region. Again, the most polluted areas measured by dust emission in 2007 expanded to include Jiangsu in the eastern region, and then Heilongjiang and Hunan in the central region. Unexpectedly, the most polluted areas in 2009 had shrunk to Liaoning and Hebei in the eastern region and Shanxi and Henan in the central region. Meanwhile, Shaanxi became one of the least polluted provinces for the first time since 2004. In 2010, Hebei became less polluted, whereas Zhejiang became more polluted than the previous year. As the spatial pattern of SO_2 emission in 2004 and 2013, the worst polluted areas with the highest dust emission in 2011 had spread out to the seven provinces (Liaoning, Hebei, Shandong, and Jiangsu in the eastern region, and Inner Mongolia, Shanxi, and Henan in the central region). The map for 2012 indicates that most of the country's provinces fell into the least polluted category. It is worthwhile to note that the dust emission in Inner Mongolia reached 3,834,671 (10 thousand tons), and in Hebei, Shanxi, and Sichuan was higher at 610,300 (10 thousand tons), both of which were the highest point on record. The most polluted province in 2013 was Shanxi, where the dust emission reached 5,951,819 (10 thousand tons) that is 12 times more than the highest point in 2011. In a word, the province Shanxi, as the leading producer of coal in China, remained the most polluted area as measured by dust emission throughout the years 2004-2013.

Water Pollution

The measurement of water pollution in the study is "Total Wastewater Discharge," which is measured by the annual volume of industrial wastewater discharge (10 thousand tons per year). According to EPA, wastewater, by definition, is water containing wastes from agricultural, industrial, residential, and commercial processes and requires treatment to remove pollutants prior to discharge. Therefore, wastewater is an important source of water pollution. In the dataset, Total Wastewater Discharge primarily consists of industrial wastewater. Purportedly, at least one third of the industrial wastewater in China is directly released into rivers and lakes without treatment. The data for wastewater discharge come from the China City Statistical Yearbook. According to Yale's Environmental Performance Index 2014, China is one of the worst performers internationally (109 out of 178 countries) in access to clean drinking water and sanitation. However, again, there is considerable variation within China. In this dataset, the total wastewater discharge is unevenly distributed across provinces ranging from 333 (10 thousand tons) in Tibet to 236,095 (10 thousand tons) in Shanxi province in 2013.

Figure 2.13 illustrates how the spatial pattern of water pollution had changed during the period 2004-2013. The worst polluted provinces measured by Wastewater Discharge in 2004 were located in Jiangsu and Zhejiang in the eastern region. The moderate polluted areas were mostly located in the eastern and central region. Most of the western region was in the least polluted category except Sichuan and Chongqing. In 2005, the high-polluted areas had spread across most of the eastern region (except Beijing, Tianjin, Shanghai, Liaoning, and Hainan), Henan and Hunan in the central region, and Sichuan in the western region. Remarkably, the high-polluted areas in 2006 had dramatically shrunk to only one province, Jiangsu, in the eastern region. More surprisingly, there were no differences in the following year 2007. Then, the most polluted areas in 2008 had expanded to the coastal region, including Shandong, Zhejiang, Guangdong, and Guangxi, and the pattern remained similar in 2009. The province of Guangxi became less polluted, whereas Henan became more polluted in 2010. The least polluted areas mostly covered the western region except the province Sichuan and Henan became one of the moderately polluted areas in 2011. For the first time, the province Fujian became one of the worst polluted areas in 2012 and then became less polluted in 2013. In summary, the province Jiangsu in the eastern region remained the most polluted province during the period 2004-2013.

Conclusion

Placing development trajectory and environmental degradation in a historical context can enrich our understanding of complex socioeconomic dynamics, facilitating the identification of environmental implications of different development phases. This chapter provides a general picture of how the development trajectory and the pattern of air and water pollution changed across regions and over time in China, more descriptively than analytically. In this chapter, I first mainly focus on the context of China and review the institutional changes in the transition to a market economy. Then, the spatial and temporal patterns of environmental degradation (including air and water pollution) are described in detail.

Overall, the development trajectory in China since the founding of PRC could be divided into two phases: the planned economy (1952-1977) and the mixed economy combining a planned and market economy (1978-present). Faced with scarce capital in an agrarian economy, China adopted the Soviet-style development strategy (primarily centered on heavy industry) beginning in the 1950s. In spite of almost 40 prefecture-level new industrial cities established during the era, urbanization largely lagged behind industrialization due to a range of aggressive policies and practices aimed at limiting urban growth, such as the *hukou* system, which prevented urbanward migration. Above, I show that China was underurbanized compared to overurbanization patterns found in other developing countries during the period (Chan & Xu, 1985; Chan & Zhang, 1999). It is worth noting that the traditional Chinese ideal of *Tianrenheyi* (unity of heaven and humanity) was replaced by the ideal *Rendingshengtian* (man must conquer nature). The harmony between human activities and the environment the Chinese carefully cultivated for thousands years, ideologically and practically, had been fundamentally reshaped. Environmental exploitation greatly accelerated in carrying out ambitious industrial development projects. However, these costs to the environment remained largely ignored by the policymakers and researchers during the period 1952-1977. With the adoption of reform and opening up policies in 1978, China adopted an export-oriented comparative advantage strategy. A series of important policies and practices were implemented to transform towards a market economy. In the rural areas, the land was decollectivized by the form of the Household Responsibility System. In the urban areas, stated-owned enterprises (SOEs) were reformed through corporatization. Although its essential feature has basically remained, the reform of the *hukou* system permitted more rural-urban migration and accelerated the scale of urbanization in China from 1980s to date. Finally, China successfully pursued foreign direct investment (FDI) and foreign-owned enterprises (FOEs), fueling rapid export-oriented industrialization linked to the world market through international trade.

Theoretically, given the special institutional context, I propose a triple conceptual framework to understand the relationship between development and the environment in China. Methodologically, I argue that it is particularly significant to study the dynamic relationships between development and the environment within China across regions and over time, using longitudinal data. Following the proposed methodological structure, I illustrate the spatial and temporal pattern of air and water pollution, respectively. In short, both air and water pollution in China is unevenly distributed across provinces over the period 2004-2013. Specifically, in terms of SO_2 emission, seven provinces (Liaoning, Hebei, Shandong, and Jiangsu in the eastern region and Inner Mongolia, Shanxi, and Henan in the central region) remained the worst polluted area. As for dust emission, the province Shanxi, as the leading producer of coal in China, has remained as the most polluted area. Unlike the spatial pattern of air pollution, the province Jiangsu and surrounding areas in the eastern region has remained the most polluted area in terms of water quality.

In the subsequent chapters, I will take a more explanatory focus on the dynamics of development and environmental degradation across cities in China. Specifically, I will examine the relationship of development to air pollution (Chapter 3) and development to water pollution (Chapter 4), focusing on how the economic development level, urbanization, industrialization, and globalization impact air and water quality.

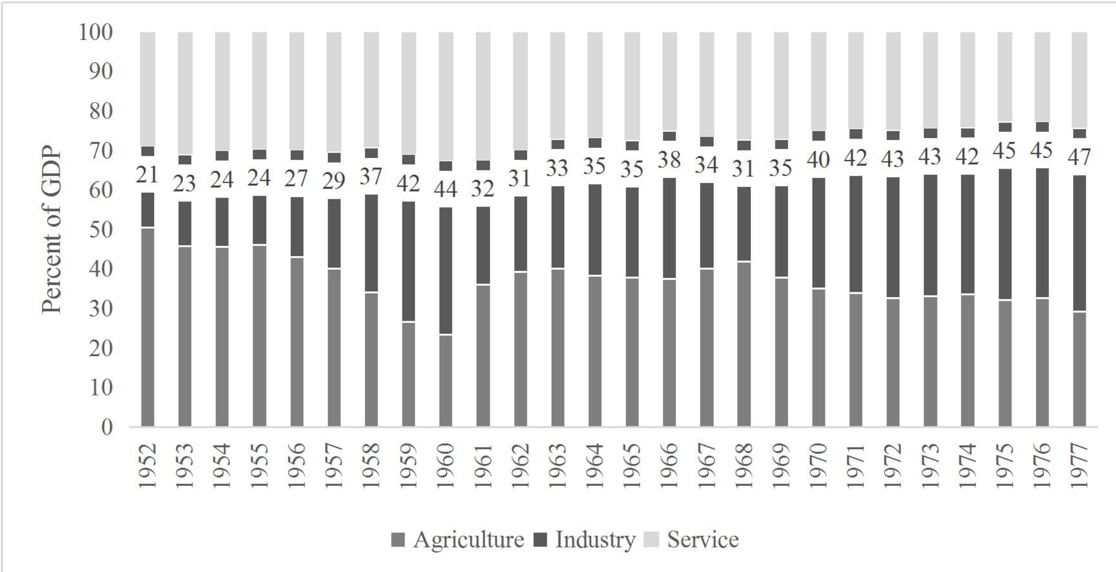


Figure 2.1

The Industrial Structure of GDP in China, 1952-1977

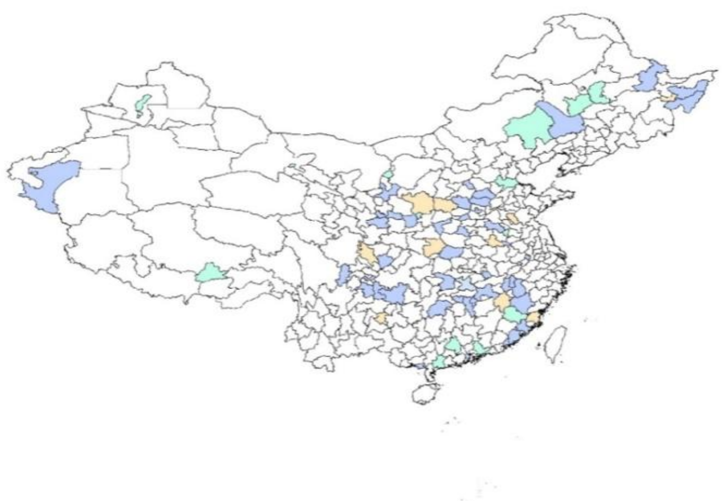
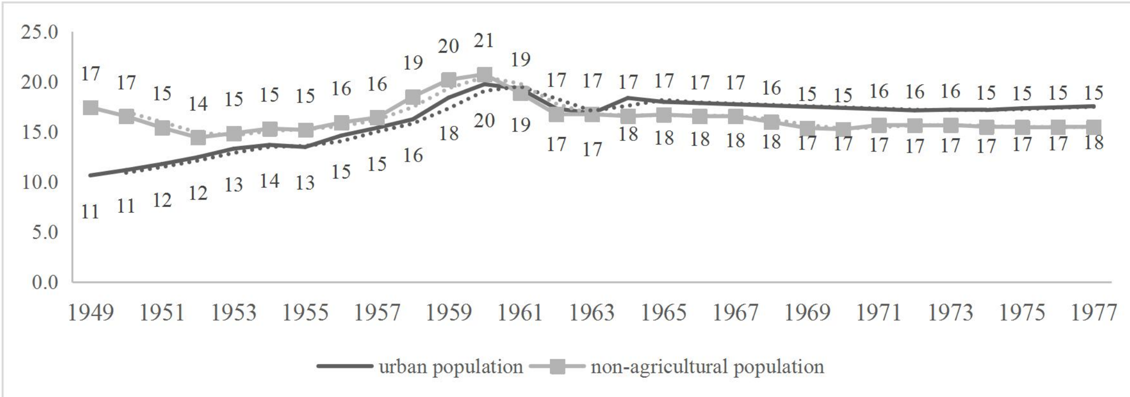


Figure 2.2

Industrial Cities Established Under the Mao Era in China, 1949-1977



Source: Data from China Statistic Yearbook 1949-1977

Figure 2.3

The Percentage of Urban and Nonagricultural Population, 1949-1977

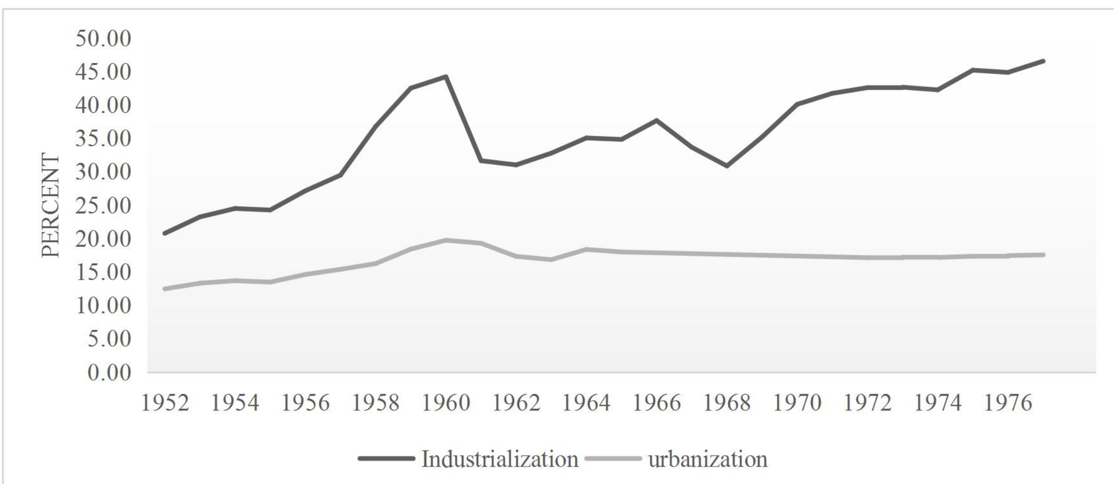


Figure 2.4

Industrialization and Urbanization in China, 1952-1977

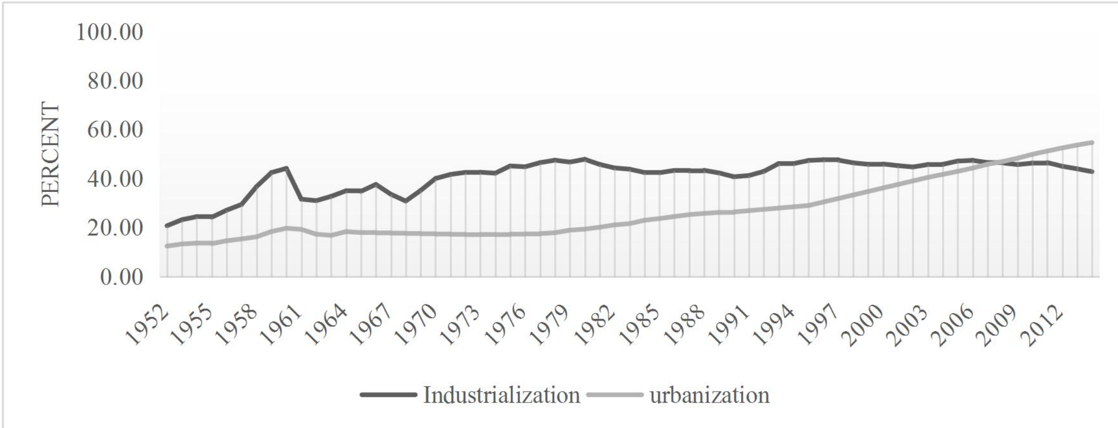


Figure 2.5

Industrialization and Urbanization in China, 1952-2014

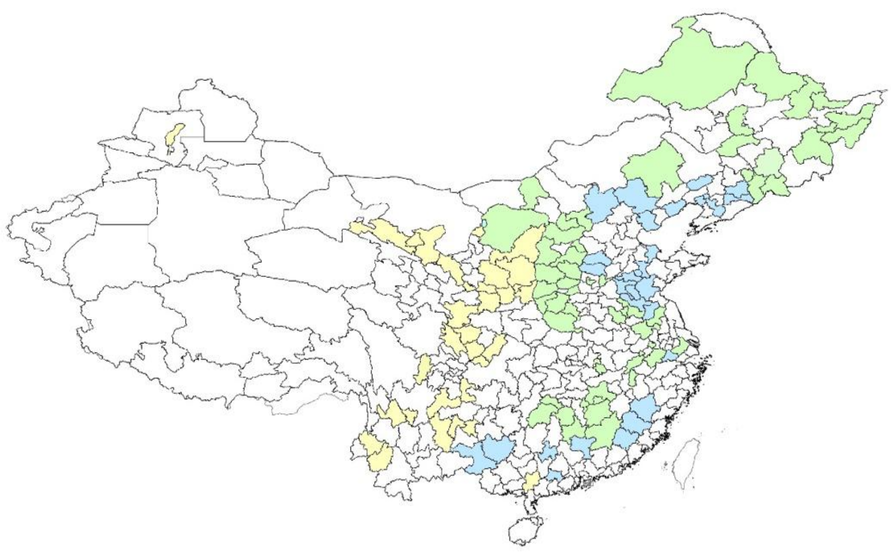


Figure 2.6

Resource-based Industrial Cities in China, 1950-2013

Table 2.1

Major Coal Producers by Country (Thousand Short Tons)

	2004	2006	2007	2008	2009	2010	2011	2012
China	2308713	2757986	2954542	3099061	3301803	3560635	3878012	4017920
USA	1112099	1162750	1146635	1171809	1074923	1084368	1095628	1016458
India	446683	500119	531521	570010	614918	619843	633774	649644
Indonesia	158418	257187	274290	274218	321045	358251	397202	488112
Australia	382608	412984	431047	432383	449631	467823	443390	463783
Russia	285437	313680	318591	336163	304228	354615	354869	390152
South Africa	267666	269817	273005	278017	275015	280562	278617	285832
Germany	232673	220554	225526	214268	202410	200955	207853	217144
Poland	178260	171135	159773	157993	148356	146257	152680	158197
World Total	6216306	6965038	7235883	7470959	7601609	7999455	8443803	8687297

Source: U.S. Energy Information Administration (EIA), 2015

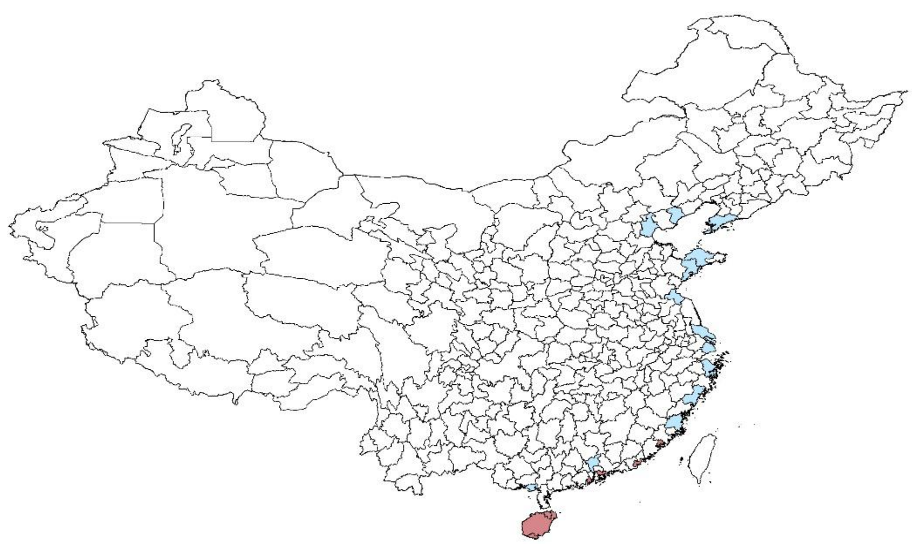


Figure 2.7

Special Economic Zones and Open Coastal Cities, 1980-

Table 2.2

Development Trajectories in China, 1949-Present

Time Period	1949-1977	1978-present
Economy System	Planned Economy	Transition to Market Economy
Major Role	Central State	State and Market
Development Strategy	Soviet-Style	Export-Oriented
Development Mode	Industrialization	Industrialization, Urbanization and Globalization
The relationship between development and environment	Development without environment	Development versus environment

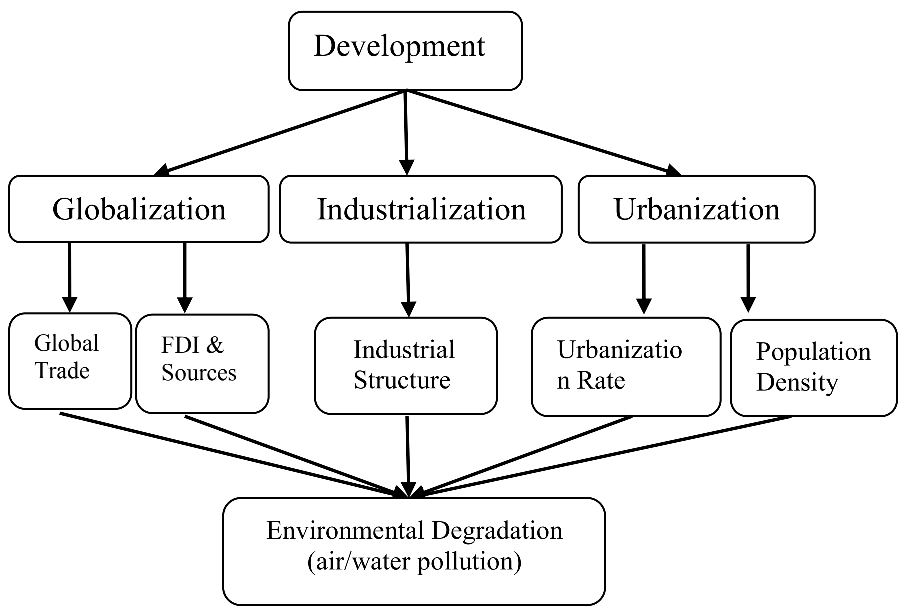
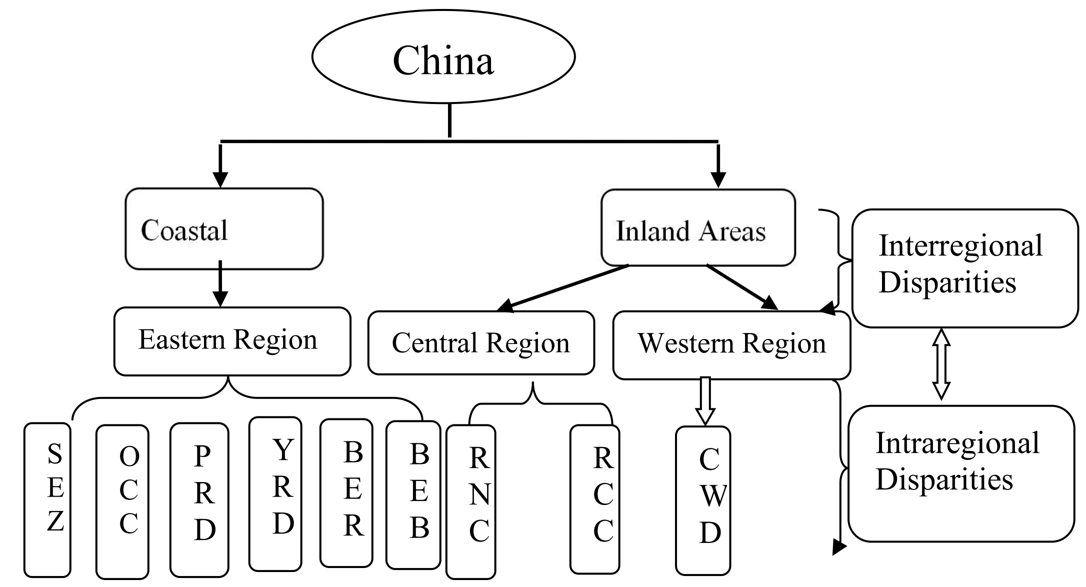


Figure 2.8

The Structure of Development and the Environment in China

Figure 2.9

The Map of China by Region



Notes: Regional development policies were outlined in each 5-year plan, respectively: the Sixth Five Year Plan (1981-1985); the Seventh Five Year Plan (1986-1990); the Eighth Five Year Plan (1991-1995); the Ninth Five Year Plan (1996-2000); the Tenth Five Year Plan (2001-2005); the Eleventh Five Year Plan (2006-2010); the Twelfth Five Year Plan (2011-2015).

Figure 2.10

Regional Development Policies in Mainland China, 1979-2015

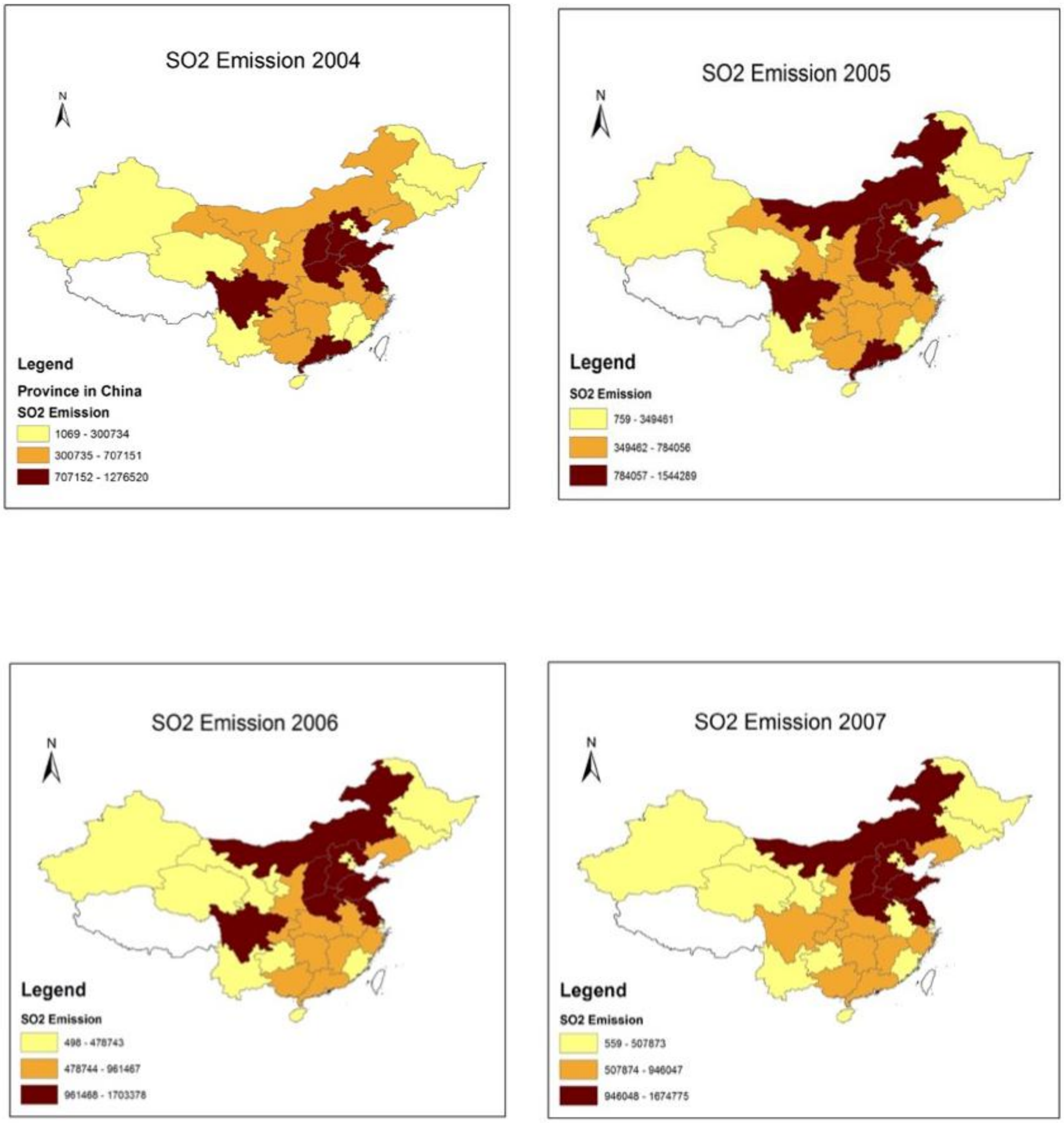


Figure 2.11

The Spatio-Temporal Pattern of SO_2 Emission, 2004-2013

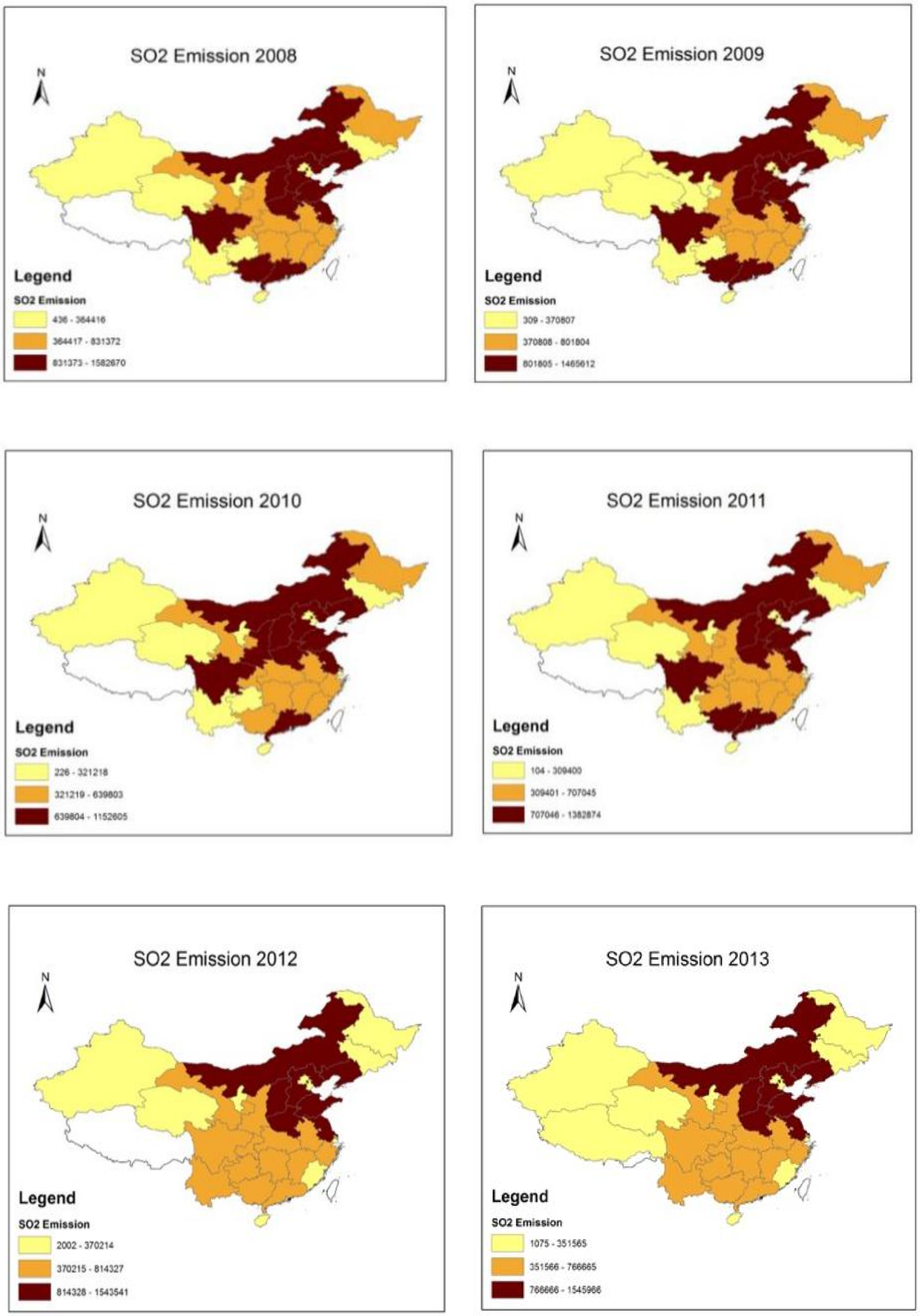


Figure 2.11 Continued

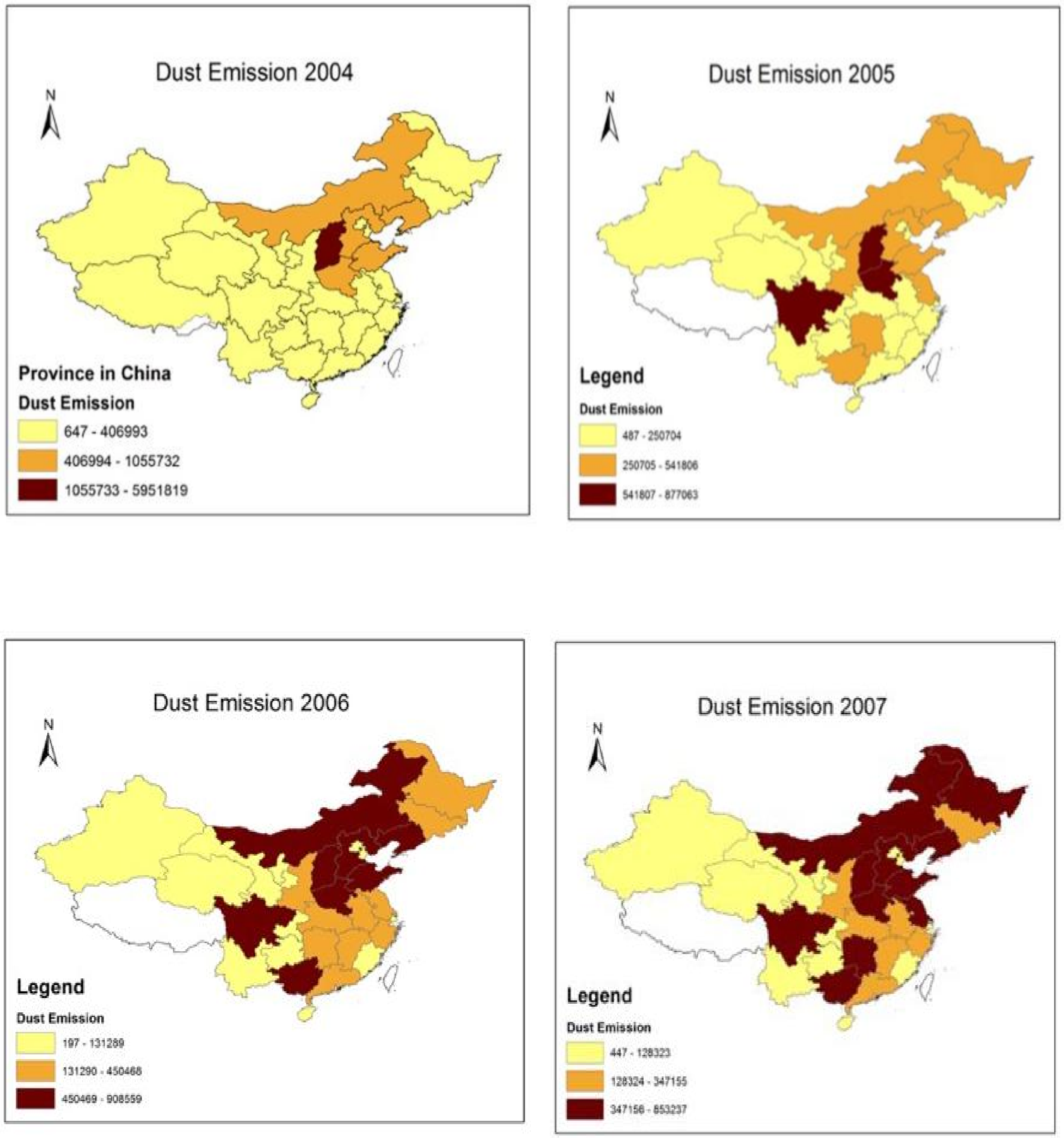


Figure 2.12

The Spatio-Temporal Pattern of Dust Emission, 2004-2013

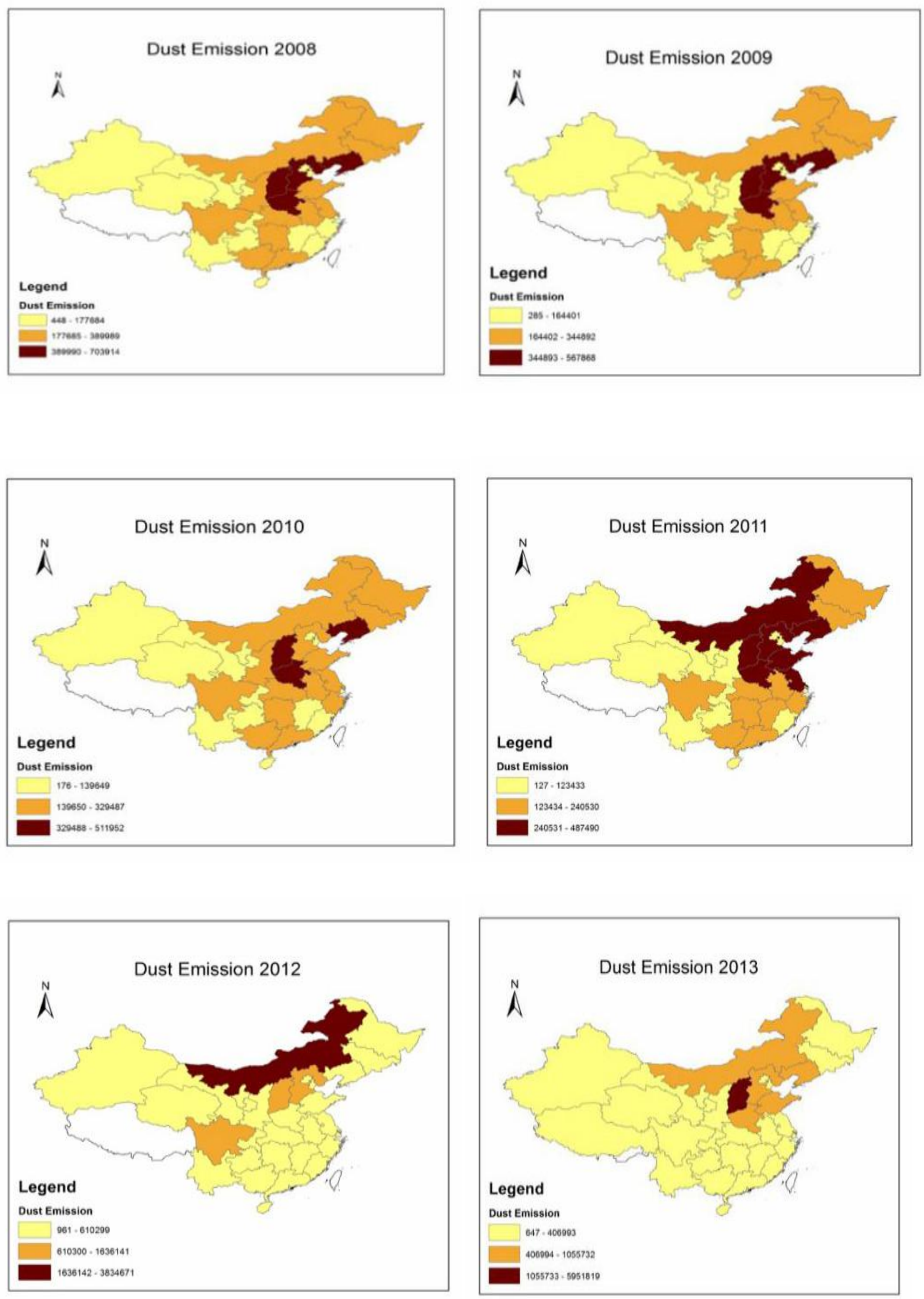


Figure 2.12 Continued

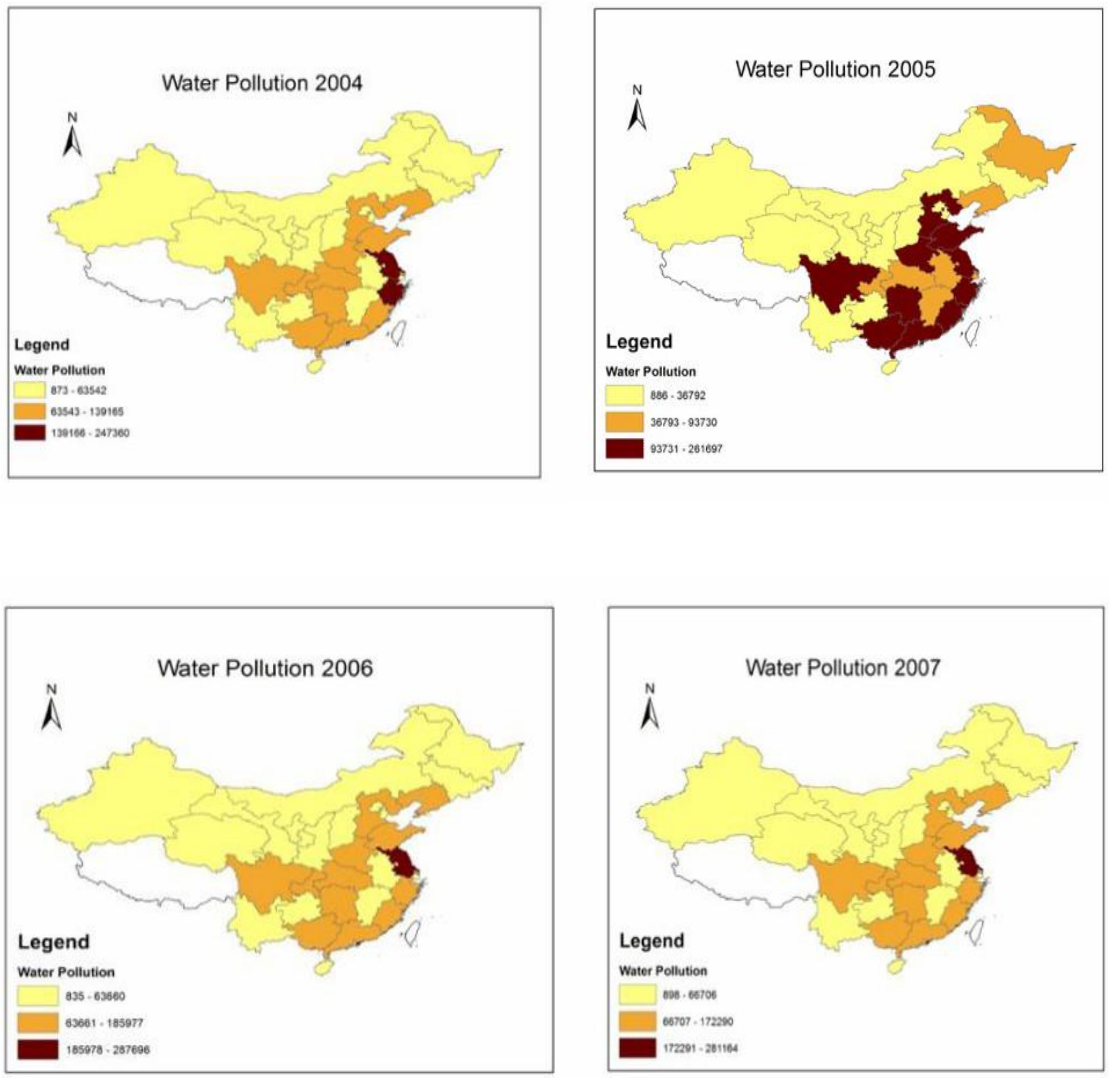


Figure 2.13

The Spatio-Temporal Pattern of Water Pollution, 2004-2013

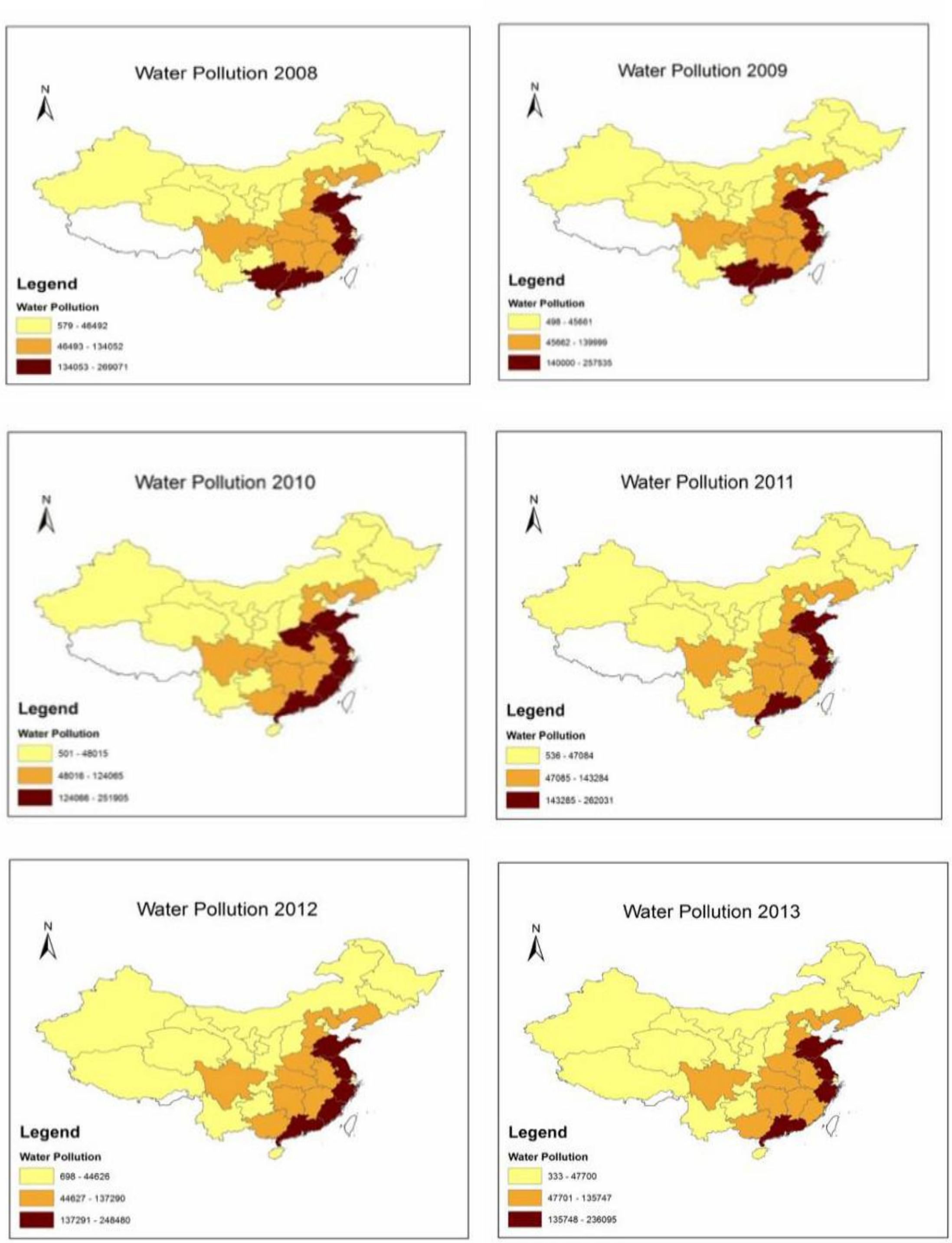


Figure 2.13 Continued

CHAPTER 3

THE DYNAMICS OF DEVELOPMENT AND AIR POLLUTION

After more than 30 years of remarkable economic growth since the policy of reform and opening up was adopted in 1978, China became the world's second largest economy by nominal GDP (Gross Domestic Product) in 2010 according to the IMF (International Monetary Fund) and the largest economy by PPP (Purchasing Power Parity) in 2014. Rapid economic growth has been accompanied by ballooning energy consumption. In 2007, China became the world's largest emitter of greenhouse gases, surpassing the United States. In 2012, China's carbon emissions were almost equivalent to the carbon emissions from both the United States and the European Union combined (Liu et al., 2015). In short, China made tremendous efforts to promote economic growth, industrialization, urbanization, and globalization, while suffering from a wide variety of environmental problems. It is widely recognized that China's environmental problems are among the most severe of any major country, and are mostly getting worse (Bao et al., 2012; Chen et al., 2011; Liu & Diamond, 2005). These pressing environmental challenges are not only causing serious economic losses and social conflicts within China, but also spilling over into other surrounding countries (Li et al., 2012; Zhu et al., 2014).

Air pollution is one of the most remarkable features of environmental degradation in China. In the early 2000s, Particular Matter ($PM_{2.5}$) concentrations in Beijing and

Shanghai were about 10 times and 6 times the standard set by the World Health Organization (WHO), respectively (Ye et al., 2003). In 2005, particulate concentrations in most Chinese cities were far above the standard of the WHO. According to the World Bank (2007), 16 out of the world's 20 most polluted cities were in China, which is commonly considered to have the worst urban air pollution on earth (World Bank, 2007). The report from Yale's Environmental Performance Index (2014) indicated that China, overall, is one of the worst performers internationally (176 out of 178 countries) with respect to its levels of $PM_{2.5}$. Based on the most recent report from the United Nations Environment Program (UNEP), although the level of sulfur dioxide (SO_2) had declined in Beijing during the period 1998-2013, such decreasing emission is at the expense of moving the emission elsewhere by relocating heavily polluting industries away from the capital (UNEP, 2016). The costs of environmental pollution are high. Polluted air can damage the health of humans who are exposed to it, in some cases even leading to premature death. According to the estimates by the World Health Organization (2009), at least a quarter of the burden of disease in the world and approximately 21% of disease in China can be attributed to air pollution (indoor and outdoor). Many epidemiological studies have confirmed that air pollution has adverse health effects, including excess risk of mortality, high rates of morbidity, and reduced lung function, etc. (Chen et al., 2013; Kunzli et al., 2005; Pope et al., 2009; Wen & Gu, 2012).

This chapter examines the effects of development, conceptualized as a triple process of industrialization, urbanization, and globalization, on air pollution in China. Theoretically, I develop a systematic framework to understand air pollution in China. Methodologically, using longitudinal data 2004-2013, I first analyze the spatial and temporal pattern of air pollution at the provincial level and then apply multilevel modeling analysis of the prefecture-city level to examine the driving forces of air pollution. The findings of the dynamics of development and air pollution are confounding given the different measurements of air pollution in the cities of China.

Theoretical Framework

Air pollution in China has become of great concern to the general public and policymakers, who expect academic research to offer evidence-based explanations of its causes and possible solutions. Academic researchers across different disciplines have increasingly turned their attention to the problem of air quality since 2000. Research on air pollution in environmental science and engineering focused on scientific inquiry into the sources of pollution emission and technological feasibility of possible solutions, respectively. For instance, Chan and Yao (2008) explored the topography and meteorology of the megacities, and the emission sources of different gaseous pollutants and particulate pollutants. Using a technology-based methodology, Lei et al. (2011) estimate particulate matter (PM) emissions across different industry sectors (such as cement, coke, iron, and steel industry) during the period 1990-2005. Zhang et al. (2007) explored the spatio-temporal variations of Nitrogen Oxides (NOx) emissions and their driving forces using satellite-derived tropospheric NO_2 columns in the Global Ozone Monitoring Experiment (GOME) and Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY). Rohde and Muller (2015) presented the spatial pattern of air pollution concentration and its sources using 4-month data from monitoring stations. Essentially, three important findings from these studies are significant to social scientists. The first study showed there might be an association between urbanization and air pollution. The second study suggested that there is a relationship between industrialization and air pollution. The last two studies indicated that air pollution was unevenly distributed across regions, and is closely linked to population density.

Unlike environmental scientists and engineers who emphasize environmental systems, social scientists are more concerned with socioeconomic systems when studying air pollution. Most existing studies on the relationship between development and air pollution are conducted using theoretical frameworks in environmental sociology, ecological economics, and economic geography (see Table 3.1) (He & Pan, 2013; Huang et al., 2015; Jorgenson & Clark, 2012; Kahn, 2009; Kuby & He, 2011). Studies in environmental sociology examine the relationship between development and CO_2 emission either based on the contending theoretical positions of ecological modernization theory and the treadmill production theory (Jorgenson & Clark, 2012), or ecological unequal exchange theory (Jorgenson, 2012). Studies in ecological economics investigate how economic growth impacts air quality across provinces in China based on the framework of the Environmental Kuznets Curve (EKC), overlooking the institutional and structural context (Shen, 2006; Song et al., 2008). Studies in economic geography analyze the patterns of SO_2 emission on the basis of the triple process of marketization, decentralization, and globalization (He et al., 2012).

Overall, although a large number of existing studies theoretically and empirically focus on development and air pollution, the findings are inconclusive. The existing literature has provided explanations for air pollution with different perspectives and identified economic development level, industrialization, urbanization, and globalization as the underlying driving forces of air pollution separately (He at al., 2008; Jorgenson, 2009; Jorgenson & Clark, 2012). However, there are weaknesses and limitations. First, there is a lack of a systematic theoretical framework embracing the findings from environmental scientists and social scientists in the study of air pollution in China. Integration of the perspectives will provide a much more comprehensive explanation for air pollution in China. As Chapter 2 elaborated, development in China has been understood as the sectoral transformation of the economy from agriculture to manufacturing and service industries, the spatial transformation of labor from rural to urban areas, and the trans-boundary flows of goods and capital from domestic to international markets. To explore the environmental implications, the theoretical framework I propose is tested in the following empirical analysis.

Secondly, as a large and geographically diverse country, air pollution is unevenly distributed across regions within China. We still know little about how the spatial pattern and temporal trend in air pollution changes in China across cities over time since few studies have been conducted to elaborate the associations between development and air pollution using multilevel, longitudinal modeling. Therefore, showing how the levels of air pollution vary with development over time in China is another objective of this study.

Lastly, the effects of development on air pollution are varied depending on the measures of air pollution. Most of the existing regression studies in the context of China choose only one indicator of air pollution, either CO_2 emission, NO_X emission, SO_2 emission, or particular matters such as $PM_{2.5}$, to draw conclusions. Given different types of pollution with different sources, the findings based on only one measure of air pollution may be of limited generalizability. For example, the largest source of NOx emissions is from the transportation sector, while the largest source of SO_2 emission is combustion of sulfur containing fossil fuels (coal and oil).

Literature Review

Economic Development and Air Pollution

The poorest and richest countries in the world tend to have cleaner air, while middle-income countries are the most polluted. It is hypothesized, therefore, that some forms of pollution appear to worsen first and then to improve later as national incomes grow. The inverted U-shape between GDP per capita and ambient air quality was first captured by the World Bank (1992). Given its resemblance to the pattern of inequality and income described by Simon Kuznets (1955), Grossman and Krueger (1995) proposed the Environmental Kuznets Curve (EKC) in their pioneering study. Specifically, the EKC posits that economic growth initially has an adverse effect on the environment, which then subsequently improves as national income increases over a turning point (the peak of inverted U-shape). According to the empirical study of Grossman and Krueger (1995), environmental conditions would dramatically improve with national per capita GDP reaching $5000-8000 (1985 PPP). Since then, research has generally supported the inverted U-shape relationship across regions such as European countries (Ansuategi, 2003; Maddison, 2006). However, further studies have found there is an N-shaped relationship, rather than an inverted U-shape, between national income and air pollution, including SO_2 emission (Torras & Boyce, 1998) and CO_2 emission (Friedl & Getzner, 2003).

In spite of most empirical studies providing evidence in support of the inverted U-shape/N-shape relationship across developed countries, there is scant evidence providing support across and within the developing countries due to the scarcity of representative data. In the context of China, data from the World Bank show that in 2012, the average national GDP per capita was $ 6188, which falls exactly in the range of the turning points identified in the existing literature. As a diverse geographical area, given regional disparities having historically been its significant feature, environmental conditions over time along with economic development vary significantly across regions.

According to the National Statistical Yearbook 2012, the GDP per capita in coastal regions (e.g., Beijing, Shanghai, Zhejiang, Jiangsu, Guangdong, etc.) was higher than $12,000, reaching the level of their counterparts in some middle-income developed countries, while that in some provinces of western regions such as Guizhou is still far below $3000, similar to many low-income countries in Africa (NSB, 2012). In the same year, in some parts of the country air was severely polluted, while in other parts it was moderately polluted. However, the relationship between economic development and air pollution is not well understood or empirically examined at the city level using the most recent longitudinal dataset. Within the existing literature, EMT (Ecological Modernization Theory) and the EKC (Environmental Kuznets Curve) provide frameworks to explore the complexity between economic development and air pollution in China. Therefore, the first hypothesis this study will test is that the environmental impact of economic development is more likely to be more severe at the initial stage of economic development, and then decrease in the long run. Here, my hypothesis is the following:

Hypothesis 1: Air pollution will increase rapidly in the early period of rapid economic growth, and then air pollution will decrease in later periods.

EMT highlights that the most serious and challenging environmental problems have been caused by modernization and industrialization, and could ultimately be solved through super modernization and industrialization. More specifically, EMT first lays out how social institutions, especially the state, respond to environmental deterioration and then provide solutions to address environmental challenges through various technological advances and innovation, along with the increasing levels of economic development. Moreover, it is widely believed that extreme environmental pollution will greatly improve environmental consciousness of the general public who aspire for higher environment quality, which in turn will lead to more measures taken to reduce environmental degradation.

Stern (2004) argued that national economic development can impact environmental quality through scale, composition, and technical effects. In the earlier stage of development, pollution increases when the scale of the economy grows. In the later stages, pollution will decrease when the composition of the economy shifts from resource-based heavy industries towards service industry and advanced pollution control technologies are adopted. In sum, as the national economy evolves, air quality may decrease in the early stages (through scale effect), and then improve in later stages (through composite and technique effects) (Stern, 2004). According to Jorgenson and Clark (2012), the decoupling between economic development level and air pollution is more likely to occur in more developed regions. Thus, air quality would greatly improve first in the regions where a higher level of economic development has been achieved. In

China, the eastern region is the most developed region, and the western region is the least developed region. This suggests the following hypothesis:

Hypothesis 2: The relationship between economic development level and air pollution varies across regions. Air pollution level in the more developed regions is more likely to lower than other less developed regions.

Industrialization and Air Pollution

According to the treadmill of production theory, industrialization is a key component of socioeconomic development. Learning how to balance industrial development and air pollution is urgent for both developed and developing countries. Most existing studies are conducted in developed countries. For instance, using national longitudinal data, Haberl and Krausmann (2001) show that there are was substantial increases in environmental efficiency during the industrialization of Austria from 1830 to 1995. For developing countries, Singh et al. (2012) provide empirical support for a detrimental effect of industrial development on air pollution in India. Federman and Levine (2010) investigate the effect of industrialization on infant mortality across almost 200 Indonesian districts during 1985-1995, a time of rapid heavy industrialization. They found no evidence of a positive relationship between industrialization and infant mortality. However, when the growth in manufacturing is concentrated in more polluting manufacturing industries, there are statistically significant increases in infant mortality.

The relationship between industrialization and air pollution in China has drawn considerable attention from scholars. Pandey et al. (2005) found that suspended particulate levels are higher in northern cities, largely due to industrial activities. Cole et al. (2007) identified most determinants of pollution emissions in China from manufacturing industries. The World Bank (2007) concluded that air pollution in China is closely associated with industrialization. According to NBS (2016), the average annual growth rate of industrial production in China is 13% during 1990-2016. There is evidence showing that the leading players in China's industrialization, state-owned enterprises (SOEs), are more polluting than heavy manufacturing companies in the US and Europe (World Bank, 1997). However, most prior studies have been focused on how industrialization has affected air pollution using cross-sectional data, and very few studies have been conducted to systematically examine how industrialization differentially affects air pollution across regions and over time. Therefore, the proposed hypothesis is as follows:

Hypothesis 3: Industrialization is positively associated with air pollution. That is, the higher the level of industrialization, the higher the level of air pollution will be.

Urbanization and Air Pollution

In essence, urbanization (especially the mass migration of people who are displaced from the land and seeking employment in urban areas) has always coincided with the rise of industrialization (Jorgenson, Rice, & Clark, 2010). Rapid urbanization has greatly impacted the environment (e.g., air pollution, water pollution, and land use expansion). In particular, urban air pollution poses a significant threat to human health throughout both the developed and developing parts of the world. Urban population is frequently exposed to high air pollution concentration in cities, where motor vehicle emissions constitute the main source of fine and ultra-fine particles (Palmgren, 2003).

According to the World Bank, urbanization is characteristic of nearly all developing countries where many of the world's most populous cities are found. The intersection between the high concentration of population (especially poor residents) and air pollution in the large populous cities in developing countries is important to study further. For example, Gupta (2012) pointed out that rapid urbanization has resulted in increasing air pollution emissions due to transportation, energy production, and industrial activity, all concentrated in densely populated areas. In China, urbanization is widely recognized as an important indicator of development since cities are much more economically advanced than rural areas.

The existing studies show that energy consumption, especially coal consumption, is the main source of anthropogenic air pollution emissions in Chinese cities, and urban air pollution in China, especially for northern cities, is mainly from coal smoke with particles (He et al., 2002). Li et al. (2012) categorized urbanization into demographic, economic, social, and spatial urbanization, and conceptualized environment based on environmental pressure, level, and control. Using panel data collected from 2000 to 2008 in the city of Lianyungang, China, they found there is U-shaped relationship between urbanization and environmental degradation. It is well documented that population size affects the environment, and there is widespread scientific agreement that population size is one of the principal driving forces behind many undesirable environmental changes. For example, cross-national evidence shows population size is an important contributor to national-level total carbon dioxide emission (Jorgenson & Clark, 2013). This suggests the following hypothesis:

Hypothesis 4: The rate of urbanization is positively associated with air pollution.

That is, the higher the rate of urbanization, the higher the level of air pollution will be.

Holding population size constant, it is intensively debated whether population density is positively or negatively linked with the environment. According to the report of the Environmental Protection Agency (EPA) in 2010, there is a strong association between population density and road vehicle nitrogen oxides (NOx) emission, based on the data for the 51 metropolitan areas of more than 1 million in population in the United States. Cooper et al. (2012) confirm that air pollution globally varied across urban and rural areas based on satellite-based estimates of $PM_{2.5}$ and NO_2. That is, the spatial structure of air pollution indicates that there is a direct relationship between population density and air pollution. However, it is worth noting that the proponents of "new urbanism" in the field of urban planning argue that higher population density is positively associated with sustainability (Glaeser, 2011). However, overall, the literature to date suggests the following hypothesis:

Hypothesis 5: Population density is positively associated with air pollution. That is, the higher the population density, the higher will be their level of air pollution.

International Trade and Air Pollution

According to the notion of socioeconomic metabolism, human societies as a whole require the continual extraction of raw materials and energy from, and deposition of waste products or pollution into, ecological systems (Rice, 2009). The patterns of cross-national exchange of energy and natural resources are structured by the economy. Specifically, according to Frank et al. (2000), cross-national exchanges between the low-skill/wage sectors in developing countries and high-skill/wage sectors in developed countries at world market prices benefited the latter at the expense of the former. Therefore, to a large extent, international trade between developed countries and developing countries is marked by unequal exchange. Hornborg (2001) noted that the study of unequal exchange of embodied labor could be combined with the study of unequal exchange of embodied land. Put briefly, in Emmanuel's view, international trade reinforces differential cross-national wage rates and contributes to higher labor exploitation in developing countries (Rice, 2009).

Although unequal exchange theory faces critiques due to lack of application-specific policies, it still has important implications for studying environmental degradation nationally and internationally. For example, in a historical analysis of the underdevelopment in the Amazon Basin from 1600 (the time of colonial conquest) to 1980, Bunker (1984) extended the notion of unequal exchange into an "ecological" model, and explored the demographic, ecological, and infrastructural consequences of extractive export economies in Brazil. Moreover, the empirical findings provided supporting evidence for the argument Rice (2009) made that inequalities in environmental degradation not only exist within the world-system hierarchy, which in turn is partially perpetuated through uneven access to and utilization of ecological resources. In short, the environmental impact of globalization through international trade is uneven between nations based on the relative level of development of the various trade partners (Paehlke, 2001; Roberts, 2001).

The theory of ecological unequal exchange has become popular with interdisciplinary studies including in human ecology, ecological economics, and environmental sociology (Hornborg, 2009; Jorgenson, 2006; Jorgenson et al., 2010). The theory generally posits that, in the global economy, developed countries are more advantaged in terms of environmental impacts than developing countries. First, in international trade, export flows from developing countries to developed countries are environmentally at the expense of the former due to externalization of environmental costs. In a cross-national panel analysis of deforestation, Jorgenson (2003) found that developed countries with higher levels of resource consumption "externalize their consumption-based environmental costs" to developing countries, which increases levels of environmental degradation within the latter (Jorgenson, 2003, p. 691).

Second, developed nations are winners of the zero-sum energy game by receiving a transfer of energy resources from developing countries, where limited restrictions are set on pollution (Hornborg, 2009). The uneven deterioration of the environment across nations is shaped and reproduced by the hierarchy of the world economy to a great extent. In Pellow's view (2006), ecological modernization in developed nations is at the expense of the acceleration of extensive environmental degradation as well as the treadmill of production based on cheap labor in developing nations, which are more likely to be the "victims" of transnational environmental injustice. In sum, the theory of unequal ecological exchange has provided a simple yet clear framework to understand how unevenly distributed environmental impacts are produced and maintained through international trade in the global economy.

Previous studies have shown that global processes have vastly increased emissions in specific nations in the global South, allowing the North to slow their rates of increasing emissions even as levels of consumption have held steady or increased (Zhang et al., 2012). For example, Roberts and Park (2007) showed that off-shoring and shifting energy/natural resource-intensive production to developing countries such as China and India has sharply increased carbon dioxide emissions (CO_2) and air pollution in these countries. Therefore, as a new center for global growth and the manufacturing hub of the world, air pollution in China is not simply China's problem (Liu & Beattie, 2016; Shapiro, 2001). Other nations, through globalization, pollution, and resource exploitation, significantly affect China's environmental quality (Liu & Diamond, 2005).

Most existing studies indicate the dramatic increase of China's CO_2 emissions could be largely attributed to the production of exports. For instance, Peters and Hertwich (2008) show that about 24% of China's CO_2 emissions in 2001 were embodied in exports, and Weber et al. (2008) found this proportion rose from 12% in 1987 to about 33% in 2005. This means developed countries benefit environmentally from international trade by transferring consumption-based production to developing countries. Furthermore, Lin et al. (2014) estimated that about 21% of export-related emissions in China were attributed to China-to-US exports. Meanwhile, they also present that the portion of the export-related pollution transported from China across the Pacific Ocean contributed to 12-24% of sulfate concentrations over the western United States. Although prior studies have quantified the substantial CO_2 emissions embodied in international trade taking China as the unit of analysis, little attention has been paid to how the relationship between international trade and other types of air pollution such as SO_2 emission and dust emission changed within China across cities and over time. Taking the position of China in the global economy into account, the proposed hypothesis is as follows:

Hypothesis 6: International trade (export) is positively associated with air pollution. That is, the higher rate of the international trade (exports) of Chinese cities, *the higher will be their level of air pollution.*

Foreign Direct Investment and Air Pollution

To further understand the environmental impact of globalization, the role of foreign direct investment (FDI) deserves more attention. Despite the argument that FDI is an important avenue for the transfer of skills and technology, the effect of FDI on the environment is highly controversial, depending on the dataset used in various studies that have examined its impact (Christmann & Taylor, 2002; Dean et al., 2009; Jorgenson, 2009; Jorgenson & Kuykendall, 2008; Spatareanu, 2007). In terms of the mechanisms underlying the effect of FDI on the environment, the perspectives can be categorized in several ways. First, the effect of FDI on the environment varies across world regions (e.g., developed vs. developing countries). There are generally two main hypotheses. One is the "pollution haven hypothesis" that highlights the gaps between developed and developing countries in natural environmental standards that draw the dirtiest and most polluted industries to developing countries (Cole et al., 2006). Unlike developed countries, central/local governments of developing countries are competing among themselves to attract foreign investors by providing the lowest taxes and the least stringent domestic environmental regulations (Frey, 2003). Foreign investors from developed countries are attracted to relaxed labor laws and weak environmental regulations in developing countries, thus creating pollution havens and propelling a global race to the bottom in terms of environmental standards. To prevent capital flight, the developing countries are also less likely to effectively enforce the relevant domestic environmental regulations that already exist (Frey, 1998). Meanwhile, developing countries are less likely to ratify international environmental treaties due to disadvantageous position in the global economy, environmental vulnerability, and domestic institutional structures (e.g., less voice and accountability) (Jorgenson et al., 2007, p. 373; Roberts et al., 2003). Moreover, a large portion of FDI attracted to developing countries finances ecologically inefficient, highly polluting, and labor-intensive manufacturing facilities and processes outsourced from developed countries (Jorgenson, 2006; Jorgenson et al., 2007). Therefore, most FDI is significantly detrimental to the local environment (especially water and air) in the developing countries. In short, the pollution haven hypothesis that FDI is positively linked to air pollution in developing countries has been empirically supported (Grimes & Kentor, 2003; Jorgenson et al., 2007). However, these viewpoints are also criticized for being too simplistic and are challenged by some studies that argue there is no association between FDI and environmental degradation (World Bank, 1997).

An alternative perspective is the pollution halo hypothesis that suggests more resource-efficient technologies and better environmental management systems brought by FDI, as well as the demands by associated costumers in the home (developed) countries, would significantly improve environmental performance in developing countries. For example, Eskeland and Harrison (2003) found that foreign firms are associated with significantly more environmental efficiency and lower levels of energy use than their counterparts in developing countries such as Mexico and Venezuela. In sum, the pollution halo hypothesis highlights the notion that FDI could effectively promote the establishment of higher environmental standards through technology transfer (Jorgenson et al., 2007) or existing environmental practices within transnational corporations (Lin et al., 2009). However, some researchers found that there is no evidence that foreign firms were significantly cleaner or new technology/equipment was associated with better environmental performance given different sectors and investors (Dasgupta et al., 2001).

These critics of the “halo” argument suggest that the effect of FDI on the environment differs across sectors and investors. Some scholars presented that foreign investment dependence in the primary sector is positively associated with pesticide and fertilizer use intensity in developing countries (Jorgenson & Kuykendall, 2008). Similarly, foreign investment in the secondary sector (e.g., resource extraction industries including mining and refining) has frequently led to serious environmental degradation. According to Spatareanu (2007), the level of environmental pressure that investors face locally, globally, and in its home country, affects its willingness to address environmental issues as part of investment. Some studies confirmed that globalization might have positive environmental effect because global ties increase self-regulation pressures on firms in low-regulation countries. In addition, firm size matters. Using firm-level evidence, Dasgupta et al. (2001) found that large firms are more likely to be associated with more pollution-intensive activities given their scale economies.

However, some studies found that smaller firms are significantly associated with more pollution since they are more difficult to monitor and regulate. For example, Lam (2005) ’study showed no evidence that foreign investment in power generation in China reduces emission, which was not consistent with what Blackman and Wu (1998) observed. One of the most important factors is that most foreign investors choose to invest in smaller power projects that only require local government approval, the regulatory power of which has been greatly reduced in order to attract foreign investors

(Roberts et al., 2004). Thus, reliance on foreign direct investment (FDI) would undermine the regulatory authority of the state in developing countries and reduce its capacity to deliver public goods (e.g., environmental protection).

Christmann and Taylor (2001) noted that multinational ownership, multinational customers, and exports to developed countries increase self-regulation of environmental performance. On the other hand, without any pressure at the local and global level as well as the home country, the transportation vehicles used by foreign-owned manufacturing enterprises in developing countries for the movement of goods and labor are more likely to be outdated and energy inefficient because of cost efficiency (Grimes & Kentor, 2003; Jorgenson et al., 2007). Therefore, different ownership patterns have different environmental implications. In the context of China, based on a detailed survey of approximately 1000 firms in three provinces in 1999, Wang and Jin (2002) found that FDI and collectively-owned enterprises have better environmental performance in terms of water pollution discharge intensity, while state-owned enterprises (SOEs) and privately-owned enterprises (POEs) are the worst performers. In particular, compared to FDI, SOEs have greater bargaining power with the local environmental authorities, which partly explained why SOEs are more likely to be the worst environmental performers (Wang et al., 2003). Therefore, the proposed hypothesis is as follows:

Hypothesis 7: FDI is negatively linked to air pollution in China over time. That is, the higher FDI in cities, the lower the level of air pollution will be.

Although most existing studies extensively examined the impact of FDI on the environment, it is worth noting the significant role of variation in the source of foreign capital. In China, the major source countries and regions of FDI are from Hong Kong, Taiwan, United States, Japan, South Korea, and UK (Tang et al., 2009). It is estimated that FDI from Hong Kong, Macao, and Taiwan account for more than 50% due to language and cultural similarity, geographic proximity, and historical ties (Tang et al., 2009; Wei, 2002). Thus, equity joint ventures in highly polluting industries funded through Hong Kong, Macao, and Taiwan are attracted by weak environmental standards and have negative effect on the environment.

In contrast, equity joint ventures funded from unethnic Chinese sources are not significantly attracted by weak standards, regardless of the pollution intensity of the industry (Dean et al., 2009). Dean et al. provide explanations of the findings that equity joint ventures from developed Western countries may adopt newer and cleaner technologies compared to those from ethnic Chinese sources, regardless of the local standards. Given the export-oriented development strategy China adopted, it is difficult to generalize the findings if we only take total FDI of a country into account since FDI is unevenly distributed in terms of national origin. Therefore, the last proposed hypothesis is to further our understanding of whether FDI is beneficial or detrimental to the air quality depending on the source of FDI. Following the study by Dean et al. (2009), I propose the hypotheses as follows:

Hypothesis 8: The sources of foreign capital from Hong Kong, Macao, and Taiwan are more likely to increase air pollution. That is, the higher investment of foreign capital from HMT a city attracts, the more severely polluted its air becomes.

Hypothesis 9: The sources of foreign capital from Western countries are more likely to decrease air pollution. That is, the higher investment of foreign capital a city attracts, the less severely polluted its air becomes.

Data and Methods

This chapter examines the effects of economic development, industrialization, urbanization, and globalization on air pollution across regions and over time. The dataset mainly comes from the China City Statistical Yearbook 2004-2013 and the China Regional Economy Statistical Yearbook 2006-2013. Complementary data are from the China Statistical Yearbook 2004-2013 and the China Environmental Statistical Yearbook 2004-2013. To test the proposed hypotheses, the data analyzed in this study include 287 cities (4 municipalities—Beijing, Tianjin, Shanghai and Chongqing, and 283 prefecture-level cities), covering 31 provinces, autonomous regions, and the municipalities directly under the central government in eastern, central, and western regions of China. The name of cities is listed (see Appendix A).

Figure 3.1 shows the map of 287 cities (4 municipalities and 283 prefecture-level cities) in China. Taking the year 2013 as an example, the land area of 287 cities analyzed in this study is 4.977 million (square km), covering 53.37% of total land area in the country. Meanwhile, the population size of these cities is 1.272 billion, consisting of 93.73% of total population in the country. That is, 93.73% of the population in China lives on 53.37% of the land in the country, indicating the population is unevenly distributed across the nation.

Table 3.2 presents the changes in total SO_2 and dust emissions across China's provinces. During the past years, in spite of overall increases in air pollution, there are different change trends in SO_2 and dust emissions across provinces. SO_2 emissions have declined in some provinces in the eastern region, including Beijing, Shanghai, Jiangsu, and Zhejiang, while also increasing rapidly in some provinces of the central and western regions such as Inner Mongolia, Henan, Jiangxi, Guizhou, and Yunnan. Some provinces of eastern regions such as Beijing and Tianjin witnessed declines of dust emission, while some other provinces, such as Shanxi and Hebei, witnessed dramatic increases.

Key Independent Variables

GDP per capita. The key independent variable is measured by GDP per capita (see the definition in Table 3.3), a commonly used indicator of overall economic development level and quality of life. Per capita GDP, as the original indicator of economic development in terms of standard of living, has two important implications. First, per capita GDP is used to facilitate the comparison with the existing studies in China and elsewhere (Grossman & Krueger, 1995; Jorgenson & Clark, 2012). Second, per capita GDP is one of the most “readily and consistently” available indicators for economic development in longitudinal analyses (Fan & Sun, 2008). The data at prefecture-city level are taken from the China City Statistical Yearbook and at the provincial level from the China Statistical Yearbook, respectively, both of which are comprehensive yearly statistics databases on the economy and social development. The GDP per capita for 287 cities ranges from a value of ¥ 1892 in Dingxi City, Gansu province in 2004 to ¥182,680 in Ordos, Inner Mongolia in 2013. The GDP per capita of the most prosperous city (Ordos) is more than 22 times that of the poorest city (Dingxi) in 2013, revealing there is a remarkable gap among different cities over the past 10 years.

Industrialization. There are three measurements of industrialization. The first is the percent of secondary industry in GDP. In 2009, the two prefecture-level cities with highest level of industrialization are Karamy (90.87%) in Xinjiang and Daqing (85.08%)

in Heilongjiang province, both of which are important oil producing and refining centers in China. The prefecture-level cities with lowest level of industrialization in 2006 are Pingliang (9%) in Gansu province and Heihe (15.73%) in Heilongjiang province. The second is industrial structure (ratio of secondary industry to the total of manufacturing and service industry in GDP), indicating the shifting of the economic structure away from manufacturing industries to service industries. The third variable is total amount of industrial electricity consumption (10,000 kwh). The prefecture-level cities with highest amount of industrial electricity consumption are Tangshan (481 million kwh) in Hebei province and Dongguan (452 million kwh) in Guangdong province. Tangshan is an important heavy industrial city in North China, while Dongguan is an industrial city and major manufacturing hub attracting foreign direct investment. The prefecture-level cities with lowest amount of industrial electricity consumption are Zhongwei, Longnan, and Dingxi, all of which are located in Gansu province. All of the above data are from the China City Statistical Yearbook. Additionally, I chose a dummy variable, RESBINDUSTC, indicating whether a city is a resource-based industrial city. Such cities, highly dependent on natural resources, are more likely to have the single resource-based industry as the pillar industry of the economy and are more environmentally polluted (Hong et al., 2011; Mao, 2014).

Urbanization. There are three measurements of urbanization. The first is total urban population size (the absolute size of the urban population). The second is the level of urbanization (the relative size of urban population to total population). The prefecture-level cities with highest level of urbanization in 2013 are Karamay (100%) in Xinjiang and Shenzhen (100%) in Guangdong province. The prefecture-level cities with lowest level of urbanization in 2012 are Ulanqab in Inner Mongolia and Dazhou in Sichuan province. The third is population density (number of residents per square kilometer). The prefecture-level cities with highest population density in 2013 are Dongguan and Shantou in Guangdong province. The prefecture-level cities with lowest population density in 2013 are Jiuquan (5.10) in Gansu province and Hulunbuir (10.51) in Inner Mongolia. The data are from the China City Statistics Yearbook. In addition, I choose a dummy variable, CITY LEVEL, indicating whether a city is a municipality, provincial capital, or sub-provincial city. Such cities, as the political, economic, and cultural center of the nation/region/province, are more likely to have higher level of urbanization and to be more densely populated.

Globalization. International trade is an important part of globalization. International trade is measured by the sum of imports and exports (in $10,000s). The prefecture-level city with highest amount of trade is Shenzhen ($4,688 million in 2013) in Guangdong province, while that with lowest amount of trade is Guyuan ($200,000 in 2013) in Gansu province. To further explore the composition of international trade, I choose the variable EXPORT, measured by total amount of goods exported (10,000 dollar). Similar to international trade, the prefecture-level city with highest amount of export is Shenzhen (2,714 million dollars in 2013) in Guangdong, while the city with lowest amount of trade is Ankang ($ 10,000 in 2006) in Shaanxi province. The data are from the China Regional Economy Statistical Yearbook 2006-2013.

International capital flow is another important feature of globalization. Foreign direct investment (FDI) is a commonly used measurement of international capital flows. In this study, FDI is measured by the total amount of realized FDI (in $10,000s). The prefecture-level cities with the highest amount of FDI are Dalian ($123 million in 2013) in Liaoning province and Suzhou (92 million dollars in 2013) in Jiangsu province. The prefecture-level cities with lowest amount of FDI are Zhongwei ($ 20,000 in 2005) in Gansu province and Hegang ($120,000 in 2004) in Heilongjiang province. In terms of the sources of foreign capital, it is measured by the absolute amount (Yuan), generally divided into foreign capital from Hong Kong, Taiwan, and Macao (HTM) and from Western countries. The provinces with highest amount of foreign capital from HTM are Guangdong, Jiangsu, Zhejiang, and Fujian, while those with lowest amount are Gansu and Guizhou. The prefecture-level cities with highest amount of foreign capital from HTM are Shenzhen (¥5, 235 million in 2013) in Guangdong province and Suzhou (¥4,978 million in 2013) in Jiangsu province. The prefecture-level cities with lowest amount of foreign capital from HTM are Qingyang and Jiayuguan in Gansu province. The provinces with highest amount of foreign capital from Western countries are Jiangsu, Guangdong, and Shandong, while those with lowest amount are Gansu and Shaanxi. The prefecture-level city with highest amount of foreign capital from Western countries is Suzhou (¥140 million in 2013) in Jiangsu province. The prefecture-level cities with lowest amount of foreign capital from Western countries are Jiayuguan in Gansu province and Chifeng in Inner Mongolia. The data come from the China City Statistical Yearbook. In addition, I use the dummy variable SEZOCC, indicating whether a city is designated as a special economic zone or an open coastal city. According to Huang et al. (2011), the cities designated as SEZ or OCC are more likely to promote international trade and attract FDI.

Additional Dummy Variables

Regions. The first additional dummy variable included was labeled as "Region," which quantifies if a province is located in eastern, central, or western region in China.

Year. I take year as a dummy variable to indicate period-specific effect of explanatory variables on dependent variable. Year included is controlled as the fixed part for the linear increase of the independent variables in the models in order to guard against spurious associations among variables with common trends (Beckfield, 2006).

Control Variables

Consumption. Consumption, measured by the absolute value of total consumer goods sold per year, is controlled. The existing literature in treadmill of consumption theory shows that increased production of the amount of the goods requires increasing consumption, which in turn has an important impact on environment. Some other empirical studies in the context of China show that industrialization and urbanization have significantly influenced consumption and lifestyle of urban China (Zhao & Wang, 2015). To examine the role of industrialization and urbanization, consumption is held constant in the study. The data come from the China City Statistical Yearbook.

Population size. Population size, measured by the absolute number of registered population, is controlled. There are a number of existing studies showing population size is an important predictor in environmental degradation (Jorgenson & Clark, 2012; Rosa et al., 2004; York, 2007; York et al., 2003). Thompson (2013) provides evidence for the significant role of population in the model of the Environmental Kuznets Curve (EKC) in impacting the turning point. Therefore, population size is controlled in this study. The data come from the China City Statistical Yearbook.

Public transportation. Public transportation, defined as the indicator of infrastructure, is widely recognized as the basic physical structures, providing facilities, commodities, and services essential to enable, sustain, or enhance economic growth and social development (Lall & Rastogi, 2007; Sullivan & Sheffrin, 2003). Roads, ports, airports, communication networks, etc. are the key components. The study uses public transportation as the indicator of infrastructure due to unavailability of other components. The data come from the China City Statistical Yearbook.

Method

Methodologically, ordinary least squares (OLS) estimation is inappropriate for such longitudinal data due to heterogeneity bias within panels. Both fixed-effects model (FEM) and random effect models (REM) are identified as better techniques for comparative studies with panel data (Beckfield, 2006; Jorgenson & Kuykendall, 2008). Here, fixed effect model (FEM) is defined as:

$$y=a+bx+e \qquad e \sim N\ (0,\ \sigma 2)$$

where y is the dependent variable, a is the unknown intercept, x represents one independent variable (IV), b is the coefficients for that IV, and e is the error term. Specifically, the estimated model in this study is,

$$AirPollution=a+b*lnGDPpc+c*lnIndustrialization+d*lnUrbanization+e*lnTrade+f*lnFDI +g* lnFIhmt +h*lnFIwest + i*lnConsumption+j*lnPopsize+h*lnPubtra+e$$

FEM with standard error is used to examine the effect of economic development, industrialization, urbanization, and globalization on air pollution over the past 10 years, given that the Hausman test is significant and net of all time-varying variables. Random effects models (REM) not only include between/within-region variation, but also time-invariant variables. Since one of my primary interests is about the hypothesized effects of economic development, industrialization, urbanization, and globalization on air pollution across regions, multilevel modeling would be a better choice than REM. Thus, multilevel modeling is applied to test the overall trend of air pollution across region and time. More importantly, the joint effect of economic development, industrialization, urbanization, and globalization on air pollution is estimated.

However, the dataset in this study results in unbalanced, longitudinal data consisting of clusters of observations at different time points for each city. This is referred to as a variance component model that is designed to estimate between- and within-cluster correlations (Rabe-hesketh & Skrondal, 2005). Typically, for longitudinal data, occasions *i* is level-1 units and subject *j* is level-2 clusters. In this dataset, level-1 is year *i*, level 2 is city *j*, and level 3 is province *k*. In other words, 10 different time points from 2004 to 2013 are nested in each city, which itself is nested in provinces. The level-1 model for city *j* in province *k* at year *i* is:

$$y_{ijk} = \tau_{1jk} + \varepsilon_{ijk}$$

Here τ_{1jk} is specific to each city *j* and constant across year *i*, called random effect with normal distribution of population mean zero and between-city variance φ.τ_{1jk} varies between city *j* and province *k*. ε_{ijk} is, specific to each city *j* of province *k* at each year *i*, called residual with a normal distribution of population mean zero and between provinces, within-city variance θ (Rabe-hesketh & Skrondal, 2005).

The level-2 model is specified for the intercept τ_{1jk}

$$\tau_{1jk} = \pi_{11k} + \pi_{12}x_j + \zeta_{jk}$$

The level-3 model is specified for the intercept π_{11k},

$$\pi_{11k} = \gamma_{111} + \zeta_k$$

The final model obtained is

$$y_{ijk} = \gamma_{111} + \pi_{12}x_j + \zeta_k + \zeta_{jk} + \varepsilon_{ijk}$$

Specifically, the estimated baseline model in this chapter is as follows,

Log (Total SO_2*/Dust Emission) =* $\beta_0+\beta_1$**lnGDPpc+*β_2**Consumption+*β_3**Popsize +*β_4 *Pubtra+*β_5**year 2004+…+* β_{14}**year2013 +e*

The multilevel model is

Log (TotalSO_2*/Dust Emission) =* $\beta_0+\beta_1$**lnGDPpc+*β_2**(lnGDPpc)*$^2+\beta_3$**lnIndustrialization +*β_4**lnUrbanizatio+*β_5**lnGloblalization+*β_5**lnConsump+*β_6*lnPopSize+*β_7**lnPubTran+*β_8**year2004+…+* β_{17}**year2013+e*

Results

Table 3.4 presents descriptive statistics for all variables, including dependent variables, independent variables, and control variables before transformation in the analysis. Then, the multilevel regression analyses are reported in the following series of tables. I present and discuss the findings, with a particular focus on the effect of economic development, industrialization, urbanization, and globalization on SO_2 and dust emission, respectively.

Tables 3.5-3.6 present the multilevel modeling analysis of economic development, industrialization, urbanization, globalization, and air pollution over the period 2004-2013. Specifically, Table 3.5 and 3.6 show the estimates of the effects of economic development on SO_2 and dust emission, respectively, net of consumption, population size, and public transportation. Model 1 is treated as a baseline model, consisting of consumption, population size, and public transportation. I add the key independent variable GDP per capita in Model 2 to examine the effect of economic development on air pollution. Then I add an additional predictor, the quadratic term of GDP per capita, into Model 3. Models 3 and Model 4 include all predictors from Model 2 as well as dummy variables. Model 5 is the most fully saturated model reported for all outcomes investigated in the analyses, consisting of all of the predictors included in Model 1 through Model 4.

Model 1, as a baseline model, obtains a crude estimate of SO_2 and dust emission, net of consumption, population size, and public transportation. Specifically, consumption, and public transportation are statistically significant for both SO_2 and dust emission while population size only positively affected dust emission. The overall fit of Model 1 is moderate (R^2= .400 for SO_2 emission, .334 for dust emission), implying that other variables matter.

In Model 2, I introduce GDP per capita to predict SO_2 and dust emission. Holding the control variables in the baseline model, the primary finding in Model 2 shows that GDP per capita is a significant factor and positively associated with SO_2 and dust emission, suggesting that the higher GDP per capita, the higher the level of air pollution is, regardless of which type (SO_2 or Dust). The increase of one unit in log GDP per capita leads to a .497 growth in log SO_2 emission, and a .373 growth in log dust emission. That is, an additional unit of GDP per capita leads to an increase in the expected SO_2 emission by 1.644 and the expected dust emission by 1.452. The overall fit improved with the R^2, rising from .400 to .448 for SO_2 emission, and from .334 to .367 for dust emission.

In Model 3, I add the quadratic term of GDP per capita to test the Hypothesis 1 that there is an inverted U-shape curve between GDP per capita and air pollution.

Controlling the explanatory variables in Model 2, the primary finding in Model 3 shows that there is an inverted U-shape between GDP per capita and SO_2 emission, suggesting that GDP capita at the initial stage is positively associated with SO_2 emission, and then negatively associated with SO_2 emission after a turning point. However, surprisingly, the findings provide no evidence for dust emission. Overall, the finding partially confirms Hypothesis 1 and supports the Environmental Kuznets Curve (EKC) that argued that air pollution first rises, and then falls as economic development proceeds (Grossman & Krueger, 1995). For SO_2 emission, Kander (2002) and Stern (2004) argued there is a structural shift away from agriculture toward industry in the earlier stages of development, during which particularly heavy industry substantively increasing emissions. In the later phases of development, there is a sectoral shift away from the resource-intensive and heavy industrial sectors toward technology-intensive industries and services, which supposedly have lower emissions (Proops & Safonov, 2004). Meanwhile, the finding also provides support for the statement by Panayotou (1997) that the simple reduced approach to the Environmental Kuznets Curve only holds for certain pollutants, but could not provide explanations for the underlying mechanism. In terms of dust emission, the effect of the structural change of industrial production is lumped given its mixing sources.

Model 4 adds dummy variables to test whether the relationship between GDP per capita and air pollution varies given the characteristics of cities. As expected, the variable RESBINDUSTC is negative and statistically significant, indicating SO_2 and dust emission are higher in a resource-based industrial city than that in a non-resource-based industrial city. The variable CITYLEVEL is negative and slightly statistically significant, suggesting there is difference in SO_2 and dust emission between different levels of cities. Specifically, SO_2 and dust emission are lower in prefecture-level cities than in the cities that are municipalities, provincial capitals, or sub-provincial cities. The variable SEZOCC is statistically significant only for dust emission, indicating there is no difference of SO_2 emission between the cities that are designated as Special Economic Zones or Open Coastal Cities and other cities.

Model 5 introduces region and year as predictors and offers a comprehensive model that demonstrates the effect of economic development on air pollution across regions over time. Both central and western regions are moderately significant for dust emission, while only the western region is significant for SO_2 emission. Consistent with what we expected, compared to more developed eastern regions with higher GDP per capita, SO_2 and dust emission are higher in these less developed regions. Interestingly, after adding the interaction effect of region, I find that it is statistically significant for SO_2 emission, but not dust emission. This finding partially confirms the expectation of Hypothesis 2 and supports the statement by Jorgenson and Clark (2012) that the decoupling between economic development level and air pollution is more likely to occur in more developed regions. Meanwhile, Model 5 also shows that the effect of the magnitude of economic development on air pollution varies over time. The variable year and the interaction effect are statistically significant for dust emission, but not for SO_2 emission, indicating only the effect of the magnitude of economic development on dust emission varies over time. Specifically, from 2005 through 2013, the effect of economic development on SO_2 emission steadily decreases until 2012. The estimated coefficient for GDP per capita decreases through time, suggesting the decoupling between economic development and dust emission during the period. The decoupling first occurred in 2005, and then the coefficient substantially decreases except for an increase in 2012.

To summarize, this comprehensive model provides insight into the decoupling of economic development and air pollution across regions and through time. Regarding the underlying causes of why higher GDP per capita could lead to better environmental quality, previous studies argued that structural transformation from heavy industry towards technology-intensive industries and services, coupled with environmental consciousness, enforcement of environmental regulations, higher environmental expenditures, and more advanced technology, would result in gradual decline of emissions (Panayotou, 1997; Stern, 2004). It is noteworthy to point out that holding constant other variables, if there is no structural change of the economy or no advanced pollution control technology applied, the increasing growth in the economy would result in increasing levels of emissions (Stern, 2004).

Tables 3.7-3.8 show the estimates of industrialization on air pollution. The Akaike Information Criterion (AIC) determines which of the two models is preferred. The lowest AIC is the preferred model. To further explore the effect of the level of industrialization on air pollution, in Model 4, I introduce two more variables INDUSTR and IELECON to test the Hypothesis 1 that the level of industrialization is positively associated with SO_2 emission. Controlling the explanatory variables in Model 3, the result in Model 4 shows the industrial structure is negative and slightly statistically significant for SO_2 emission, while industrial electricity consumption is positive and statistically significant for dust emission. The finding demonstrates that the higher the level of industrial electricity consumption, the higher the level of air pollution is.

Model 5 adds dummy variables RESBINDUSTC and year to test whether the relationship between industrialization and air pollution varies given the characteristics of cities over time. As expected, the variable RESBINDUSTC is negative and statistically significant. The negative estimated coefficient indicates air pollution is higher in a resource-based industrial city than that in a non-resource-based industrial city. Model 5 also introduces year as predictor to show how the effect of the magnitude of industrialization on air pollution varies over time. In the initial period of 2005-2007, year is not statistically significant. Then the decoupling between industrialization and air pollution first occurs in 2009. From the year 2009 through 2013, the coefficient is negative and statistically significant, indicating the effect of industrialization on both SO_2 and dust emission decreases through time.

In sum, Table 3.7 and 3.8 provide us insight into the decoupling of industrialization and and SO_2 and dust mission, respectively, over time. The between-region standard deviation is estimated as 0.018 in Model 1, and it changes to 0.005 in Model 5. The between-province within-regions standard deviation is estimated as 0.852 in Model 1, and then it changes to 0.633 in Model 5. The value of AIC is calculated as 7750.27/7959.23 in Model 1, and then it gradually decreases to 5960.47/6485.46 in Model 5, indicating Model 5 is a better model that provides more comprehensive understanding of the effect of industrialization on air pollution over time.

Tables 3.9-3.10 show the estimates of urbanization on air pollution. In Model 6, I add the variables URBAN to test Hypothesis 4. In Model 7, I introduce the variable POPD to test the Hypothesis 5 that population density is positively associated with air pollution. Controlling the explanatory variables in Model 6, inconsistent with the commonly held view, the primary finding in Model 7 shows that population density is negative and statistically significant for SO_2 emissions. In terms of dust emission, it is negative and slightly statistically significant, revealing that the higher the level of population density, the lower the level of dust emissions is (Eriksson & Zehaie, 2005).

In Model 8, I add dummy variables CITYLEVEL and year to test whether the relationship between urbanization and air pollution varies given the characteristics of cities over time. As expected, the variable CITYLEVEL is statistically significant. The estimated coefficient is positive, indicating air pollution is lower in prefecture-level cities than that in the cities which are municipality, provincial capitals, or sub-provincial cities. Model 8 also introduces year as predictor to estimate how the effect of the magnitude of urbanization on air pollution varies over time. In the initial period of 2005-2007, year is not statistically significant. Then, decoupling between urbanization and air pollution first occurs in 2008. The year effect from 2008 through 2013 is negative and statistically significant, indicating the effect of urbanization on air pollution decreases through time. The between-region standard deviation is estimated as 0.030 in Model 6, and it increases to 0.070 in Model 8. The between-province within-regions standard deviation is estimated as 0.819 in Model 6, and then it also increases to 0.959 in Model 8. The value of AIC is calculated as 7217.84/7607.59 in Model 6, and then it gradually decreases to 6428.52/6754.88 in Model 8, indicating Model 8 is a better model that provides much more comprehensive understanding of the effect of urbanization on air pollution over time.

Tables 3.11-3.12 show the estimates of globalization on air pollution. In Model 9, I add the variables TRADE to test the proposed Hypothesis 6. Holding constant the explanatory variables from Model 1 of Table 3.7, the primary result is that trade has a positive and statistically significant effect, indicating that the higher the amount of total international trade, the higher the level of air pollution is.

In Model 10, I introduce the variable total FDI to test Hypothesis 7 that FDI is positively associated with air pollution. Controlling the explanatory variables, FDI is slightly statistically significant, revealing FDI is positively associated with SO_2 emission. However, for dust emission, Hypothesis 7 is rejected. Therefore, the primary finding indicates that the effect of FDI on air pollution is mixed.

Model 11 adds the variable FIHTM to test Hypothesis 8 that foreign capital from Hong Kong, Taiwan, and Macao is positively associated with air pollution. Controlling the explanatory variables, the finding shows that FIHTM is positive and statistically significant for SO_2 emission, revealing that the higher the amount of foreign capital from HTM, the higher the level of SO_2 emission is. As for dust emission, the variable FIHTM is slightly statistically significant. Model 12 adds the variable FIWEST to test Hypothesis 9 that foreign capital from Western countries is positive and strongly associated with air pollution. Holding constant the explanatory variables, the results show that FIWEST is not statistically significant, suggesting there is no evidence to support the statement that foreign capital from Western countries is more likely to increase SO_2 emission. For dust emission, the result shows that FIWEST is not statistically significant, indicating foreign capital from Western countries has no effect on dust emission.

Meanwhile, in Model 13, I introduce the variable DCIV to test the effect of domestic capital on air pollution. Controlling the explanatory variables, the finding in Model 14 shows that DCIV is strongly statistically significant, indicating there is no effect of the investment from domestic capital on air pollution.

In Model 14, I add dummy variables SEZOCC and year to test whether the relationship between globalization and air pollution varies given the characteristics of cities over time. The variable SEZOCC is statistically significant for dust emission, but not for SO_2 emission. The results indicate there is no difference in SO_2 emissions between the cities that are designed as Special Economic Zones or Open Coastal Cities and other cities. Additionally, Model 15 introduces year as predictor to show how the effect of the magnitude of globalization on air pollution varies over time. The decoupling between globalization and air pollution first occurs in 2008. From 2008 through 2013, year is negative and statistically significant, indicating the effect of globalization on air pollution decreases through time.

Overall, Tables 3.11-3.12 provide a comprehensive view of how the effect of globalization and air pollution changed over time. The between-region standard deviation is estimated as .055 in Model 9, and it increases to .023 in Model 14. The between-province within-regions standard deviation is estimated as .864 in Model 9, and then it decreases to .733 in Model 14. The value of AIC is calculated as 5598.65 in Model 9, and then it gradually decreases to 4102.92 in Model 14, indicating Model 9 is a better model that provides much fuller understanding of the effect of globalization on air pollution across regions and over time.

Table 3.13 shows the joint effect of economic development, industrialization, urbanization, and globalization on air pollution. In Model 15, all key independent variables are included to examine the joint effects of economic development, industrialization, urbanization, and globalization on air pollution. The results are mixed given different measurements of air pollution. For instance, the variable URBAN is positively associated with SO_2 emission, but has no impact on dust emission. The result shows that FDI has no association with air pollution. The sources of foreign capital exert different influences on air pollution given its different types. The variable FIHTM has no effect on SO_2 emission, but is positively associated with dust emission. By contrast, the variable FIWEST is positive but not significantly associated with either SO_2 emission or dust emission.

Model 16 adds dummy variables to test whether the joint effects of economic development, industrialization, urbanization, and globalization on air pollution vary according to the characteristics of cities. As expected, the variable RESBINDUSTC is negative and strongly statistically significant, indicating air pollution is lower in a resource-based industrial city than that in a non-resource-based industrial city. The variable CITYLEVEL is positive and slightly statistically significant. Meanwhile, the variable SEZOCC has no effect on SO_2 emissions, but is positive and strongly statistically significant for dust emission. This result suggests that dust emissions are lower in the cities that are designated as Special Economic Zone or Open Coastal Cities than other cities. Then, I add dummy variables for year to show how the effect of the magnitude of development on air pollution changes over time. The year 2007 is not statistically significant for SO_2 emissions, but slightly statistically significant for dust emission. The decoupling between development and air pollution first occurred around 2008. The year through 2008-2013 is negative and statistically significant, indicating the effect of the magnitude of development on air pollution decreases through time.

In summary, Table 3.13 provides a comprehensive statistical view on how the effects of development on air pollution changed over time in the early part of the 21st century. The between-region standard deviation is estimated as .000 in Model 15, and then increases in Model 16 for SO_2 emission, while decreasing for dust emission from Model 15 to Model 16. The between-province within-regions standard deviation increases for both SO_2 emission and dust emission. The value of AIC for air pollution decreases from Model 15 to Model 16, indicating Model 16 is a better model that provides much fuller understanding of the effects of development on air pollution.

Conclusion

This chapter aims to address the question how development within a developing country impacts air quality across regions and over time. The chapter provides a snapshot of how the dynamics of development influences air pollution during the 10 years, 2004-2013, and examines whether industrialization, urbanization, and globalization serve as pathways in the association between development and air pollution in the context of the rapidly expanding economy of the most populous country in the world. Empirically, this chapter examines the effects of development on air pollution in China using longitudinal data at prefecture-city level. The aim is to test the theoretical framework proposed in Chapter 1 and present how major factors such as economic development level, industrialization, urbanization, and globalization have affected air pollution across regions and over time. Multilevel models are deployed to test for the presence of regional disparities in the relationship between economic development and air pollution and the variance in disparities between- and within- provinces/regions.

Recall that Hypothesis 1 and 2 posited an inverted U-shape relationship between economic development and air pollution. That is, economic development initially has an adverse effect on air quality, which then subsequently improves as the level of national economic development increases over a turning point (the peak of the inverted U-shape). The hypothesis is partially validated. There is strong evidence in Table 3.5 showing an inverted U-curve between economic development and SO_2 emission at 95% confidence level and the turning point is estimated as GDP per capita reached ¥61659.5. However, there is no evidence to show that there is an inverted U-relationship between economic development and dust emission. Therefore, the EKC does not apply to dust emission. Meanwhile, there are regional disparities in the effect of economic development on SO_2 emission, but not dust emission.

Recall that Hypothesis 3 suggested that industrialization is positively associated with air pollution. That is, the higher the level of industrialization, the more air pollution there will be. The findings from Tables 3.7-3.8 confirm this hypothesis and provide strong evidence to support the statement that the higher levels of manufacturing industry and industrial electricity consumption are associated with higher level of air pollution (both SO_2 and dust emissions). The decoupling between industrialization and air pollution first occurred around the year 2008-2009. Specifically, the effect of industrialization on SO_2 emissions decreased from 2009 to 2013, while its effects on dust emissions decreased from 2008-2011 and then increased in 2012.

Hypothesis 4 and 5 suggested that urbanization is positively associated with air pollution. That is, the higher the level of urbanization, the higher the level of air pollution will be. The findings from Tables 3.9-3.10 confirm the hypothesis that the higher rates of urbanization are associated with higher levels of air pollution. Hypothesis 5 is partially supported since the findings are mixed and vary according to the indicators of air pollution. Specifically, population density is slightly positively associated with SO_2 emissions, while negatively associated with dust emissions. The decoupling between urbanization and air pollution first occurred around the year 2007-2008. Specifically, the effect of urbanization on SO_2 emissions decreased from 2008 to 2013, while the effects on dust emission decreased through 2007-2011 and then increased in 2012.

Recall Hypotheses 6-9 suggested that globalization is positively associated with air pollution. That is, the higher the level of globalization, the more severe the air pollution will be. The findings from Tables 3.11-3.12 confirm Hypothesis 6, that the higher the level of international trade, the higher the level of air pollution will be. Hypotheses 7-8, are partially supported since the findings are mixed and vary depending on which type of air pollution is under consideration. Overall, there is no evidence showing that FDI affects air pollution. More importantly, this study shows that different sources of foreign capital have different effects on air pollution. There is no evidence to show that foreign capital from Western countries affects dust emissions.

More specifically, Table 3.12 presents that foreign capital from Hong Kong, Taiwan, and Macao is positively associated with SO_2 emissions, but the effect is offset after controlling for domestic capital. Similarly, foreign capital from Hong Kong, Taiwan, and Macao are slightly positively associated with dust emissions, while the effect is offset after controlling domestic capital. The decoupling between globalization and air pollution first occurred around the year 2007-2008. Specifically, the effect of globalization on SO_2 emissions decreased from 2008 to 2013, while on dust emissions, it decreased over 2007-2011 and then increased in 2012.

Overall, this empirical study is designed to respond to the demand for systematic analysis of the relationship between development and the environment in China (Liu & Bettie, 2016). This chapter examines how development processes impact air pollution at the prefecture-city level. It provides new findings on how industrialization, urbanization, and globalization, as driving forces, as well as economic development level, have affected air quality. Inconsistent with Dinda's observation that the EKC is more likely to hold for the environmental impact locally (Dinda, 2004), the findings demonstrate that there is an inverted U-shape relationship between economic development and SO_2 emission (but not dust emission). More importantly, the results show that the cities with the higher levels of industrialization and urbanization have higher levels of air pollution. In terms of globalization, the findings are mixed. For cities with higher levels of international trade, there are higher levels of air pollution. For cities with higher level of foreign capital from Hong Kong, Taiwan, and Macao, levels of air pollution are greater.

Although previous research has made valuable contributions, this study advances the literature in several ways. First, this study focuses on the relationship between development and air pollution at the city level within the largest developing country in the world. In Chapter 2, I describe the development mode of China since the policies of reform and opening up were introduced in 1978, leading to rapid industrialization, urbanization, and globalization. Therefore, this study is a systematical empirical analysis testing the theoretical framework of the triple process of development in China. Secondly, the joint effects of economic development level, industrialization, urbanization, and globalization on air pollution have been tested, while previous studies mostly examine the effect of those factors separately with respect to water pollution. Third, multilevel modeling is used to analyze the most recent city-level data. This study is the first to provide a comprehensive comparative quantitative analysis of the relationship between development and air pollution from 287 cities across regions and over time, as prior research takes China itself or provinces within China as the units of analysis. Last but most importantly, the findings have policy implications for the development trajectories, and industrialization and globalization particularly for developing countries, contributing to the literature by examining the independent role of population density and the sources of foreign capital in relation to air pollution locally.

There are several limitations to this study. First, the indicators of air pollution are SO_2 emissions and dust emissions, which are used as indicators for air quality in the environmental studies. The findings may not be generalizable to other indicators of air quality, particularly particulate matter ($PM_{2.5}$ and PM_{10}). In future research, particulate matter will be explored when the long-term data at the city level become available. Secondly, the theoretical framework is constructed in the context of China, where the role of the state and policies should be seriously taken into account. Given the unavailability of data, this study fails to examine the effect of such policies implemented by central and local governments on air pollution. The effects of specific policies should be examined in future studies.

Table 3.1

Summary of Different Theoretical Frameworks in Different Fields

Indicators	Variables	Environmental Sociology	Ecological Economics	Economic Geography
Economic Development	GDP per capita	Yes	Yes	
Industrialization	Manufacturing	Yes	Yes	
	Industrial Electricity (	Yes	Yes	
Urbanization	Rate of Urbanization	Yes		Yes
	Population Density			Yes
Globalization	Trade (or Export)	Yes	Yes	Yes
	FDI	Yes	Yes	Yes

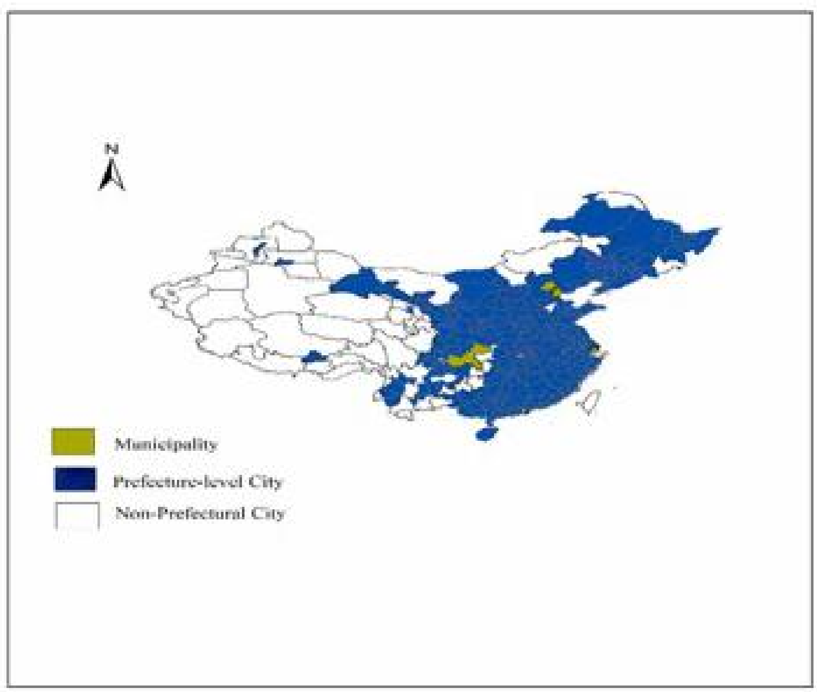


Figure 3.1

Map of China in This Study

Table 3.2

Changes of Air Pollution by Provinces, 2004-2013 (10,000 tons)

Provinces	SO2 Emission		Dust Emission	
	Change	Percent	Change	Percent
	1814394	100%	6399868	100%
Eastern Region				
Beijing	-54682	-3.01%	-1301	-0.02%
Tianjin	-14690	-0.81%	-27489	-0.43%
Hebei	50172	2.77%	416189	6.50%
Shandong	269446	14.85%	161062	2.52%
Liaoning	326229	17.98%	212308	3.32%
Shanghai	-60634	-3.34%	37429	0.58%
Jiangsu	-45871	-2.53%	59814	0.93%
Zhejiang	-102621	-5.66%	54084	0.85%
Fujian	158580	8.74%	160457	2.51%
Guangdong	-256254	-14.12%	99574	1.56%
Guangxi	-210199	-11.59%	-189776	-2.97%
Hainan	765	0.04%	554	0.01%
Central Region				
Shanxi	41961	2.31%	5080875	79.39%
Inner Mongolia	463481	25.54%	377081	5.89%
Jilin	155568	8.57%	3841	0.06%
Heilongjiang	57378	3.16%	-22120	-0.35%
Anhui	70889	3.91%	128098	2.00%
Henan	206334	11.37%	-147915	-2.31%
Hubei	79984	4.41%	4968	0.08%
Hunan	-31329	-1.73%	-110475	-1.73%
Jiangxi	269325	14.84%	132947	2.08%

Table 3.2 Continued

Provinces	SO2 Emission		Dust Emission	
	Change	Percent	Change	Percent
Western Region				
Chongqing	-89876	-4.95%	46325	0.72%
Sichuan	-238701	-13.16%	-457587	-7.15%
Guizhou	265785	14.65%	700	0.01%
Yunnan	253362	13.96%	106877	1.67%
Tibet	1075	0.06%	647	0.01%
Shaanxi	6368	0.35%	141522	2.21%
Gansu	83753	4.62%	40665	0.64%
Qinghai	26924	1.48%	20200	0.32%
Ningxia	56189	3.10%	49847	0.78%
Xinjiang	75683	4.17%	20467	0.32%

Table 3.3

Lists of Definitions of Independent and Control Variables

Variables	Variable Label	Definition	Period
Economic Development	GDPPC	The annual amount of GDP per capita	2004-2013
Industrialization	MAINDU	The ratio of manufacturing industry to total GDP	2004-2013
	INDUSTR	The ratio of manufacturing industry to total non-primary sector	2004-2013
	IELECON	The annual consumption of industrial electricity	2004-2014
	RESBINDU	Whether a city is resource-based industry city	2004-2013
Urbanization	URBANP	The size of urban population	2004-2013
	URBAN	The ratio of urban population to total population size	2004-2013
	POPD	The population density of the city	2004-2013
	CITYLEVE]	Whether a city is municipality, provincial capital or sub-provincial city	2004-2013
Globalization	TRADE	The annual amount of international trade	2005-2013
	EXPORT	The ratio of export to total international trade	2005-2013
	FDI	The annual amount of Realized FDI	2004-2013
	FIHTM	The annual amount of FDI from Hong Kong, Macao and Taiwan	2004-2013
	FIWEST	The annual amount of FDI from Western countries	2004-2013
	DCIV	The annual amount of domestic capital	2004-2013
	SEZOCC	Whether a city is Special Economic Zone or Open Coastal City	2004-2013
Control Variables	CONSUM	The annual amount of total consumption	2004-2013
	POPSIZE	The size of population in the whole city	2004-2013
	PUBTRA	The number of public transportation per 10,000 person	2004-2013

Table 3.4

Descriptive Statistics of the Analysis

Variables	Min	Max	Mean	Std. Dev
Dependent Variables				
SO_2	12	705751	62995.74	63813.60
Dust	34	5168812	30408.65	120553.81
Independent Variables				
GDP pc	99	182680	24939.28	21173.03
Manufacturing	9	91	48.85	11.48
Industrial Electri	0	8057600	432689.10	730180.33
Urbanization	0	1	0.34	0.21
Popu density	5	2662	416.22	318.80
Trade	2	46680286	866686.46	3147905.42
Export	0	27135572	468126.95	1584273.97
FDI	0	1518453	51052.65	125151.03
FI from HTM	0	54732030	1759357.92	5013512.49
FI from West	0	144700000	3120012.50	10663102.67
Domes Invest	6007	138900000	11726056.27	16486018.97
Control Variables				
Consumption	11209	77028167	3851169.87	6248666.11
Population size	16	3343	425.52	303.18
Public transport	0	115	6.7395	6.69319

Note: *N*=2870

Table 3.5

Multilevel Estimates of Economic Development and SO_2 Emission in China

	Model 1	Model 2	Model 3	Model 4	Model 5
Independent Variables					
GDPPC(ln)		0.672***	1.717***	1.558***	1.631***
		(0.050)	(0.338)	(0.327)	(0.320)
GDPPC2(ln)			-0.055**	-0.061***	-0.050**
			(0.018)	(0.017)	(0.017)
Dummy Variables					
RESBINDUSTC				-0.451***	-0.455***
				(0.035)	(0.034)
CITYLEVEL				-0.148*	0.290***
				(0.062)	(0.065)
SEZOCC				-0.001	0.065***
				(0.070)	(0.067)
Central Regions					0.420***
					(0.211)
Western Regions					0.845*
					(0.217)
2005					-0.061
					(0.063)
2006					-0.015
					(0.064)
2007					-0.126†
					(0.065)
2008					-0.288***
					(0.067)
2009					-0.484***
					(0.070)
2010					-0.621***
					(0.072)
2011					-0.819***
					(0.075)
2012					-0.890***
					(0.078)
2013					-1.062***
					(0.082)

Table 3.5 Continued

	Model 1	Model 2	Model 3	Model 4	Model 5
Control Variables					
CONSUM(ln)	0.280***	-0.259***	-0.232***	0.002	0.352***
	(-0.025)	(0.047)	(0.048)	(0.053)	(0.053)
POPSIZE(ln)	0.434***	1.015***	0.983***	0.388***	0.001***
	(0.030)	(0.052)	(0.053)	(0.064)	(0.061)
PUBTRA(ln)	0.322***	0.257***	0.259***	0.233***	0.167***
	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Constant	3.521***	1.451***	-3.708*	-1.069	-6.102***
	(0.226)	(0.268)	(1.672)	(1.636)	(1.632)
R^2 Between	0.388	0.476	0.470	0.456	0.586
R^2 Overall	0.400	0.448	0.447	0.297	0.325
Between Cities	0.969	0.914	0.920	0.772	0.457
Within Cities	0.832	0.809	0.808	0.766	0.728
ICC	0.576	0.561	0.565	0.504	0.283

Notes:
1. †$p<0.1$; *$p<0.05$; **$p<0.01$; ***$p<0.001$(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. GDPPC= gross domestic product per capita; GDPPC2 =Quadratic term of gross domestic product per capita.
4. ICC=Intraclass correlation coefficient;

Table 3.6

Multilevel Estimates of Economic Development and Dust Emission in China

	Model 1	Model 2	Model 3	Model 4	Model 5
Independent Variables					
GDPPC(ln)		0.551***	0.533	0.378	0.979**
		(0.052)	(0.355)	(0.350)	(0.339)
GDPPC2(ln)			0.001	-0.004	-0.025
			(0.018)	(0.018)	(0.018)
Dummy Variables					
RESBINDUSTC				-0.364***	-0.369***
				(0.038)	(0.036)
CITYLEVEL				-0.172**	0.183**
				(0.066)	(0.068)
SEZOCC				0.334***	-0.455***
				(0.075)	(0.067)
Central Regions					0.755**
					(0.257)
Western Regions					0.621*
					(0.263)
2005					-0.053
					(0.067)
2006					-0.047
					(0.067)
2007					-0.198**
					(0.065)
2008					-0.442***
					(0.071)
2009					-0.675***
					(0.074)
2010					-0.852***
					(0.076)
2011					-1.033***
					(0.079)
2012					-0.510***
					(0.083)
2013					-0.714***
					(0.086)

Table 3.6 Continued

	Model 1	Model 2	Model 3	Model 4	Model 5
Control Variables					
CONSUM(ln)	0.206***	-0.236***	-0.237***	-0.036	0.173**
	(0.026)	(0.049)	(0.050)	(0.056)	(0.056)
POPSIZE(ln)	0.565***	1.042***	1.043***	0.504***	0.438***
	(0.031)	(0.055)	(0.056)	(0.068)	(0.065)
PUBTRA(ln)	0.164***	0.110***	0.110***	0.098***	0.041†
	(0.025)	(0.026)	(0.026)	(0.026)	(0.025)
Constant	3.202***	1.511***	1.600	3.813*	-2.883†
	(0.234)	(0.281)	(1.755)	(1.748)	(1.731)
R^2 Between	0.286	0.345	0.348	0.528	0.580
R^2 Overall	0.334	0.367	0.368	0.224	0.284
Between Cities	0.909	0.870	0.870	0.758	0.567
Within Cities	0.862	0.848	0.848	0.821	0.779
ICC	0.526	0.513	0.513	0.460	0.346

Notes:
1. †p<0.1; *p<0.05; **p<0.01; ***p<0.001(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. GDPPC= gross domestic product per capita; GDPPC2 =Quadratic term of gross domestic product per capita.
4. ICC=Intraclass correlation coefficient;

Table 3.7

Multilevel Estimates of Industrialization and SO_2 Emission in China

	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed-Effect					
GDPPC(ln)		0.678***	0.184**	0.119*	0.228***
		(0.050)	(0.055)	(0.050)	(0.059)
MAINDU(ln)			1.499***	1.103***	0.624**
			(0.086)	(0.204)	(0.217)
INDUSTR(ln)				-0.464†	-0.101
				(0.239)	(0.254)
IELECON(ln)				0.389***	0.278***
				(0.015)	(0.016)
RESBINDUSTC					-0.308***
					(0.032)
2005					-0.001
					(0.058)
2006					0.141*
					(0.059)
2007					0.079
					(0.060)
2008					-0.009
					(0.062)
2009					-0.110†
					(0.065)
2010					-0.180**
					(0.067)
2011					-0.315***
					(0.071)
2012					-0.323***
					(0.074)
2013					-0.415***
					(0.076)
Control Variables					
CONSUM(ln)	0.278***	-0.266***	-0.003	-0.274***	-0.036

Table 3.7 Continued

	Model 1	Model 2	Model 3	Model 4	Model 5
	(0.025)	(0.047)	(0.047)	(0.045)	(0.051)
POPSIZE(ln)	0.438***	1.025***	0.803***	0.756***	0.445***
	(0.030)	(0.052)	(0.051)	(0.048)	(0.059)
PUBTRA(ln)	0.323***	0.257***	0.211***	0.103***	0.095***
	(0.024)	(0.024)	(0.023)	(0.022)	(0.022)
Constant	3.502***	1.426***	-1.904***	-0.422	0.575
	(0.294)	(0.322)	(0.348)	(0.816)	(0.855)
Variance Components					
Regional-level	0.018	0.020	0.003	0.016	0.005
Provincial-level	0.852	0.752	0.534	0.502	0.633
Log Likelihood	-3868.14	-3770.19	-3626.51	-3264.41	-2959.23
AIC	7750.27	7556.37	7271.03	6550.81	5960.47

Notes:
1. †p<0.1; *p<0.05; **p<0.01; ***p<0.001(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. AIC=Akaike information criterion

Table 3.8

Multilevel Estimates of Industrialization and Dust Emission in China

	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed-Effect					
GDPPC(ln)		0.557***	0.150*	0.103†	0.138*
		(0.052)	(0.059)	(0.056)	(0.065)
MAINDU(ln)			1.233***	1.257***	0.909***
			(0.092)	(0.228)	(0.239)
INDUSTR(ln)				-0.858**	-0.584*
				(0.266)	(0.279)
IELECON(ln)				0.327***	0.235***
				(0.016)	(0.018)
RESBINDUSTC					-0.260***
					(0.035)
2005					-0.002
					(0.064)
2006					0.079
					(0.065)
2007					-0.030
					(0.066)
2008					-0.205**
					(0.069)
2009					-0.351***
					(0.071)
2010					-0.473***
					(0.073)
2011					-0.589***
					(0.078)
2012					-0.005
					(0.082)
2013					-0.154†
					(0.084)
Control Variables					
CONSUM(ln)	0.204***	-0.244***	1.485	-0.288***	-0.075
	(0.026)	(0.049)	(0.360)	(0.050)	(0.056)
POPSIZE(ln)	0.569***	1.051***	0.866***	0.861***	0.552***
	(0.031)	(0.055)	(0.055)	(0.054)	(0.065)
PUBTRA(ln)	0.166***	0.111***	0.074**	-0.028	-0.032
	(0.025)	(0.025)	(0.025)	(0.025)	(0.024)

Table 3.8 Continued

	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	3.185***	1.485***	-1.252**	-1.424	-0.109
	(0.330)	(0.360)	(0.391)	(0.920)	(0.948)
Variance Components					
Regional-level	0.092	0.090	0.064	0.105	0.078
Provincial-level	0.675	0.611	0.464	0.422	0.479
Log Likelihood	-3972.61	-3909.86	-3822.34	-3591.09	-3221.73
AIC	7959.23	7835.72	7662.67	7204.18	6485.46

Notes:
1. †p<0.1; *p<0.05; **p<0.01; ***p<0.001(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. AIC=Akaike information criterion

Table 3.9

Multilevel Estimates of Urbanization and SO_2 Emission in China

	Model 6	Model 7	Model 8
Fixed-Effect			
GDPPC(ln)	0.687***	0.663***	0.692***
	(0.048)	(0.048)	(0.055)
URBAN(ln)	0.548***	0.568***	0.256***
	(0.033)	(0.034)	(0.041)
POPD(ln)		-0.098***	0.047*
		(0.027)	(0.028)
CITYLEVEL			0.546***
			(0.067)
2005			-0.053
			(0.0640
2006			0.0285
			(0.064)
2007			-0.066
			(0.066)
2008			-0.192**
			(0.069)
2009			-0.363***
			(0.072)
2010			-0.461***
			(0.074)
2011			-0.635***
			(0.079)
2012			-0.703***
			(0.083)
2013			-0.850***
			(0.087)
Control Variables			
CONSUM(ln)	-0.417***	-0.385***	0.025
	(0.046)	(0.047)	(0.054)
POPSIZE(ln)	1.244***	1.222***	0.550***
	(0.052)	(0.052)	(0.066)
PUBTRA(ln)	0.216***	0.215***	0.190***
	(0.024)	(0.023)	(0.024)
Constant	2.928***	3.396***	-0.163

Table 3.9 Continued

	Model 6	Model 7	Model 8
VarianceCom	(0.335)	(0.350)	(0.546)
Regional-level	0.030	0.009	0.070
Provincial-level	0.819	0.823	0.959
Log Likelihood	-3599.92	-3593.41	-3194.26
AIC	7217.84	7206.83	6428.52

Notes:
1. †$p<0.1$; *$p<0.05$; **$p<0.01$; ***$p<0.001$(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. AIC=Akaike information criterion

Table 3.10

Multilevel Estimates of Urbanization and Dust Emission in China

	Model 6	Model 7	Model 8
Fixed-Effect			
GDPPC(ln)	0.571***	0.520***	0.538***
	(0.051)	(0.051)	(0.059)
URBAN(ln)	0.431***	0.474***	0.209***
	(0.035)	(0.036)	(0.043)
POPD(ln)		-0.202***	-0.086**
		(0.029)	(0.030)
CITYLEVEL			0.407***
			(0.071)
2005			-0.048
			(0.068)
2006			-0.024
			(0.068)
2007			-0.167*
			(0.070)
2008			-0.381***
			(0.073)
2009			-0.603***
			(0.076)
2010			-0.751***
			(0.079)
2011			-0.917***
			(0.084)
2012			-0.390***
			(0.088)
2013			-0.580***
			(0.092)
Control Variables			
CONSUM(ln)	-0.369***	-0.301***	0.040
	(0.049)	(0.050)	(0.057)
POPSIZE(ln)	1.229***	1.184***	0.607***
	(0.056)	(0.055)	(0.071)
PUBTRA(ln)	0.080**	0.077**	0.049†
	(0.025)	(0.025)	(0.026)

Table 3.10 Continued

	Model 6	Model 7	Model 8
Constant	2.671***	3.638***	0.996†
	(0.379)	(0.383)	(0.572)
Variance Components			
Regional-level	0.110	0.067	0.092
Provincial-level	0.639	0.627	0.697
Log Likelihood	-3794.80	-3770.23	-3357.44
AIC	7607.59	7560.46	6754.88

Notes:
1. †$p<0.1$; *$p<0.05$; **$p<0.01$; ***$p<0.001$(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. AIC=Akaike information criterion.

Table 3.11

Multilevel Estimates of Globalization and SO_2 Emission in China

	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14
Fixed-Effect						
GDPPC(ln)	0.656***	0.726***	0.800***	0.786***	0.039	0.102
	(0.055)	(0.062)	(0.064)	(0.065)	(0.094)	(0.094)
TRADE(ln)	0.250***	0.177***	0.161***	0.159***	0.149***	0.061*
	(0.028)	(0.029)	(0.031)	(0.032)	(0.031)	(0.030)
FDI(ln)		0.040*	0.017	0.016	0.048*	-0.015
		(0.019)	(0.020)	(0.021)	(0.020)	(0.020)
FIHTM (ln)			0.030*	0.025	0.005	0.020
			(0.016)	(0.016)	(0.016)	0.015
FIWEST (ln)				0.009	0.016	0.012
				(0.018)	(0.018)	(0.017)
DCIV(ln)					0.532***	0.560***
					(0.049)	(0.048)
SEZOCC						0.082
						(0.066)
2007						-0.091
						(0.057)
2008						-0.259***
						(0.058)
2009						-0.414***
						(0.059)
2010						-0.542***
						(0.062)
2011						-0.720***
						(0.065)
2012						-0.783***
						(0.069)

Table 3.11 Continued

	Model 9	Model 10	Model 11	Model12	Model 13	Model 14
2013						-0.901**
						(0.072)
Control Variables						
CONSU(ln)	-0.557***	-0.640***	-0.724***	-0.710***	-0.70***	-0.224**
	(0.055)	(0.061)	0.061	0.061	0.060	0.060
POPSIZ(ln)	1.170***	1.276***	1.352***	1.339***	0.826***	0.170*
	(0.059)	(0.062)	0.063	0.063	0.078	0.083
PUBTR(ln)	0.308***	0.301***	0.336***	0.319***	0.288***	0.161***
	(0.030)	0.030	0.030	0.0303	0.030	0.029
Constant	3.405***	3.439***	3.423***	3.476***	5.385***	3.109***
	(0.414)	0.450	0.460	0.467	0.478	0.586
Variance Components						
Regional-level	0.055	0.057	0.073	0.076	0.049	0.023
Provincial-level	0.864	0.880	0.777	0.773	0.680	0.733
Log Likelihood	-2789.32	-2607.41	-2485.19	-2427.32	-2369.67	-2029.46
AIC	5598.65	5236.82	4994.38	4880.65	4767.34	4102.92

Notes:

1. †p<0.1; *p<0.05; **p<0.01; ***p<0.001(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. AIC=Akaike information criterion

Table 3.12

Multilevel Estimates of Globalization and Dust Emission in China

	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15
Fixed-Effect						
GDPPC(ln)	0.649***	0.746***	0.777***	0.763***	0.178	0.164
	(0.061)	(0.069)	(0.073)	(0.075)	(0.109)	(0.111)
TRADE(ln)	0.132***	0.062†	0.060†	0.061†	0.053	-0.005
	(0.031)	(0.033)	(0.036)	(0.036)	(0.036)	(0.035)
FDI(ln)		0.030	0.017	0.021	0.046†	-0.001
		(0.021)	(0.023)	(0.024)	(0.024)	(0.023)
FIHTM(ln)			0.034†	0.033†	0.018	0.030†
			(0.018)	(0.018)	(0.018)	(0.017)
FIWEST(ln)				0.001	0.007	0.023
				(0.021)	(0.020)	(0.020)
DCIV(ln)					0.416***	0.403***
					(0.057)	(0.056)
SEZOCC						0.405***
						(0.077)
2007						-0.142*
						(0.067)
2008						-0.394***
						(0.068)
2009						-0.606***
						(0.070)
2010						-0.798***
						(0.072)
2011						-0.981***
						(0.076)
2012						-0.470***
						(0.081)
2013						-0.668***
						(0.084)
Control Variables						
CONSUM (ln)	-0.412***	-0.495***	-0.556***	-0.541***	-0.532***	-0.101
	(0.061)	(0.068)	(0.069)	(0.070)	(0.069)	(0.071)
POPSIZE(ln)	1.128***	1.255***	1.303***	1.291***	0.889***	0.270**

Table 3.12 Continued

	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15
	(0.065)	(0.070)	(0.072)	(0.073)	(0.091)	(0.098)
PUBTRA(ln)	0.099**	0.100**	0.117**	0.111**	0.087*	0.003
	(0.033)	(0.033)	(0.034)	(0.035)	(0.035)	(0.034)
Constant	1.716***	1.520**	1.644**	1.666**	3.157***	1.876**
	(0.457)	(0.496)	(0.511)	(0.522)	(0.548)	(0.674)
Variance Components						
Regional-level	0.116	0.095	0.100	0.010	0.081	0.039
Provincial-level	0.626	0.663	0.616	0.616	0.545	0.508
Log Likelihood	-3012.09	-2857.18	-2760.88	-2718.84	-2692.39	-2340.49
AIC	6044.17	5736.36	5545.76	5463.68	5412.79	4724.99

Notes:
1. †p<0.1; *p<0.05; **p<0.01; ***p<0.001(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. AIC=Akaike information criterion

Table 3.13

Multilevel Estimates of Economic Development, Industrialization, Urbanization, Globalization and Air Pollution in China, 2004-2013

	SO_2 Emission		Dust Emission	
	Model 15	Model 16	Model 15	Model 16
GDPPC(ln)	0.253***	0.394***	0.251**	0.309**
	(0.070)	(0.079)	(0.085)	(0.094)
MAINDU(ln)	1.213***	0.749**	1.596***	1.066**
	(0.234)	(0.244)	(0.283)	(0.295)
INDUSTR(ln)	-0.815**	-0.677*	-1.446***	-1.168**
	(0.274)	(0.290)	(0.330)	(0.345)
IELECON(ln)	0.333***	0.240***	0.311***	0.224***
	(0.019)	(0.020)	(0.023)	(0.024)
URBAN(ln)	0.174***	0.039	0.048	-0.059
	(0.036)	(0.041)	(0.044)	(0.049)
POPD(ln)	-0.147***	-0.025	-0.260***	-0.135***
	(0.027)	(0.029)	(0.032)	(0.034)
TRADE(ln)	0.082**	0.048*	-0.008	-0.023
	(0.028)	(0.028)	(0.034)	(0.034)
FDI(ln)	0.005	-0.016	0.011	-0.008
	(0.018)	(0.019)	(0.022)	(0.022)
FIHTM(ln)	0.023	0.036*	0.042*	0.050**
	(0.014)	(0.015)	(0.017)	(0.017)
FIWEST(ln)	0.001	0.018	0.001	0.031
	(0.016)	(0.016)	(0.019)	(0.019)
RESBINDUSTC		-0.320***		-0.297***
		(0.035)		(0.042)
CITY LEVEL		0.196**		0.102
		(0.072)		(0.086)
SEZOCC		0.057		0.331***
		(0.064)		(0.076)
2007		-0.071		-0.117†
		(0.058)		(0.064)
2008		-0.169*		-0.292***
		(0.061)		(0.067)
2009		-0.279***		-0.462***
		(0.064)		(0.071)
2010		-0.348***		-0.645***

Table 3.13 Continued

	SO_2 Emission		Dust Emission	
	Model 15	Model 16	Model 15	Model 16
		(0.067)		(0.075)
2011		-0.491***		-0.786***
		(0.072)		(0.081)
2012		-0.517***		-0.239***
		(0.078)		(0.088)
2013		-0.610***		-0.440***
		(0.083)		(0.093)
Control Variables				
CONSUM(ln)	-0.593***	-0.247***	-0.429***	-0.123
	(0.063)	(0.069)	(0.076)	(0.082)
POPSIZE(ln)	1.073***	0.664***	1.010***	0.607***
	(0.067)	(0.079)	(0.081)	(0.094)
PUBTRA(ln)	0.192***	0.160***	-0.025	-0.042
	(0.028)	(0.029)	(0.034)	(0.035)
Constant	1.491	-0.048	-1.818	-2.077***
	(0.942)	(1.078)	(1.153)	(1.275)
Variance Components				
Regional-level	0.000	0.037	0.047	0.041
Provincial-level	0.574	0.661	0.420	0.444
Log Likelihood	-2067.45	-1869.93	-2480.52	-2206.28
AIC	4170.89	3795.86	4997.04	4468.56

Notes:
1. †$p<0.1$; *$p<0.05$; **$p<0.01$; ***$p<0.001$(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. AIC=Akaike information criterion

CHAPTER 4

THE DYNAMICS OF DEVELOPMENT AND WATER POLLUTION

Remarkable economic development in China has greatly reduced the level of poverty and improved the quality of life since the policies of reform and opening up were adopted in 1978. Meanwhile, rapid development during the same period posed serious environmental challenges. According to the World Bank (2006), a water crisis in terms of its quantity and quality is the most challenging for China. It is commonly recognized that the health of ecosystems and humans depends heavily on the quantity and quality of the water resources available. Water is necessary for all biological life and clean water is essential to human health. Since there are different indicators of the adequacy of water resources, including availability, use, quality, and access, water issues are by nature interdisciplinary and multifaceted. Given the crucial role of water in maintaining healthy ecosystems and human life, studies of the human impact on water resources are mostly concentrated on water consumption, water access, flood control, and water pollution.

Water pollution is one of the more pressing environmental problems for China. The deterioration of water quality in China began in the 1980s (Ebenstein, 2012). The water monitoring system shows that in 1996, about 40% of the monitored river water did not meet minimum water quality standards, while roughly 70% of the monitored river water was unsafe for drinking in 2006. However, it is estimated that about 115 million farmers in rural areas still rely heavily on surface water as their main source of drinking water (World Bank, 2006). In urban areas, approximately three-quarters of surface water and 55% of the ground water is polluted and considered unsuitable for drinking.

According to Yale's Environmental Performance Index 2006 & 2014, China is one of the worst performers (116 out of 133 countries in 2006 and 109 out of 178 countries in 2014) in access to clean drinking water and sanitation. It is worth noting that water scarcity can exacerbate water pollution. Specifically, the deterioration of water quality in China is compounded with the scarcity and uneven distribution of water. First, water is scarce in China. Although China has the fifth largest endowment of fresh water resources in the world, by per capita it is about one quarter of global average (World Bank, 2003). In a survey of more than 600 cities in China, 1 in 6 had severe water shortage (Li, 2003). Second, water is unevenly distributed across the nation. It is estimated that 83% of water is concentrated in South China (South of Yangze River), while 17% of water is overexploited to support 41% of its population in North China. In many water-scarce provinces in North China, the average annual water availability per capita is less than one tenth of the world average (World Bank, 2006). Moreover, Ebenstein (2012) points out that water quality in rivers and wells is greatly affected by the amount of rainfall and the dilution of chemicals in the waterways. The striking differences of interannual and seasonal variations in rainfall between South and North China further exacerbate water pollution across regions.

Data from the WHO demonstrate that it is the poor, the young, the women, the elderly, and excluded groups who suffer most from poor sanitation. Inadequate access to clean water and sanitation in rural areas and unhealthy water in urban areas can result in acute waterborne diseases such as diarrhea (Bryce et al., 2005; Jalan & Ravallion, 2003) and typhoid (Cutler & Miller 2005), and increasing infant mortality (Galiani et al., 2005). There is a growing concern about the link between water pollution and cancer (Economy, 2004; Gulis et al., 2002). Tao et al. (1999) find that halogenated hydrocarbons, a by-product of chlorine, result in higher rates of esophageal cancer in men in Shanghai, China. Codd (2000) finds that polluted water becomes populated with cyanobacteria (blue-green algae), leading to the formation of microcystins, which have been linked directly to liver cancer. Gulis et al. (2002) estimate that overall cancer incidence and stomach cancer is higher in polluted areas in Slovakia. Beaumont et al. (2008) confirmed the finding that there is a higher risk ratio for stomach cancer in areas where drinking water was contaminated. Griffiths (2007) indicated that incidents of contaminated river water from industrial activity have led to outbreaks of cancer in rural villages in China.

It is a widely held view that human activities play a significant role in influencing water availability and quality (Leichenko & O'brien, 2008). There are a large number of studies interpreting the relationship between economic development and water pollution in terms of the Environmental Kuznets Curve (Lee et al., 2010; Paudel et al., 2005; Thompson, 2014). However, methodologically, Lin and Liscow (2013) observed that the reduced form model of the EKC has a potential endogeneity problem. The World Bank (2006) pointed out that rapid industrialization and urbanization generates numerous amounts of water pollutants, lowering water quality. Broadly, there are three main categories of water pollution emissions in China: industrial, municipal, and agricultural (World Bank, 2006). Ebenstein (2012) examined the effect of industrialization on water pollution and confirmed that extensive use of fertilizers by farmers and industrial wastewater dumping by manufacturing firms have polluted water in many rivers. Consistent with the findings of the World Bank (2006), Conca (2006) also noted that urban growth and industrial expansion has greatly increased water demands. Most existing studies on the environmental impact of globalization focus on either water pollution or water marketization (Kalami et al., 2013). For instance, Kalami et al. (2013) found that increasing FDI leads to growth in the amount of water pollution in developing countries. However, systematic analysis of the relationship between development and water pollution across regions and over time is lacking. This study primarily examines the effect of development, conceptualized as a triple process of industrialization, urbanization, and globalization, on water pollution in China. Theoretically, as illustrated in Chapters 1 and 2, I develop a systematic framework to understand water pollution in China. Using longitudinal data 2004-2013, I first analyze the spatial and temporal pattern of water pollution at the provincial level and then apply multilevel modeling analysis at the prefecture-city level to examine the driving forces of water pollution. The findings, based on different regression models across the cities of China, indicate that the relationships between the dynamics of development and water pollution are complex.

Literature Review

Economic Development and Water Pollution

The inverted U-shape between economic development and environmental degradation was first described by the World Bank (1992). Then the finding was further explored in the pioneering empirical study of Grossman and Krueger (1995), who noted that the Environmental Kuznets Curve (EKC) resembles the pattern of income and inequality described by Simon Kuznets (1955). Essentially, the EKC hypothesized that in the earlier stage of development, economic growth increases environmental degradation, then decreases environmental degradation after economic development reaches a turning point. That is, economic growth is initially positively associated with environment pollution, and then negatively associated with environmental destruction after the peak of the inverted U-shape.

Since the initial study by Grossman and Krueger (1995), there have been a considerable number of EKC studies published using different indicators of environmental pollution, including air pollution (Merleyde et al., 2006), water pollution (Paudel et al., 2005; Paudel & Schafer, 2009), deforestation (Barbier, 2004; Culas, 2007), and regression models with cross-sectional data and time-series data. The findings are mixed and confounding. For example, many empirical studies confirmed the EKC, indicating that there is an inverted U-shape between economic development and air pollution. Some other studies also found that whether the EKC is confirmed is highly dependent on the specific indicators of air pollution that are used. In terms of the EKC and water pollution, the findings are very controversial. Some studies confirmed the EKC hypothesis (Cole, 2004; Torras & Boyce, 1998). For example, using nonpoint surface water data at state level, Paudel et al. (2005) confirmed the EKC hypothesis on water pollution in Louisiana. Meanwhile, the findings of other studies are not consistent with the hypothesis of the EKC for water pollution. Lee et al. (2010) found there is no evidence supporting the EKC on water pollution using global level data from 97 countries during the period 1980-2001. Based on the previous empirical studies of the

EKC hypothesis, Dinda (2004) noted that the EKC hypothesis is more likely to hold for short-term environmental pollution locally than long-term environmental impacts globally. The interest of this chapter is to test the EKC hypothesis on water pollution using prefecture-city level data across regions and over time in China. Therefore, I propose the following hypothesis.

Hypothesis 1: The economic development level is positively associated with water pollution over time. That is, economic development will exacerbate water quality.

The existing literature theoretically and empirically presents the underlying mechanisms that are responsible for the EKC hypothesis. Theoretically, Environmental Modernization Theory (EMT) highlights that the most serious environmental problems have been caused by modernization and industrialization, and can ultimately be solved through super-modernization and industrialization. Along with the increasing level of economic development, EMT lays out how different agents respond to environmental deterioration. In specific, EMT provides alternative solutions to address environmental challenges through various technological advances and innovation and increasing environmental consciousness of the citizens. Empirically, the EKC studies generally found that structural change and technological progress serve as the main mechanisms for supporting the EKC (Dinda, 2004). Ekin (1997) found that the empirical results of the EKC greatly vary across regions. Lee et al. (2010) confirmed the regional disparities of the EKC hypothesis on water pollution. As Jorgenson and Clark (2012) noted, the decoupling between economic development level and environmental degradation is more likely to occur in more developed regions. In short, environmental conditions would greatly improve first in the regions where a higher level of economic development has been achieved. The corresponding second proposed hypothesis is as follows:

Hypothesis 2: There are different patterns of the relationship between economic development level (GDP per capita) and water pollution across regions. In other words, GDP per capita is significantly positively associated with water pollution in the least developed regions, while negatively associated after a turning point in the more developed regions.

Industrialization and Water Pollution

Industrialization involves both increasing human well-being by providing higher standards of living and undermining human well-being by generating pollution. Substantive studies show that industrial pollution is the main contributor to water pollution. Hettige et al. (2000) note that the first stages of economic development typically witness rapid industrial expansion and declining water quality. Using factory-level data provided by National Environmental Protection Agency, Dasgupta et al. (2001) assess the water pollution abatement costs for Chinese industry. They suggest that changing to a full emissions charge system would greatly reduce overall abatement costs, while uniform pollution charges could produce higher water quality. The report from the World Bank (2006) show that, to a large extent, the significant deterioration of water quality in China is linked with rapid industrialization, which generated a large amount of water pollutants. Ebenstein (2012) concluded that industrialization has led to a severe deterioration in water quality in the country's lakes and rivers, leading China to become one of the world's worst polluters. More specifically, he found that the deterioration of water quality is caused by both the point and nonpoint source pollution, which increase dramatically due to the rapid industrialization. Hettige et al. (2000) found that material-intensive industrial production tends to be pollution-intensive. Inconsistent with the finding, Ebenstein (2012) argues that chemical sectors are the largest polluter for water, accounting for 19% of the dumping of the industrial wastewater. To summarize, most prior studies extensively examined how industrialization has impacted water pollution across sectors. However, few studies systematically explore how industrialization differentially affects water pollution across regions in China.

Hypothesis 3: Industrialization is positively associated with water pollution. That is, the higher the rate of industrialization, the greater the level of water pollution will be.

<u>Urbanization and Water Pollution</u>

By definition, urbanization refers to change in size, density, and heterogeneity of the places where an increasing proportion of the population lives (Fernando, 2009). It is well established that urbanization entails the expansion of energy production and corresponding environmental degradation (increasing water and air pollution) due to transportation and industrial activities (Gupta, 2012; York, 2007). Although living in cities offers potential access to better health care systems, the densely populated urban environments could introduce health hazards and concentrate health risks. The World Health Organization (WHO, 2010) recognizes that the health challenges linked to the process of urbanization could be related to the deterioration of water quality.

In China, the growing urban population has been accommodated through rapid expansion of existing cities and the emergence of new cities (World Bank, 2006). Specifically, rapid urban growth results in a rising water demand from the established water supply system. Areas on the edges of rapidly expanding Chinese cities, where housing and infrastructure are often inadequate and unregulated small businesses proliferate, are particularly likely to lack adequate sanitation and pollution controls. According to Chinese Academy for Environmental Planning (2004), urban growth will lead to an increase in water demand of 6.5, 32, and 35% from agricultural, industrial, and residential consumption, respectively, from 2003 to 2020. According to Wu and Tan (2012), due to growing domestic water consumption and limitations of industrial water use reduction, total urban water demand will increase continuously along with urbanization. However, with a relatively constant water supply, the increased water demand will have to be met mainly through water savings and improved water quality (World Bank, 2006). The increasing scale and pace of urbanization poses challenging threats to clean water and sanitation (Holdaway, 2010; Jia et al., 2014; Zeng et al., 2015). This suggests the following hypothesis:

Hypothesis 4: The rate of urbanization is positively associated with water pollution. That is, the higher the rate of urbanization, the higher the level of water pollution will be.

After controlling population size, proponents of New Urbanism argued that population density is a vital indicator in examining urbanization and the environment (Glaeser, 2011; Goal, 2006). Goel (2006) argued that there is a direct relationship between population density and the level of water pollution. Sheribin et al. (2011) found that population distribution plays a significant role in impacting the water supply and water quality. That is, the spatial structure of water pollution should be related to spatial pattern of the population distribution. More importantly, high population density is predicted to be an important risk factor for water-associated disease across the developing countries, especially in Africa and Asia (Schmidt et al., 2011; Yang, 2012). Accordingly, here I propose the following hypothesis.

Hypothesis 5: Population density is positively linked with water pollution. That is, the higher the population density of a city, the higher the level of water pollution will be.

International Trade and Water Pollution

At the international level, the environment has been greatly transformed and shaped by the accelerating pace and scale of globalization (IMF, 2002; Smith, 2006). However, the existing literature on the environmental impact of globalization is highly mixed theoretically and empirically (Christmann & Taylor, 2001; Lenzen et al., 2012). Specifically, globalization itself is widely recognized as a complicated process that has both positive and negative environmental impacts. Globalization proponents argue that lower barriers to international trade and foreign investment encourage firms to transfer advanced environmental technologies from developed countries with strict environmental standards to developing countries. Moreover, the global process can also increase self-regulation pressures on firms. In contrast, globalization opponents contended that increasing international trade encourages governments to lower production costs within their jurisdiction by neglecting to enact laws to protect the environment (Drezner, 2000; Gray, 2002; Zhang & Fu, 2008).

The theory of ecologically unequal exchange posits that in the global economy, the developed countries are more advantaged than developing countries in terms of the environmental impact of their prosperity. In the international trade, exports flowing from developing countries to developed countries are often at the environmental expense of the former. In a cross-national panel analysis of deforestation, Jorgenson (2006) found that developed countries with "higher levels of resource consumption externalize their consumption-based environmental costs to developing countries, which increase levels of environmental degradation within the latter" (Jorgenson, 2006, p. 691).

In terms of water, similarly, some scholars provide evidence that developed countries increasingly import water-intensive goods from developing countries to alleviate pressure on domestic water resources, which in turn increases water scarcity and pollution within the latter (Dalin et al., 2012; Lenzen et al., 2013). Therefore, to a large extent, many of the consumer goods that people in the developed countries enjoy are exported from developing countries that bear the environmental costs of their production. The higher levels of commodities exported from developing to developed countries, the greater the rates of environment degradation within the former become. Not surprisingly, the environmental impact of globalization through international trade is uneven both between nations and within nations (Paehlke, 2001; Roberts & Parks, 2007). Therefore, my proposed hypothesis for international trade is as follows:

Hypothesis 6: Exports are positively linked with water pollution across China. That is, the higher the level of exports from a city, the higher the level of water pollution will be.

Foreign Direct Investment (FDI) and Water Pollution

There are two main hypotheses have been grouped in the numerous empirical studies: one is the "pollution haven hypothesis," and the other is the "pollution halo hypothesis." The pollution haven hypothesis suggests that lax natural environmental standards attract the dirtiest and most polluting industries to developing countries. Foreign investors from developed countries are attracted by weak labor laws and weak environmental protection regulations in developing countries, thus creating pollution havens and propelling a global "race to the bottom" in environmental standards. The proponents of the pollution haven hypothesis claim that the effect of FDI on environmental degradation manifests itself in several ways. First, free trade and the market may erode infant industry sectors in developing countries (Gilpin, 2001). Second, unlike developed countries, the developing countries tend to have less strict domestic environmental regulations (Frey, 2003; Redclift & Sage, 1998). For example, central and local governments of developing countries are competing among themselves to attract foreign investors by providing the lowest taxes and the least stringent labor and environmental regulations (Babb, 2005).

More importantly, developing countries are generally less likely to ratify international environmental treaties due to a disadvantageous position in the world economy, environmental vulnerability, and domestic institutional structures (e.g., less voice and accountability) (Jorgenson et al., 2007; Roberts, 1996; Roberts et al., 2004). Therefore, to prevent capital flight, the developing countries are also less likely to effectively enforce and implement the relevant domestic environmental regulations that already exist (Frey, 2006). Eventually, a large portion of foreign direct investment attracted to developing countries finances ecological inefficiency and concentrates in highly polluting and labor-intensive manufacturing facilities and processes outsourced from developed countries (Jorgenson, 2006; Jorgenson et al., 2007), which are significantly detrimental to the environment (especially water and air). Therefore, the proposed hypothesis is the following:

Hypothesis 7: FDI is negatively linked to water pollution in China over time. That is, the higher FDI in cities, the lower the level of water pollution will be.

The research findings on the effects of globalization on the environment are inconsistent, and suggest the need for further systematic research. Some studies confirm that globalization might have positive environmental effects because global ties increase self-regulation pressures on firms in low-regulation countries. Using survey data from firms, Christmann and Taylor (2001) found that multinational ownership increases self-regulation of environmental performance. Moreover, different ownership arrangements have different environmental effects. For instance, equity joint ventures in highly polluting industries funded through Hong Kong, Macao, and Taiwan are attracted by weak environmental standards. Equity joint ventures funded from nonethnic Chinese sources are not significantly attracted by weak standards, regardless of the pollution intensity of the industry (Dean et al., 2009). Similar to the analysis in air pollution, given the export-oriented development strategy China adopted, it is difficult to generalize the findings if we only take total FDI of a country into account since FDI is unevenly distributed across the nation. Therefore, the last proposed hypothesis is to further our understanding of whether FDI is beneficial or detrimental to the water quality depending on the source of FDI. Following the study by Dean et al. (2009), the corresponding hypotheses are as follows:

Hypothesis 8: The foreign capital from Hong Kong, Macao, and Taiwan are more likely to increase water pollution. That is, the higher investment of foreign capital from

HMT a city attracts, the more severely polluted its water will become.

Hypothesis 9: The sources of foreign capital from Western countries are more likely to decrease water pollution. That is, the higher investment of foreign capital from Western countries a city attracts, the less severely polluted its water will become.

Data and Methods

This study examines the effects of economic development, industrialization, urbanization, and globalization on water pollution across China's regions and over the time period 2004-2013. The data mainly come from the China City Statistical Yearbook 2004-2013 and the China Regional Economy Statistical Yearbook 2006-2013. Complementary data are from the China Statistical Yearbook 2004-2013 and the China Environmental Statistical Yearbook 2004-2013. To test the proposed hypotheses, the data analyzed in this study includes 287 cities (4 municipalities and 283 prefecture-level cities), covering 31 provinces, autonomous regions, and the municipalities directly under the central government in eastern, central, and western regions of China.

Dependent Variables

The dependent variable is water pollution. The measurement of water pollution is total wastewater discharge, which is defined as the annual volume of wastewater discharge (10 thousand tons per year). According to the Environmental Protection of Agency (EPA), wastewater is the water containing wastes from agricultural, industrial, and residential processes, and requires treatment to remove pollutants prior to discharge. Therefore, wastewater is an important source of water pollution. It is estimated that at least 30% of the industrial wastewater in China is directly released into rivers and lakes without treatment. The data come from the China City Statistical Yearbook.

Table 4.1 presents the changes of total wastewater discharges across provinces through 2004-2013. During the past 10 years, there are different change trends of water pollution across regions. Water pollution increased in both eastern and central regions, while it declined in the western region. Within the region, there are different trends across provinces. Water pollution declined in some provinces of the eastern region such as Beijing, Tianjin, Shanghai, and Jiangsu, but increased rapidly in some other provinces such as Hebei, Shandong, and Guangdong. Some provinces in the central region such as Shanxi, Henan, and Jiangxi witnessed the increase of water pollution, while some other provinces including Heilongjiang, Hubei, and Hunan witnessed the dramatic decline. Water pollution in Chongqing and Sichuan declined dramatically, while increasing in the rest of the western region except Ningxia.

Independent Variables

GDP per capita. The key independent variable is measured by GDP per capita (see Table 3.3), a commonly used indicator of overall economic development level and quality of life. Per capita GDP, as the original indicator of economic development in terms of standard of living, has two important implications. First, per capita GDP is used to facilitate the comparison with the existing studies in China and elsewhere (Fan & Sun, 2008; Grossman & Krueger, 1995; Jorgenson & Clark, 2012; Tsui, 2007). Second, per capita GDP is one of the most “readily and consistently” available indicators for economic development in longitudinal analyses (Fan & Sun, 2008). The data at prefecture-city level are taken from the China City Statistical Yearbook and at the provincial level from the China Statistical Yearbook respectively, both of which are comprehensive and authoritative yearly statistics databases on the economy and social development. Descriptive statistics for dependent and independent variables are presented in Table 3.4.

Industrialization. There are three measurements of industrialization. The first is the percentage of the economy that is generated by secondary industry. According to the data, in 2009, the two prefecture-level cities with highest level of industrialization are Karamy (90.87%) in Xinjiang and Daqing (85.08%) in Heilongjiang province, both of which are important oil producing and refining centers in China. The prefecture-level cities with lowest level of industrialization in 2006 are Pingliang (9%) in Gansu province and Heihe (15.73%) in Heilongjiang province. The second measure is the ratio of secondary industry to the total of nonagriculture industry in terms of GDP, indicating the shifting of the economic structure away from manufacturing industries to service industries. The third variable is total amount of industrial electricity consumption (10,000 kwh). The prefecture-level cities with highest amount of industrial electricity consumption are Tangshan (481 million kwh) in Hebei province and Dongguan (452 million kwh) in Guangdong province. Tangshan is an important heavy industrial city in North China, while Dongguan is an industrial city and major manufacturing hub by attracting foreign direct investment. The prefecture-level cities with lowest amount of industrial electricity consumption are Zhongwei, Longnan, and Dingxi, all of which are located in Gansu province. All of the above data are from the China City Statistical Yearbook. Additionally, I compute a dummy variable, RESBINDUSTC, indicating whether a city is a resource based industrial city. Such cities, highly dependent on natural resources, are more likely to have the single resource-based industry as the pillar industry of the economy and more environmentally polluting (Hong et al., 2011; Mao, 2014)

Urbanization. There are three measurements of urbanization. The first is total urban population size (the absolute size of the urban population). The second is the level of urbanization (the relative size of urban population to total population). The prefecture-level cities with highest level of urbanization in 2013 are Karamay (100%) in Xinjiang and Shenzhen (100%) in Guangdong province. The prefecture-level cities with lowest level of urbanization in 2012 are Ulanqab in Inner Mongolia and Dazhou in Sichuan province. The third is population density (number of residents per square kilometer). In 2013, the prefecture-level cities with highest population density are Dongguan and Shantou in Guangdong province, while the prefecture-level cities with lowest population density in 2013 are Jiuquan (5.10) in Gansu province and Hulunbuir (10.51) in Inner Mongolia. The data are from the China City Statistics Yearbook. In addition, I compute a dummy variable, CITY LEVEL, indicating whether a city is designated as a municipality, provincial capital or sub-provincial city.

Globalization. International trade is an important part of globalization. International trade is measured by the sum of imports and exports (10,000 dollar). The prefecture-level city with highest amount of trade is Shenzhen (4,688 million dollars in 2013) in Guangdong, while the city with lowest amount of trade is Guyuan (200,000 dollars in 2013) in Gansu province. To further explore the composition of international trade, I choose the variable EXPORT, measured by total amount of goods exported (10,000 dollar). Similar to international trade, the prefecture-level cities with highest amount of exports is Shenzhen (2,714 million dollars in 2013) in Guangdong, while the city with lowest amount of trade is Ankang (10,000 dollars in 2006) in Shaanxi province. The data are from the China Regional Economy Statistical Yearbook 2006-2013.

International capital flow is another important feature of globalization. Foreign direct investment (FDI) is a commonly used measurement of international capital flows. In this study, FDI is measured by the total amount of realized FDI (10,000 dollar). The prefecture-level cities with highest amount of FDI are Dalian (123 million dollars in 2013) in Liaoning province and Suzhou (92 million dollars in 2013) in Jiangsu province. The prefecture-level cities with lowest amount of FDI are Zhongwei ($ 20,000 in 2005) in Gansu province and Hegang ($120,000 in 2004) in Heilongjiang province. In terms of the sources of foreign capital, it is measured by the absolute amount (Yuan), generally divided into foreign capital from Hong Kong, Taiwan, and Macao (HTM) and from Western countries. The provinces with highest amount of foreign capital from HTM are Guangdong, Jiangsu, Zhejiang, and Fujian, while with lowest amount are Gansu and Guizhou. The prefecture-level cities with highest amount of foreign capital from HTM are Shenzhen (5,235 million yuan in 2013) in Guangdong province and Suzhou (4,978 million dollars in 2013) in Jiangsu province. The prefecture-level cities with lowest amount of foreign capital from HTM are Qingyang and Jiayuguan in Gansu province. The provinces with highest amount of foreign capital from Western countries are Jiangsu, Guangdong, and Shandong, while those with lowest amount are Gansu and Shaanxi. The prefecture-level city with highest amount of foreign capital from Western countries is Suzhou (140 million yuan in 2013) in Jiangsu province. The prefecture-level cities with lowest amount of foreign capital from western countries are Jiayuguan in Gansu province and Chifeng in Inner Mongolia. The data are from the China City Statistical Yearbook. In addition, I use the dummy variable SEZOCC, indicating whether a city is designated as a special economic zone or an open coastal city. According to Huang et al. (2011) and Zeng (2011), the cities designed as SEZ or OCC are more likely to promote international trade and attract FDI.

Additional Dummy Variables

Region. The first additional dummy variable included was labeled as *"Region,"* which quantifies if a province is located in eastern, central or western region in China.

Year. I take year as a dummy variable to indicate period-specific effect of explanatory variables on dependent variable. At the same time, year included is controlled as the fixed part for the linear increase of the independent variables in the models in order to guard against spurious associations among variables with common trends (Beckfield, 2006).

Control Variables

Consumption. Consumption, measured by the absolute value of total consumer goods sold per year, is controlled. The existing literature in treadmill of consumption theory shows that increased production of the amount of the goods requires increasing consumption, which in turn has an important impact on environment. Some other empirical studies in the context of China show that industrialization and urbanization have significantly influenced consumption and lifestyle in urban China (Zhao & Wang, 2015). To examine the role of industrialization and urbanization, consumption is held constant in the study.

Population size. Population size, measured by the absolute number of registered population, is held constant. There are a number of existing studies showing that population size is an important predictor in environmental degradation (Jorgenson & Clark, 2012; Rosa et al., 2004; York, 2007). Thompson (2013) provided evidence for the significant role of population in the model of the Environmental Kuznets Curve (EKC) in impacting the turning point. Therefore, population size is controlled in this study

Public transportation. Public transportation is defined as the indicator of infrastructure, which is widely recognized as the basic physical structures, and provides facilities, commodities, and services essential to enable, sustain, or enhance economic growth and social development (Lall & Rastogi, 2007; Sullivan & Sheffrin, 2003). Roads, ports, airports, communication networks, etc. are the key components. The study uses public transportation as the indicator of infrastructure due to unavailability of other components. The data come from the China City Statistical Yearbook.

Method

Methodologically, ordinary least squares (OLS) estimation is inappropriate for such longitudinal data due to heterogeneity bias within panels. Both fixed-effects model (FEM) and random effect models (REM) are identified as better techniques for comparative studies with panel data (Beckfield, 2006; Jorgenson & Kuykendall, 2008).

Specifically, the estimated model in this study,

$$WaterPollution=a+b*lnGDPPC+c*Industrialization+d*Urbanization+e*lnTRADE+f*lnEXPORT+g*lnFDI+h*lnFIHTM+i*lnFIWEST+j*lnCONSUM+k*lnPOPS+l*ln\,PUBTRA+e$$

FEM is used to examine the effect of economic development, industrialization, urbanization, and globalization on water pollution over the past 10 years, given that the Hausman test is significant and net of all time-varying variables. Random effect models (REM) not only include between/within-region variation, but also time-invariant variables. Since one of my primary interests is the economic development, industrialization, urbanization, and globalization on water pollution across regions, multilevel modeling would be a better choice than REM. Thus, multilevel modeling is applied to test the overall trend of water pollution across regions and time. More importantly, the joint effect of economic development, industrialization, urbanization, and globalization on water pollution is estimated.

The compiled dataset results in unbalanced, longitudinal data consisting of clusters of observations at different time points for each city. This is referred to as a variance component model that is designed to estimate between- and within-cluster correlations (Rabe-hesketh & Skrondal, 2005). Typically, for longitudinal data, occasions *i* is level-1 units and subject *j* is level-2 clusters. In this dataset, level-1 is year *i*, level 2 is city *j*, and level 3 is province *k*. In other words, 10 different time points from 2004 to 2013 are nested in each city which itself is nested in provinces. The level-1 model for city *j* in province *k* at year *i* is:

$$y_{ijk} = \beta + \tau_{1jk} + \varepsilon_{ijk}$$

Specifically, the estimated baseline model in this chapter is as follows,

Log (Total Water Pollution)=β_0+β_1**lnGDPpc*+β_2**Consumption*+β_3**Popsize*+ β_4*Pubtra*+β_5**year2004*+···+ β_{14}**year2013 +e*

The multilevel model is

Log (Total Water Pollution)=β_0+β_1**lnGDPpc*+β_2**(lnGDPpc)*^{2}+β_3**lnIndustrialization*

$+\beta_4*lnUrbanization+\beta_5*lnGloblalization+\beta_5*lnConsump+\beta_6 lnPopSize+\beta_7*lnPubTran+\beta_8*year2004+\cdots+\beta_{17}*year2013+e$

Results

Table 4.2 presents descriptive statistics of all variables, including dependent variables, independent variables, and control variables in the analysis before transformation. Then, results of multilevel regression analyses are reported in the following series of tables. I present and discuss each of the findings, with a particular focus on the effects of economic development, industrialization, urbanization, and globalization on water pollution.

Table 4.3 reports the estimated effects of economic development on water pollution over the period 2004-2013 with the respective 95% confidence interval, net of region, year, consumption, population size, and public transportation. We report unstandardized coefficients, standard errors, R-Squares between, R-Square overall, and ICC. R-Square between is the square correlation between city-specific mean of y and the predicted city-specific mean of y, quantifying the explained variation between cities. R^2 overall is the square correlation between y itself and predicted mean of y, referring to the explained variation overall in the model (Allison, 2009; Hamilton, 2006).

Model 1 is treated as a baseline model, consisting of consumption, population size, and public transportation. I add the key independent variable GDP per capita in Model 2 to examine the effect of economic development on water pollution. Then I add an additional predictor, the quadratic term of GDP per capita into Model 3. Models 3 and Model 4 include all predictors from Model 2 as well as dummy variables. Model 5 is the most fully saturated model reported for all outcomes investigated in the analyses, consisting of all of the predictors included in Model 1 through Model 4.

Model 1, as a baseline model, obtains a crude estimate of the effects of consumption, population size, and public transportation on water pollution. Table 4.3 shows that consumption, population size, and public transportation have positive effects that are statistically significant, indicating that all of the control variables positively affect water pollution. The overall fit of Model 1 is moderate (R^2 =.579), implying that other variables are important as well.

In Model 2, I introduce GDP per capita to predict water pollution. Holding constant the control variables in the baseline model, the primary finding in Model 2 is that GDP per capita is a significant factor and positively associated with water pollution, suggesting that the higher the level of GDP per capita, the higher is that level of water pollution. In Model 3, I introduce the quadratic term of GDP per capita to test Hypothesis 1 that there is an inverted U-shape relationship between GDP per capita and water pollution. Controlling the explanatory variables in Model 2, the quadratic term of GDP per capita is not statistically significant. The result confirms the findings from Lee et al. (2010) that there is no inverted U-shape between economic development and water pollution. Inconsistent with Dinda's (2004) statement that the EKC is more likely to hold for environmental degradation locally, the primary finding in Model 3 provides no evidence supporting the EKC hypothesis at the city level within China.

Model 4 adds dummy variables to test whether the relationship between GDP per capita and water pollution varies given the characteristics of cities. As expected, the variable RESBINDUSTC is negative and statistically significant, indicating water pollution is higher in a resource-based industry city than that in a non-resource-based industrial city. The variable CITYLEVEL is not statistically significant, indicating there is no difference in water pollution levels between the prefecture-level cities and other cities. The variable SEZOCC is positive and statistically significant, indicating the water pollution is lower in the cities which are designed as Special Economic Zones or Open Coastal Cities than other cities.

Introducing region and year as predictors, Model 5 offers a comprehensive model that demonstrates the effects of economic development on water pollution across regions over time. For the variable central and western regions, none of them is statistically significant, indicating there are no regional disparities in the impact of economic development on water pollution. After introducing the interaction effect of region, it is still not statistically significant for water pollution. This is inconsistent with the finding from Lee et al. (2010), and does not support Hypothesis 2. There is no evidence that the decoupling between economic development and water pollution occurs in more developed regions of China. Model 5 also shows the magnitude of the effects of economic development on water pollution varies over time. Through the year 2005-2013, it is negative and statistically significant, indicating the effect of economic development on water pollution decreases through time. More specifically, the estimated coefficient for GDP per capita decreases, suggesting the decoupling between economic development and water pollution during the period. The decoupling first occurred in 2005, and then the coefficient decreases until 2013. However, after controlling the interaction effect of year, it is not statistically significant. There is no difference in the effect of economic development on water pollution from 2004-2013.

Overall, this comprehensive model provides us insight into how the impact of economic development on water pollution changed across regions and through time. Compared to Model 4, it is worth noting in Model 5 that the variable CITYLEVEL becomes positive and statistically significant, suggesting water pollution is higher in the other cities than those that are municipality, provincial capitals, or sub-provincial cities.

In sum, recall that Hypothesis 1 and 2 predict there is an inverted U-curvilinear relationship between the economic development level and water pollution across regions and over time. That is, economic development (GDP per capita) initially has an adverse effect on water quality, which then subsequently improves as national income increases over a turning point (the peak of the inverted U-shape). Inconsistent with this hypothesis, the results based on the longitudinal dataset at prefecture-city level show that there is a linear positive relationship between economic development and water pollution, and no regional disparities. These results provide no empirical evidence that there is an inverted U-shape between the economic development and water pollution at 95% confidence level nor that there are regional disparities in the effect of economic development on water pollution. This study confirms the statement that the findings of the EKC hypothesis on water pollution are confounding. Many scholars including Panayotou (1993) argued that the structural transformation from heavy industry towards technology-intensive industries and services, along with environmental consciousness, enforcement of environmental regulations, higher environmental expenditures, and more advanced technology, would result in improvement of environmental quality. Regarding why the EKC hypothesis does not hold for water pollution, the possible explanations are that no structural change of the economy or advanced pollution control technology are applied to lower water pollution at higher levels of development. Moreover, the reduced form of the EKC model should include more predictors such as industrial expansion and urban growth to further systematically explore the relationship between economic development and water pollution.

Tables 4.4-4.6 present the multilevel modeling analysis of industrialization, urbanization, globalization, and water pollution over the period 2004-2013. The Akaike Information Criterion (AIC) determines which of the two models is preferred. The lowest AIC is the preferred model. Specifically, Table 4.4 shows the estimates of industrialization water pollution. Model 1, as a baseline model, obtains a crude estimate of the effect of industrialization on water pollution, net of consumption, population size, and public transportation. Specifically, GDP per capita, population size, and public transportation are statistically significant, indicating all but consumption positively affect water pollution. In Model 2, I introduce the variable MAINDU to test Hypothesis 3 that the level of industrialization is positively associated with water pollution. Controlling the explanatory variables in Model 1, the primary finding shows that the share of secondary industry in GDP is positive and statistically significant, revealing that the higher the contribution of secondary industry to overall GDP, the higher is the level of water pollution. Unexpectedly, the variable GDP per capita becomes less statistically significantly after controlling the level of industrialization.

To further explore the effect of the level of industrialization on water pollution, in Model 3, I introduce two more variables, INDUSTR and IELECON, to test that the level of industrialization is positively associated with water pollution. Controlling the explanatory variables in Model 2, the primary result in Model 3 shows that the industrial structure is not statistically significant, while industrial electricity consumption is positive and statistically significant. The finding demonstrates that the higher the level of industrial electricity consumption, the higher the level of water pollution is. Model 4 adds dummy variables RESBINDUSTC and year to test whether the relationship between industrialization and water pollution varies given the characteristics of cities over time. Inconsistent with what was expected, the variable RESBINDUSTC is negative but not statistically significant. The result indicates that there is no difference of water pollution between resource-based industrial city and non-resource-based industrial city. Model 4 introduces year as predictor to show how the magnitude of the effects of industrialization on water pollution varies over time. The year 2005 is not statistically significant. Then the decoupling between industrialization and water pollution first occurs in 2006, and from then through 2013, the coefficient is negative and statistically significant, indicating that the effect of industrialization on water pollution decreases over time.

In sum, Table 4.4 provides us insight into the decoupling of industrialization and water pollution over time. The between-region standard deviation is estimated as 0.000 in Model 1, and then it again changes to 0.000 in Model 4. The between-province within-regions standard deviation is estimated as 0.253 in Model 1, and then it changes to 0.197 in Model 3. The value of AIC is calculated as 7150.320 in Model 1, and then it gradually decreases to 5946.791 in Model 4, indicating Model 4 is a better model that provides much more comprehensive understanding of the effect of industrialization on water pollution over time.

Table 4.5 shows the estimates of urbanization on water pollution. In Model 5, I add the variables URBAN to test Hypothesis 4. Holding constant the control variables from Model 1 of Table 4.4, the results confirm Hypothesis 4 and shows that the level of urbanization is positive and statistically significant, indicating the higher the level of urbanization, the higher the level of water pollution is.

In Model 6, I introduce the variable POPD to test Hypothesis 5 that population density is positively associated with water pollution. Controlling the explanatory variables in Model 5, inconsistent with the commonly held view, the primary finding in Model 6 shows that population density is negative and statistically significant, revealing that the higher the level of population density, the lower is the level of water pollution. As with dust emission, this result for water pollution supports the claims of New Urbanism that higher density is more sustainable (Glaeser, 2011).

In Model 7, I add dummy variables CITYLEVEL and year to test whether the relationship between urbanization and water pollution varies given the characteristics of cities over time. As expected, the variable CITYLEVEL is statistically significant. The estimated coefficient is positive, indicating water pollution is lower in prefecture-level cities than that in the cities which are municipality, provincial capitals, or sub-provincial cities. Model 7 also introduces year as predictor to estimate how the effect of the magnitude of urbanization on water pollution varies over time. In 2005, year is slightly statistically significant. Thus, the decoupling between urbanization and water pollution first occurred in 2005. Over 2006-2013, year is negative and statistically significant, indicating the effect of urbanization on water pollution decreases over time.

In short, Table 4.5 provides us insight into how the effects of urbanization on water pollution changed over time. The between-region standard deviation is estimated as 0.000 in Model 5-7, indicating there is no variation in the effects of urbanization on water pollution between regions. The between-province within-regions standard deviation is estimated as 0.306 in Model 5, and then it also increases to 0.355 in Model 7. The value of AIC is calculated as 6901.27 in Model 5, and then it gradually decreases to 6121.99 in Model 7, indicating Model 7 is a better model that provides much more comprehensive understanding of the effect of urbanization on water pollution over time.

Table 4.6 shows the estimates of globalization on water pollution. In Model 8, I add the variables TRADE (EXPORT), respectively, to test Hypothesis 6. Holding constant the explanatory variables, the primary finding is that trade has a positive and statistically significant effect, indicating that the higher the amount of total international trade, the higher the level of water pollution. Consistent with the existing finding, international trade is positive and statistically significant, suggesting exports are indeed more likely to increase water pollution.

In Model 9, I introduce the variable FDI to test that FDI is positively associated with water pollution. Controlling the explanatory variables, the primary finding confirms the hypothesis, and shows that FDI is positive and statistically significant, revealing that the higher the amount of FDI, the higher is the level of water pollution.

Model 10 adds the variable FIHTM and FIWEST to test Hypothesis 8 that how the sources of foreign capital impact water pollution. Controlling the explanatory variables, the primary finding shows FIHTM is positive and strongly statistically significant, revealing that the higher the amount of foreign capital from Hong Kong, Taiwan, and Macao, the higher the level of water pollution is. Meanwhile, the results also show that FIWEST is positive and slightly statistically significant, suggesting that the higher the amount of foreign capital from Western countries, the higher the level of water pollution is.

In Model 11, I introduce the variable DCIV to test the effect of domestic capital on water pollution. Controlling the explanatory variables, the finding shows that DCIV is positive and strongly statistically significant, indicating the investment from domestic capital is positively associated with water pollution.

In Model 12, I add dummy variables SEZOCC and year to test whether the relationship between globalization and water pollution varies given the characteristics of cities over time. The variable SEZOCC is positive and statistically significant, indicating the water pollution is higher in the cities that are designed as Special Economic Zones or Open Coastal Cities than other cities. Additionally, Model 12 also introduces year as predictor to show how the effect of the magnitude of globalization on water pollution varies over time. The year 2007 is not statistically significant. The decoupling between globalization and total water pollution first occurred in 2008. The year from 2008 through 2013 is negative and statistically significant, indicating the effects of globalization on water pollution decreases through time.

In short, Table 4.6 provides a comprehensive perspective of how the effects of globalization on water pollution changed over time. The between-region standard deviation is estimated as 0.000 through Model 8-12, indicating there is no variation across region. The between-province within-regions standard deviation is estimated as .299 in Model 8, and then it decreases to .188 in Model 12. The value of AIC is calculated as 5265.46 in Model 8, and then it gradually decreases to 3908.45 in Model 12, indicating Model 12 is a better model that provides much fuller understanding of the effects of globalization on water pollution across regions and over time.

Table 4.7 shows the joint effects of economic development, industrialization, urbanization, and globalization on water pollution. In Model 13, all key independent variables are included to examine the joint effects of economic development, industrialization, urbanization, and globalization on water pollution. The variables GDPPC and POPD are negative and statistically significant, indicating that economic development level, urbanization rate, and population density are negatively associated with water pollution. Meanwhile, the variables MAINDU, TRADE, FDI, FIHTM, and FIWEST are positive and statistically significant, suggesting industrialization, international trade, and foreign capital are positively associated with water pollution. The coefficients of each variable represent the magnitude of their effect on water pollution.

Model 14 adds dummy variables to test whether the joint effects of economic development, industrialization, urbanization, and globalization on water pollution vary according to the characteristics of cities. As expected, the variable RESBINDUSTC is negative and statistically significant, indicating water pollution is lower in a resource-based industrial city than that in a non-resource-based industrial city. The variable CITYLEVEL is positive and statistically significant, indicating water pollution is higher in the cities that are municipality, provincial capitals, or sub-provincial cities than prefecture-level cities. The variable SEZOCC is positive and strongly statistically significant, suggesting water pollution is higher in the cities that are designed as Special Economic Zones or Open Coastal Cities than other cities.

In Model 15, I add dummy variables for year to show how the effect of the magnitude of development on water pollution changes over time. The decoupling between development and water pollution first occurred in 2008. Year is negative and statistically significant, indicating the magnitude of the effects of development on water pollution decreases through time. The between-province within-regions standard deviation is estimated as .173 in Model 13, and then it decreases to .152 in Model 15. The value of AIC is calculated as 3938.49 in Model 13, and then gradually decreases to 3664.22, indicating Model 15 is a better model that provides much fuller understanding of the effect of development on water pollution across regions and over time.

Conclusion

This chapter aims to present how development within a developing country impacts water quality across regions and over time. The chapter provides a snapshot of how the dynamics of development influence water pollution during 2004-2013, and examines whether industrialization, urbanization, and globalization serve as pathways in the association between development and water pollution in a rapidly growing economy with the largest population in the world. Empirically, this chapter examines how water pollution is affected by the dynamics of development in China using longitudinal data at the prefecture-city level. The objective is to test the theoretical framework proposed in Chapter 1 and present how major factors such as economic development level, industrialization, urbanization, and globalization have impacted water pollution across regions and over time. Multilevel models are deployed to test for the presence of regional disparities in the relationship between economic development and water pollution and the variance in disparities between and within provinces/regions.

Recall that Hypothesis 1 and 2 posited an inverted U-shape relationship between economic development and water pollution. That is, economic development initially has an adverse effect on water quality, which then subsequently improves as the level of national economic development increases over a turning point (the peak of the inverted U-shape). Both of the two hypotheses are rejected, indicating that there is no inverted U-curve between economic development and water quality at 95% confidence level or regional disparities in terms of the effect. However, it is worth noting that the quadratic term of GDP per capita became from nonsignificant to significant in the joint effect. Therefore, the changing regression results suggest that whether the EKC hypothesis holds for water quality depends on the covariates controlled.

Recall that Hypothesis 3 suggested that industrialization is positively associated with water pollution. That is, the higher the level of industrialization, the more water pollution there will be. The findings from Table 4.4 confirm this hypothesis and provide strong evidence to support the statement that the higher levels of manufacturing industry are associated with higher levels of water pollution. The decoupling between industrialization and water pollution first occurred around the year 2008. Specifically, the effect of industrialization on water pollution decreased from 2008 to 2013.

Hypothesis 4 and 5 suggested that urbanization is positively associated with water pollution. That is, the higher the level of urbanization, the higher will be the level of water pollution. The findings from Table 4.5 confirm Hypothesis 4 that the higher rates of urbanization are associated with higher levels of water pollution. However, Hypothesis 5 is rejected. Specifically, the findings show that population density is negatively associated with water pollution. Similar to the effect of population density on dust emission, this result provides strong empirical evidence for the New Urbanism claims that the higher the population density, the more sustainable the city is.

Recall that Hypotheses 6-9 suggested that globalization is positively associated with water pollution. That is, the higher the level of globalization, the more likely are increases in the level of water pollution. The findings from Table 4.6 confirm Hypothesis 6, that the higher the level of international trade (export), the higher the level of water pollution will be. Inconsistent with the widely held view in the existing literature, it is important to point out that exports are not significantly associated with water pollution. Hypothesis 7 is strongly supported in this study. More specifically, the higher the amount of FDI, the higher is the level of water pollution. Regarding the sources of foreign capital, the findings confirm Hypothesis 8 and 9. Specifically, Table 4.6 shows that both foreign capital from Hong Kong, Taiwan, and Macao and Western countries are positively associated with water pollution. More importantly, there is strong empirical evidence to show that domestic capital affects water pollution. Unlike air pollution, the effect of foreign capital is not offset after controlling domestic capital. The decoupling between globalization and water pollution first occurred in 2008. Specifically, the effect of globalization on water pollution decreased from 2008 to 2013.

Overall, this empirical study is designed to respond to the demand for systematic analysis of the relationship between development and environmental degradation in China (Liu & Bettie, 2016). This chapter examines how the dynamics of development impact water pollution at the city level. It provides new findings on how industrialization, urbanization, and globalization, as driving forces, as well as economic development level, have affected water quality. Inconsistent with Dinda's observation that the EKC is more likely to hold for the environmental impact locally (Dinda, 2004), the findings demonstrate that there is no an inverted U-shape relationship between economic development and water pollution. More importantly, the results show that the cities with the higher levels of industrialization and globalization have higher levels of water pollution. In terms of urbanization, the findings are mixed. For cities with higher rates of urban population, there are higher levels of water pollution. For cities with higher level of population density, the levels of water pollution are lower. Regarding why higher population density is associated with lower water pollution, the New Urbanism perspective in urban studies provide an inspirational explanation that growth in population density is an important determinant of increases in supply and water treatment (Macdonald et al., 2016).

Although prior research has made valuable contributions, this study advances the literature in several ways. First, this study focuses on the relationship between development and water pollution at the city level within the largest developing country in the world. In Chapter 2, I describe the development mode of China since the policies of reform and opening up were introduced in 1978, leading to rapid industrialization, urbanization, and globalization. Therefore, this study is a systematic empirical analysis testing the theoretical framework of the triple process of development in China. Secondly, the joint effects of economic development level, industrialization, urbanization, and globalization on water pollution have been tested, while previous studies mostly examine the effect of those factors separately with respect to water pollution. Third, multilevel modeling is used to analyze the most recent city-level data. Up to date, this study is the first to provide a comprehensive comparative quantitative analysis of the relationship between development and water pollution from 287 cities across region and over time, as prior research takes China itself or provinces within China as the units of analysis. Last but most importantly, the findings have policy implications for development trajectories, and industrialization and globalization particularly for developing countries, contributing to the literature by examining the independent role of population density and the sources of foreign capital in relation to water pollution locally. There are several limitations in this study. The measurement of water pollution is total industrial wastewater, which is not a commonly used indicator for water quality in the studies of environmental science. The findings may not be generalizable to other indicators of water quality, particularly residential wastewater in the cities. Secondly, the theoretical framework is constructed in the context of China, where the role of the state and policies should be seriously taken into account. Given the unavailability of data, this study fails to examine the effect of such policies implemented by central and local governments on water pollution. Therefore, the effects of specific policies should be examined in future studies. Third, the mediation analysis between industrialization, urbanization, globalization, and economic development is lacking in this study due to the constraint of time and length of the analysis.

Table 4.1

Changes of Water Pollution by Provinces, 2004-2013 (10,000 tons)

Provinces	Change	Percent
	59795	100%
Eastern Region	85002	142.16%
Beijing	-3917	-6.55%
Tianjin	-2488	-4.16%
Hebei	15839	26.49%
Shandong	69307	115.91%
Liaoning	-4601	-7.69%
Shanghai	-13412	-22.43%
Jiangsu	-11265	-18.84%
Zhejiang	4606	7.70%
Fujian	7567	12.65%
Guangdong	15460	25.86%
Guangxi	7828	13.09%
Hainan	78	0.13%
Central Region	48085	80.42%
Shanxi	15785	26.40%
Inner Mongolia	8411	14.07%
Jilin	14262	23.85%
Heilongjiang	-4183	-7.00%
Anhui	3720	6.22%
Henan	22933	38.35%
Hubei	-5865	-9.81%
Hunan	-29316	-49.03%
Jiangxi	22338	37.36%
Western Region	-73292	-122.57%
Chongqing	-51362	-85.90%
Sichuan	-50958	-85.22%
Guizhou	5204	8.70%
Yunnan	12617	21.10%
Tibet	333	0.56%
Shaanxi	3094	5.17%
Gansu	6129	10.25%
Qinghai	1120	1.87%
Ningxia	-575	-0.96%
Xinjiang	1106	1.85%

Table 4.2

Descriptive Statistics of the Analysis

Variables	Min	Max	Mean	Std.Dev
Dependent Variables				
WaterWaste	2	88027	7606.96	10162.93
Independent Variables				
GDP pc	99	182680	24939.28	21173.03
Manufacturing	9	91	48.85	11.48
IndustrialElectri	0	8057600	432689.10	730180.33
Urbanization	0	1	0.34	0.21
Popudensity	5	2662	416.22	318.80
Trade	2	46680286	866686.46	3147905.42
Export	0	27135572	468126.95	1584273.97
FDI	0	1518453	51052.65	125151.03
FI from HTM	0	54732030	1759357.92	5013512.49
FI from West	0	144700000	3120012.50	10663102.67
Domes Invest	6007	138900000	11726056.27	16486018.97
Control Variables				
Consumption	11209	77028167	3851169.87	6248666.11
Population size	16	3343	425.52	303.18
Public transport	0	115	6.7395	6.69319

Note: *N*=2870

Table 4.3

Multilevel Estimates of Economic Development and Water Pollution in China,

	Model 1	Model 2	Model 3	Model 4	Model 5
Independent Variables					
GDPPC(ln)		0.475***	0.825**	0.586*	1.092***
		(0.047)	(0.317)	(0.323)	(0.310)
GDPPC2(ln)			-0.018	-0.016	-0.024
			(0.016)	(0.017)	(0.016)
Dummy Variables					
RESBINDUSTC				-0.120**	0.290***
				(0.035)	(0.034)
CITY LEVEL				0.017	0.065***
				(0.060)	(0.065)
SEZOCC				0.360***	-0.455***
				(0.068)	(0.067)
Central Regions					-0.156
					(0.110)
Western Regions					0.001
					(0.120)
2005					-0.122*
					(0.061)
2006					-0.396***
					(0.062)
2007					-0.529***
					(0.063)
2008					-0.689***
					(0.065)
2009					-0.768***
					(0.067)
2010					-0.918***
					(0.069)
2011					-1.092***
					(0.073)

Table 4.3 Continued

	Model 1	Model 2	Model 3	Model 4	Model 5
2012					-1.226***
					(0.076)
2013					-1.391***
					(0.079)
Control Variables					
CONSUM(ln)	0.375***	-0.007	0.002	0.188***	0.421***
	(0.023)	(0.044)	(0.045)	(0.052)	(0.051)
POPSIZE(ln)	0.443***	0.855***	0.844***	0.419***	0.414***
	(0.028)	(0.049)	(0.050)	(0.063)	(0.059)
PUBTRA(ln)	0.236***	0.190***	0.191***	0.195***	0.111***
	(0.023)	(0.023)	(0.023)	(0.024)	(0.023)
Constant	-0.024	-1.483***	-3.209**	-1.686	-8.799***
	(0.209)	(0.251)	(1.568)	(1.611)	(1.577)
R^2 Between	0.732	0.776	0.776	0.762	0.742
R^2 Overall	0.579	0.596	0.597	0.424	0.518
Between Cities	0.577	0.544	0.545	0.422	0.223
Within Cities	0.771	0.759	0.759	0.756	0.705
ICC	0.359	0.339	0.340	0.237	0.091

Notes:
1. †$p<0.1$; *$p<0.05$; **$p<0.01$; ***$p<0.001$(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. GDPPC= gross domestic product per capita; GDPPC2 =Quadratic term of gross domestic product per capita.
4. ICC=Intraclass correlation coefficient.

Table 4.4

Multilevel Estimates of Industrialization and Water Pollution in China

	Model 1	Model 2	Model 3	Model 4
Fixed-Effect				
GDPPC(ln)	0.483***	0.045	-0.008	0.242***
	(0.046)	(0.052)	(0.049)	(0.059)
MAINDU(ln)		1.329***	0.482*	-0.243
		(0.080)	(0.200)	(0.217)
INDUSTR(ln)			0.356	1.070***
			(0.233)	(0.252)
IELECON(ln)			0.308***	0.233***
			(0.014)	(0.016)
RESBINDUSTC				-0.044
				(0.032)
2005				-0.089
				(0.058)
2006				-0.259***
				(0.059)
2007				-0.348***
				(0.060)
2008				-0.439***
				(0.062)
2009				-0.436***
				(0.064)
2010				-0.507***
				(0.066)
2011				-0.624***
				(0.070)
2012				-0.699***
				(0.074)
2013				-0.756***
				(0.076)
Control Variables				
CONSUM(ln)	-0.012	0.224***	0.048	0.215***
	(0.044)	(0.044)	(0.044)	(0.050)
POPSIZE(ln)	0.866***	0.667***	0.591***	0.409***

Table 4.4 Continued

	Model 1	Model 2	Model 3	Model 4
	(0.049)	(0.048)	(0.047)	(0.059)
PUBTRA(ln)	0.188***	0.148***	0.081***	0.046*
	(0.023)	(0.022)	(0.021)	(0.022)
Constant	-1.607***	-4.591***	-1.278	-0.482
	(0.267)	(0.311)	(0.788)	(0.842)
Variance Components				
Regional-level	0.000	0.005	0.002	0.000
Provincial-level	0.253	0.160	0.174	0.197
Log Likelihood	-3567.216	-3436.406	-3196.947	-2952.395
AIC	7150.320	6890.813	6415.894	5946.791

Notes:
1. †p<0.1; *p<0.05; **p<0.01; ***p<0.001(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. AIC=Akaike information criterion.

Table 4.5

Multilevel Estimates of Urbanization and Water Pollution in China

	Model 5	Model 6	Model 7
Fixed-Effect			
GDPPC(ln)	0.483***	0.447***	0.610***
	(0.045)	(0.046)	(0.052)
URBAN(ln)	0.406***	0.436***	0.164***
	(0.031)	(0.032)	(0.038)
POPD(ln)		-0.136***	-0.063*
		(0.026)	(0.027)
CITY LEVEL			0.644***
			(0.063)
2005			-0.109†
			(0.061)
2006			-0.375***
			(0.061)
2007			-0.496***
			(0.062)
2008			-0.642***
			(0.065)
2009			-0.705***
			(0.068)
2010			-0.829***
			(0.070)
2011			-0.989***
			(0.074)
2012			-1.118***
			(0.078)
2013			-1.271***
			(0.082)
Control Variables			
CONSUM(ln)	-0.118**	-0.071	0.025***
	(0.044)	(0.044)	(0.054)
POPSIZE(ln)	1.019***	0.987***	0.550***
	(0.049)	(0.049)	(0.066)
PUBTRA(ln)	0.159***	0.157***	0.190***
	(0.022)	(0.022)	(0.024)
Constant	-0.476†	0.183	-0.163***
	(0.279)	(0.306)	(0.546)

Table 4.5 Continued

	Model 5	Model 6	Model 7
Variance Components			
Regional-level	0.000	0.000	0.000
Provincial-level	0.306	0.353	0.355
Log Likelihood	-3441.63	-3427.55	-3041.00
AIC	6901.27	6875.09	6121.99

Notes:
1. †p<0.1; *p<0.05; **p<0.01; ***p<0.001(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. AIC=Akaike information criterion.

Table 4.6

Multilevel Estimates of Globalization and Water Pollution in China

	Model 8	Model 9	Model 10	Model 11	Model 12
Fixed-Effect					
GDPPC(ln)	0.461***	0.391***	0.412***	-0.271**	-0.218*
	(0.051)	(0.057)	(0.059)	(0.085)	(0.090)
TRADE(ln)	0.284***	0.230***	0.225***	0.216***	0.184***
	(0.026)	(0.027)	(0.029)	(0.028)	(0.029)
FDI(ln)		0.098***	0.048*	0.077***	0.040*
		(0.017)	(0.019)	(0.018)	(0.019)
FIHTM(ln)			0.043**	0.025†	0.034*
			(0.015)	(0.014)	(0.014)
FIWEST(ln)			0.032*	0.040*	0.037*
			(0.016)	(0.016)	(0.016)
DCIV (ln)				0.486***	0.483***
				(0.044)	(0.046)
SEZOCC					0.468***
					(0.062)
2007					-0.073
					(0.055)
2008					-0.183**
					(0.056)
2009					-0.243**
					(0.057)
2010					-0.305***
					(0.059)
2011					-0.435***
					(0.062)
2012					-0.529***
					(0.066)
2013					-0.628***
					(0.068)

Table 4.6 Continued

	Model 8	Model 9	Model 10	Model 11	Model 12
Control Variables					
CONSUM(ln)	-0.222***	-0.280***	-0.367***	-0.357***	-0.056
	(0.052)	(0.056)	(0.056)	(0.054)	0.058
POPSIZE(ln)	0.903***	0.922***	0.967***	0.497***	0.123
	(0.055)	(0.057)	(0.058)	(0.071)	0.080
PUBTRA(ln)	0.150***	0.137***	0.161***	0.131***	0.064*
	(0.028)	(0.027)	(0.028	(0.027)	0.028
Constant	-0.555	0.401	0.863*	2.604*	0.447
	(0.343)	(0.375)	(0.380)	(0.401)	0.535
Variance Components					
Regional-level	0.000	0.000	0.000	0.000	0.000
Provincial-level	0.299	0.309	0.183	0.218	0.188
Log Likelihood	-2622.73	-2412.62	-2152.30	-2211.25	-1932.17
AIC	5265.46	4847.24	4332.59	4448.51	3908.35

Notes:
1. †p<0.1; *p<0.05; **p<0.01; ***p<0.001(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. AIC=Akaike information criterion.

Table 4.7

Multilevel Estimates of Economic Development, Industrialization, Urbanization, Globalization, and Water Pollution in China, 2004-2013

	Model 13	Model 14	Model 15
GDPPC(ln)	-0.145*	-0.210**	0.016
	(0.067)	(0.071)	(0.076)
MAINDU(ln)	0.498*	0.298	0.019
	(0.221)	(0.234)	(0.237)
INDUSTR(ln)	0.222	0.290	0.459
	(0.258)	(0.279)	(0.281)
IELECON(ln)	0.278***	0.251***	0.233***
	(0.018)	(0.020)	(0.020)
URBAN(ln)	-0.054	-0.021	-0.101*
	(0.034)	(0.038)	(0.040)
POPD(ln)	-0.163***	-0.102***	-0.097***
	(0.025)	(0.028)	(0.028)
TRADE(ln)	0.183***	0.201***	0.188***
	(0.026)	(0.028)	(0.028)
FDI(ln)	0.055**	0.056**	0.044*
	(0.017)	(0.018)	(0.018)
FIHTM(ln)	0.042**	0.041**	0.045**
	(0.014)	(0.014)	(0.014)
FIWEST(ln)	0.027†	0.037*	0.025
	(0.015)	(0.016)	(0.016)
RESBINDUSTC		-0.077*	0.395*
		(0.035)	(0.062)
CITY LEVEL		0.155*	0.285***
		(0.067)	(0.069)
SEZOCC		0.388***	-0.087***
		(0.063)	(0.034)
2007			-0.056
			(0.053)
2008			-0.130*
			(0.055)
2009			-0.178**

Table 4.7 Continued

	Model 13	Model 14	Model 15
			(0.058)
2010			-0.230***
			(0.061)
2011			-0.345***
			(0.066)
2012			-0.427***
			(0.071)
2013			-0.498***
			(0.076)
Control Variables			
CONSUM(ln)	-0.114†	-0.039	0.106
	(0.059)	(0.064)	(0.067)
POPSIZE(ln)	0.531***	0.416***	0.347**
	(0.063)	(0.076)	(0.076)
PUBTRA(ln)	0.059*	0.100***	0.059*
	(0.027)	(0.028)	(0.029)
Constant	1.328	1.583	-0.582
	(0.895)	(0.991)	(1.031)
Variance Components			
Regional-level	0.000	0.000	0.000
Provincial-level	0.173	0.152	0.152
Log Likelihood	-1952.25	-1830.80	-1804.11
AIC	3938.49	3701.60	3664.22

Notes:
1. †p<0.1; *p<0.05; **p<0.01; ***p<0.001(two-tailed tests).
2. Line 1: unstandardized coefficients; line 2: standard error in parentheses.
3. AIC=Akaike information criterion.

CHAPTER 5

CONCLUSIONS AND DISCUSSIONS

How development interacts with the environment is intensively debated in the existing theoretical and empirical literature in the social sciences. This dissertation aimed to contribute to our understanding of the complex dynamics between development and the environment in a rapidly changing social setting: China. Given the size of its population and economy, the development trajectory it adopted, and the unique institutional context, environmental degradation at an unprecedented scale within this country is of global concern and important to study.

Chapter 2 reviewed the paradoxically different development trajectories (Soviet-style development strategy vs. comparative advantage development strategy) that China adopted since the founding of the People's Republic of China in 1949, and showed how the country industrialized, urbanized, and globalized during the past 6 decades. Based on this review, this chapter then proposed a theoretical framework for analyzing the relationship between development and the environment from the perspective of industrialization, urbanization, and globalization. Moreover, this chapter provided a snapshot of how spatio-temporal patterns of air and water pollution have changed across China's provinces over the time period from 2004-2013. Specifically, for SO_2 emissions, seven provinces (Liaoning, Hebei, Shandong, and Jiangsu in the eastern regions and Inner Mongolia, Shanxi, and Henan in the central region) were revealed to be the most polluted areas throughout the period 2004-2013. In terms of dust emissions, Shanxi, the leading producer of coal in China, remained the most polluted area throughout the years 2004-2013. As for water pollution, the province Jiangsu in the eastern region has remained the most polluted province during the period 2004-2013.

Chapter 3 empirically examined the relationship between development and air pollution, and proposed several hypotheses. Following from the idea of an Environmental Kuznets Curve (EKC), I argued that there is an inverted U-shape relationship between economic development level and air pollution in China, regardless of specific indicators. Then, I hypothesized that industrialization, urbanization, and globalization are positively associated with air pollution. In particular, I examined how population density, the sources of foreign capital, and domestic capital affected air quality. The findings show that there is an inverted U-shape relationship between GDP per capita and SO_2 emissions (but not dust emissions), indicating that whether the EKC holds depends on the indicators of air quality being used. The cities with higher levels of industrialization and urbanization are more likely to have higher levels of air pollution. Surprisingly, the results show that cities with higher levels of population density have lower levels of dust emissions. More interestingly, the effects of the sources of capital on air pollution are mixed and vary depending on which types of air pollution examined. The cities with a higher level of foreign capital from Hong Kong, Taiwan, and Macao are more likely to have a higher level of SO_2 emissions but not dust emissions, whereas a higher level of foreign capital from Western countries is associated with more dust emissions.

Similarly, Chapter 4 empirically examined the relationship between development and water pollution, proposing several corresponding hypotheses. Following from the idea of the Environmental Kuznets Curve (EKC), I hypothesized that there is an inverted U-shape relationship between economic development level and water pollution in China. Then, I argued that industrialization, urbanization, and globalization are positively associated with water pollution. In particular, I examined how population density, the source of foreign capital, and domestic capital affected water quality. I found that there is no inverted U-shape between GDP per capita and water pollution, indicating that the EKC does not hold for some indicators of environmental degradation, such as water pollution. Further, inconsistent with the existing studies, this chapter also showed that the EKC does not hold for long-term environmental outcomes locally. I further found that the cities with higher levels of industrialization and globalization are positively associated with higher levels of water pollution. Surprisingly, I found that cities with higher levels of population density have relatively lower levels of water pollution. More interestingly, the cities with higher levels of globalization, regardless of the indicators (e.g., exports, FDI, or different sources of foreign capital) are more likely to have higher levels of water pollution. More interestingly, I also found that domestic capital has significant effect on water quality.

There are several important lessons emerge from the findings reported in this dissertation. The first is about the complexity and significance of the unique context that China represents. As the world's most populous nation with the world's most dynamic developing economy, the sustainable development of China is of global interest given its size and unique institutional and structural characteristics. The paradoxically different development trajectories China adopted, originally from a centrally planned economy followed by its transformation towards a market economy, have played crucial roles in shaping the determinants of environmental degradation in China. Meanwhile, the landscape and ecosystem in China have been significantly transformed at an unprecedented pace by the large-scale industrialization, urbanization, and globalization. In spite of an existing literature that has extensively examined how China developed and reformed since the adoption of the opening up policy, the environmental implications of its rapid development are not well understood. Although some scholars have started to assess the appropriateness of the existing findings as a way of interpreting environmental degradation in China (Mol, 2006; Yee et al., 2013), the historical and institutional context of China's development trajectories has rarely been systematically studied in comparative development-environment research. This dissertation advances our understanding of the relationship between development and the environment in terms of industrialization, urbanization, and globalization.

Secondly, using multilevel modeling with the most recent longitudinal data available allows greater confidence in the findings than most previous research on the development-environment relationship in China. The previous studies take China as a whole or provinces within China as the units of analysis. Thus, to date, exploring environmental degradation across nationally inclusive Chinese cities has not before been attempted. Empirically, this dissertation, as a comprehensive comparative sociological analysis, presents the relationship between development and the environment using the data from 287 prefecture-level cities from 2004-2013. The findings show that environmental degradation and the effects of economic development on environmental degradation differ across regions and over time given different indicators of environment. Air is most severely polluted in the less developed central and western regions, while water is most severely polluted in more developed eastern regions. The findings show that industrialization and urbanization negatively impact air quality, while industrialization and globalization play significant roles in undermining water quality.

Third, this dissertation contributes to the literature by examining the independent role of the factors that have not been studied previously within China: the source of foreign direct investment, domestic investment, and population density. For instance, this dissertation extensively focused on the relationship between globalization and the environment in the most populous developing country, providing evidence that foreign capital from HTM and Western countries, domestic capital, and population density have different impacts on environmental degradation depending on which indicators are analyzed.

In addition, this dissertation has several practical implications. For instance, this dissertation has significant implications for policymakers and practitioners in addressing economic disparities and environmental degradation in terms of regional development strategies. In particular, it has strong policy implications for examining how the sources of foreign capital have differentially affected the environment. This dissertation provided evidence on whether foreign capital is beneficial or detrimental to the environment, depending on the source and the type of environmental degradation. Moreover, this dissertation is sensitive to the intersection between population density and environmental degradation, and finds that higher population density is significantly positively correlated with SO_2 emission, but negatively associated with dust emission and water pollution.

There are several limitations in this dissertation. The theoretical framework I proposed is constructed in the context of China, where the role of the state and policies should be seriously taken into account. Due to the unavailability of data, this study fails to examine the effect on water pollution of policies implemented by central and local governments. The effects of specific policies should be examined in future studies. More importantly, the relationship between industrialization, urbanization, globalization, and development should be articulated in a more detailed way. The mediation analysis between the three factors and development is lacking in this dissertation due to time constraints and length limitations. Meanwhile, the findings may not be generalizable to other indicators of environmental degradation given that they are based on the empirical study of only SO_2 emissions, dust emissions, and wastewater discharge. Therefore, future research is needed when the data for other indicators of air and water pollution are available.

APPENDIX A

LISTS OF REGIONS, PROVINCES AND CITIES

IN MULTILEVEL ANALYSIS

Table A1

Regions (3)	**Provinces (31)**	**Cities (287)**
Eastern	12	115
	Beijing	1
	Tianjin	1
	Shanghai	1
	Hebei	11
	Jiangsu	13
	Zhejiang	11
	Shandong	17
	Guangdong	21
	Fujian	9
	Guangxi	14
	Hainan	2
	Liaoning	14
Central	9	110
	Jilin	8
	Heilongjiang	12
	Shanxi	11
	Inner Mongolia	9
	Anhui	17
	Hubei	12
	Hunan	13
	Henan	17
	Jiangxi	11

Table A1 Continued

Regions (3)	**Provinces (31)**	**Cities (287)**
Western	10	62
	Sichuan	18
	Shaanxi	10
	Guizhou	4
	Yunnan	8
	Qinghai	1
	Ningxia	5
	Gansu	12
	Xinjiang	2
	Tibet	1
	Chongqing	1

Table A2

Region	**Province**	**Cities**	Shandong	17		Xiamen
Eastern	Beijing	Beijing		Jinan		Putian
	Tianjin	Tianjin		Qingdao		Sanming
	Shanghai	Shanghai		Zibo		Quanzhou
	Hebei	11		Zao zhuang		Zhang zhou
		Shijiazhuang		Dongying		Nanping
		Tangshan		Yantai		Longyan
		Qinhuangdao		Weifang		Ningde
		Handan		Jining	Guang xi	14
		Xingtai		Tai'an		Nanning
		Baoding		Weihai		Liuzhou
		Zhangjiakou		Rizhao		Guilin
		Chengde		Laiwu		Wuzhou
		Cangzhou		Linyi		Beihai
		Langfang		Zhangzhou		Fangchen ggang
		Hengshui		Liaocheng		Qinzhou
	Jiangsu	13		Binzhou		Guigang
		Nanjing		Heze		Yulin

Table A2 Continued

	Wuxi	Guangdong	21		Baise
	Xuzhou		Guangzhou		Hezhou
	Changzhou		Shaoguan		Hechi
	Suzhou		Shenzhen		Laibin
	Nantong		Zhuhai		Chongzuo
	Lianyungang		Shantou	Hainan	2
	Huai'an		Foshan		Haikou
	Yancheng		Jiangmen		Sanya
	Yangzhou		Zhanjiang	Liaoning	14
	Zhenjiang		Maoming		Shenyang
	Taizhou		Zhaoqing		Dalian
	Suqian		Huizhou		Anshan
Zhejiang	11		Meizhou		Fushun
	Hangzhou		Shanwei		Benxi
	Ningbo		Heyuan		Dandong
	Wenzhou		Yangjiang		Jinzhou
	Jiaxing		Qingyuan		Yingkou
	Huzhou		Dongguan		Fuxin
	Shaoxing		Zhongshan		Liaoyang
	Jinhua		Chaozhou		Panjin
	Quzhou		Jieyang		Tieling
	Zhoushan		Yunfu		Chaoyang
	Taizhou	Fujian	9		Huludao
	Lishui		Fuzhou		

Table A3

Region	**Province**	**Cities**	Anhui	17	Henan	17
Central	Jilin	8		Hefei		Zhengzhou
		Changchun		Wuhu		Kaifeng
		Jilin		Bengbu		Luoyang
		Siping		Huainan		Pingdingshan
		Liaoyuan		Ma'anshan		Anyang
		Tonghua		Huaibei		Hebi
		Baishan		Tongling		Xinxiang
		Songyuan		Anqing		Jiaozuo

Table A3 Continued

	Baicheng		Huangshan		Puyang
Heilongjiang	12		Chuzhou		Xuchang
	Harbin		Fuyang		Luohe
	Qiqihar		Suzhou		Sanmenxia
	Jixi		Chaohu		Nanyang
	Hegang		Liu'an		Shangqiu
	Shuangyashan		Bozhou		Xinyang
	Daqing		Chizhou		Zhoukou
	Yichun		Xuancheng		Zhumadian
	Jiamusi	Hubei	12	.Jiangxi	11
	Qitaihe		Wuhan		Nanchang
	Mudanjiang		Huangshi		Jingdezhen
	Heihe		Shiyan		Pingxiang
	Suihua		Yichang		Jiujiang
Shanxi	11		Xiangfan		Xinyu
	Taiyuan		Ezhou		Yingtan
	Datong		Jingmen		Ganzhou
	Yangquan		Xiaogan		Ji'an
	Changzhi		Jingzhou		Yichun
	Jincheng		Huanggang		Fuzhou
	Shuozhou		Xian'ning		Shangrao
	Jinzhong		Suizhou		
	Yuncheng	Hunan	13		
	Xinzhou		Changsha		
	Linfen		Zhuzhou		
	Lvliang		Xiangtan		
Inner Mong	9		Hengyang		
	Hohhot		Shaoyang		
	Baotou		Yueyang		
	Wuhai		Changde		
	Chifeng		Zhangjiajie		
	Tongliao		Yiyang		
	Ordos		Chenzhou		
	Hulunbuir		Yongzhou		
	Bayannur		Huaihua		
	Ulanqab		Loudi		

Table A4

Region	**Province**	**Cities**	Shaanxi	10		Wuzhong
Western	Sichuan	18		Xi'an		Guyuan
		Chengdu		Tongchuan		Zhongwei
		Zigong		Baoji	Gansu	12
		Panzhihua		Xianyang		Lanzhou
		Luzhou		Weinan		Jiayuguan
		Deyang		Yan'an		Jinchang
		Mianyang		Hanzhong		Baiyin
		Guangyuan		Yulin		Tianshui
		Suining		Ankang		Wuwei
		Neijiang		Shangluo		Zhangye
		Leshan	Yunnan	8		Pingliang
		Nanchong		Kunming		Jiuquan
		Meishan		Qujing		Qingyang
		Yibin		Yuxi		Dingxi
		Guang'an		Baoshan		Longnan
		Dazhou		Zhaotong	Xinjiang	2
		Ya'an		Lijiang		Urumqi
		Bazhong		Simao		Karamay
		Ziyang		Lincang	Tibet	1
	Guizhou	4	Qinghai	1		Lhasa
		Guiyang		Xining	Chongqing	1
		Liupanshui	Ningxia	5		Chongqing
		Zunyi		Yinchuan		
		Anshun		Shizuishan		

APPENDIX B

CORRELATION OF THE COVARIATES IN THE ANALYSIS

	GDPPC (ln)	MAINDU (ln)	INDUSTR (ln)	IELECON (ln)	URBAN (ln)	POPD (ln)
GDPPC(ln)	1.000					
MAINDU(ln)	0.482	1.000				
INDUSTR(ln)	0.163	0.877	1.000			
IELECON(ln)	0.579	0.359	0.103	1.000		
URBAN(ln)	0.455	0.129	-0.119	0.446	1.000	
POPD(ln)	0.143	0.201	0.098	0.272	0.098	1.000
TRADE(ln)	0.625	0.182	-0.091	0.695	0.343	0.361
EXPORT(ln)	0.591	0.170	-0.085	0.669	0.323	0.378
FDI(ln)	0.620	0.213	-0.038	0.651	0.285	0.370
FIHTM(ln)	0.570	0.253	0.041	0.603	0.212	0.428
FIWEST(ln)	0.640	0.253	-0.001	0.696	0.273	0.368
CONSUM(ln)	0.557	0.148	-0.086	0.745	0.175	0.337
POPSIZE(ln)	-0.061	-0.074	-0.082	0.472	-0.215	0.240
PUBTRA(ln)	0.566	0.250	-0.028	0.510	0.302	0.101

	TRADE (ln)	EXPORT (ln)	FDI (ln)	FIHTM (ln)	FIWEST (ln)	CONSUM (ln)	POPSIZE (ln)	PUBTRA(ln)
TRADE(ln)	1.000							
EXPORT(ln)	0.967	1.000						
FDI(ln)	0.799	0.783	1.000					
FIHTM(ln)	0.809	0.808	0.803	1.000				
FIWEST(ln)	0.847	0.830	0.821	0.810	1.000			
CONSUM(ln)	0.790	0.773	0.806	0.759	0.825	1.000		
POPSIZE(ln)	0.437	0.437	0.490	0.464	0.496	0.752	1.000	
PUBTRA(ln)	0.492	0.467	0.502	0.400	0.482	0.469	0.090	1.000

REFERENCES

Amin, S. (1976). *Unequal development: An essay on the social formations of peripheral capitalism.* New York and London: Monthly Review.

Andersen, M. (2002). Ecological modernization or subversion? The effect of Europeanization on Eastern Europe. *American Behavioral Scientist, 45*(9), 1394-1416.

Anderson, P. N. (2008). Worlds apart: Globalization and the environment politics and the life sciences. *Politics and the Life Sciences, 27*(2), 60-65.

Bao, L. J., Maruya, K.A., Snyder, S. A., & Zeng, E.Y. (2012). China's water pollution by persistent organic pollutants. *Environmental Pollution, 163*, 100-108.

Barro, R. J., & Lee, J.W. (2001). International data on educational attainment: Updates and implications. *Oxford Economic Papers*, *53*(3), 541-563.

Bernstein, T. P. (1977). *Up to the mountains and down to the villages: The transfer of youth from urban to rural China.* New Haven, CT: Yale University Press.

Bornschier, V., & Chase-Dunn, C. (1985). *Transnational corporations and underdevelopment.* New York, NY: Praeger.

Bosworth, B., & Collins, S. M. (2003). The empirics of growth: An update. *Brookings Papers on Economic Activity*, *2*, 113-206.

Bunker, S. G. (1984). Modes of extraction, unequal exchange, and the progressive underdevelopment of an extreme periphery: The Brazilian amazon, 1600-1980. *American Journal of Sociology, 89*, 1017-1064.

Buttel, F. H. (2000). Ecological modernization as social theory. *Geoforum*, *31*, 57-65.

Buttel, F. H. (2004). Treadmill of production: An appreciation, assessment, and agenda for research. *Organization and Environment, 17*(3), 323-36.

Buttel, F. H., & Taylor, P. J. (1992). Environmental sociology and global environmental change: A critical reassessment. *Society and Natural Resources, 5*, 211-230.

Cao, X., & Prakash, A.(2012). Trade competition and environmental regulations: Domestic political constraints and issue visibility. *The Journal of Politics, 74*(1), 66-82.

Chai, J. (1996). Divergent development and regional income gap in China. *Journal of Contemporary Asia, 26*, 46-58.

Chan, K.W. (1992). Economic growth strategy and urbanization policy in China. *International Journal of Urban and Regional Research, 16*(2), 275-305.

Chan, K.W. (2010). The household registration system and migrant labor in China: Notes on a debate. *Population and Development Review*, *36*(2), 357-364.

Chan, K. W., & Xu, X. Q. (1985). Urban population growth and urbanization in China since 1949: Reconstructing a baseline. *The China Quarterly, 104*, 583-613.

Chan, C. K., & Yao, X. (2008). Air pollution in mega cities in China. *Atmospheric Environment, 42*, 1-42.

Chan, K.W., & Zhang, L. (1999). The *Hukou* system and rural-urban migration: The process and changes. *The China Quarterly, 160*, 818-855.

Chase-Dunn, C., & Jorgenson, A. K. (2003). Regions and interaction networks: An institutional-materialist perspective. *International Journal of Comparative Sociology, 44*, 433-450.

Chen, I. C., Hill, J. K., Ohlemüller, R., Roy, D.B., & Thomas, C.D. (2011). Rapid range shifts of species associated with high levels of climate warming. *Science*, *333*, 1024-1026.

Chen, P. (1972). Overurbanization, rustication of urban-educated-youths, and politics of rural transformation. *Comparative Policy*, *4*, 361-86.

Cheng, T., & Selden, M. (1994). The origin and social consequences of China's *Hukou* system. *The China Quarterly*, *139*, 644-668.

Chow, G. (1993). Capital formation and economic growth in China. *The Quarterly Journal of Economics, 108*(3), 809-842.

Chow, G. (2004). Economic reform and growth in China. *Annuals of Economics and Finance, 5*, 127-152.

Chow, G. (2006). Globalization and China's economic development. *Pacific Economic Review*, *11*(3), 271-285.

Christmann, P., & Taylor, G. (2001). Globalization and the environment: Determinants of firm self-regulation in China. *Journal of International Business Studies, 32*(3), 439-458.

Christmann, P., & Taylor, G. (2002). Globalization and the environment: Strategies for international voluntary environmental initiatives. *Academy of Management Executive, 16*(3), 121-135.

Cole, M. A., & Elliott, R. J. R. (2005). FDI and the capital intensity of "dirty" sectors: A missing piece of the pollution haven puzzle. *Review of Development Economic, 9*(4), 530-548.

Cong, S., Zheng, S.Q., & Wang, R. (2014). Restricting driving for better traffic and clearer skies: Did it work in Beijing? *Transport Policy, 32*, 34-41.

Cooper, M. J., Martin, R.V.,van Donkelaar, A., Lamsal, L., Brauer, M., & Brook, J.R. (2012). A satellite-based multi-pollutant index of global air quality. *Environmental Science and Technology, 46*(16), 8523-8524.

Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic Literature*, *42*(1), 7-71.

Dasgupta, S., Huq, M., Wheeler, D., & Zhang, C. (2001). Water pollution abatement by Chinese industry: Cost estimates and policy implications. *Applied Economics, 33*, 547-557.

Dean, J. M., Lovely, M. E., & Wang, H. (2009). Are foreign investors attracted to weak environmental regulations? Evaluating the evidence from China. *Journal of Development Economics, 90*(1), 1-13.

Di, W. (2007). Pollution abatement cost savings and FDI inflows to polluting sectors in China. *Environment and Development Economics, 12*(6), 775.

Dietz, T., Rosa E A., & York, R. (2012). Environmentally efficient well-being: Is there a Kuznets curve? *Applied Geography, 32*, 21-28.

Dinda, S. (2004). Environmental Kuznets curve hypothesis: A survey. *Ecological Economics, 49*, 431-455.

Dunlap, R., & Catton, W. (1979). Environmental sociology. *Annual Review of Sociology, 5*, 243-273.

Economy, E. (2010). *The river runs black: The environmental challenge to China's future*. Ithaca, NY: Cornell University Press.

Edmonds, R. L. (1998). Studies on China's environment. *The China Quarterly*, *156*, 725-732.

EIA. (2015). *Annual energy outlook 2015 with projections to 2040.* Washington, DC: U.S Energy Information Administration. Retrieved from https://www.eia.gov/outlooks/aeo/pdf/0383(2015).pdf.

Eskeland, G.S., & Harrison, A.E. (2003). Moving to greener pastures? Multinationals and the pollution haven hypothesis. *Journal of Development Economics,70*(1), 1-23.

Evin, M. (2012). *The retreat of the elephants: An environmental history of China*. New Haven, CT: Yale University Press.

Fan, C. C. (1995). Of belts and ladders: State policy and uneven regional development in post-Mao China. *Annals of the Association of American Geographers, 85*, 421-449.

Federman, M., & Levine, D. L. (2010). Industrialization, pollution, and infant mortality. *Environment and Development Economics, 15*(5), 557-584.

Fisher, D., & Freudenburg, W. (2004). Post-industrialization and environmental quality: An empirical analysis of the environmental state. *Social Forces, 83*, 157-188.

Fleisher, B. M., & Chen, J. (1997). The coast-noncoast income gap, productivity, and regional economic policy in China. *Journal of Comparative Economics, 25*, 220-236.

Foster, J. B. (2005). The treadmill of accumulation Schnaiberg's environment and Marxian political economy. *Organization & Environment, 18*(1), 7-18.

Foster, J. B. (2007). The ecology of destruction. *Monthly Review, 58*(9), 1-14.

Frank, D. J., Hironaka, A., & Schofer, E. (2000). The nation-state and the natural environment over the twentieth century. *American Sociological Review, 65*, 96-116.

Freudenburg, W. R. (2006). Environmental degradation, disproportionality, and the double diversion: The importance of reaching out, reaching ahead, and reaching beyond. *Rural Sociology, 71*, 3-32.

Frey, R. S. (1998). The export of hazardous industries to the peripheral zones of the world-system. *Journal of Developing Societies, 14*, 66-81.

Frey, R. S. (2003).The transfer of core-based hazardous production processes to the export processing zones of the periphery: The maquiladora centers of northern Mexico. *Journal of World-Systems Research, 9*(2), 317-354.

Friedl, B., & Getzner, M. (2003). Determinants of CO_2 emissions in a small open economy. *Ecological Economics, 45*(1), 133-148.

Fu, B. (2007). Environmental problems and challenges in China. *Environmental Science & Technology*, *41*, 7597-7602.

Fujita, M., & Hu, D. (2001). Regional disparity in China 1985-1994: The effects of globalization and economic liberalization. *The Annals of Regional Science*, *35*(1), 3-37.

Glaeser, E. (2011). *Triumph of the city: How our greatest invention makes us richer, smarter, greener, healthier, and happier.* New York, NY: Penguin Press.

Goldman, M. (2002). Review of globalization and environmental reform. *Contemporary Sociology, 31*, 727-728.

Goodman, D. S. G., & Segal, G. (Eds.) (1994). *China deconstructs: Politics, trade and regionalism*. London: Routledge.

Gould, K. A., & Lewis, T. L. (2009). *Twenty lessons in environmental sociology*. New York, NY: Oxford University Press.

Gould, K. A., Pellow, D., & Schnaiberg, A. (2004). Interrogating the treadmill of production: Everything you wanted to know about the treadmill but were afraid to ask. *Organization & Environment, 17*, 296-316.

Grimes, P., & Kentor, J. (2003). Exporting the greenhouse: Foreign capital penetration and CO_2 emissions 1980-1996. *Journal of World-Systems Research, 9*, 261-275.

Grossman, G. M., & Krueger, A.B. (1995). Economic growth and the environment. *Quarterly Journal of Economics, 110*, 353-377.

Gu, C. L. (1992). *Urban system in China: History, present and prospects*. Shanghai: Commercial Press (in Chinese).

Haberl, H., & Krausmann, F. (2001). Changes in population, affluence and environmental pressures during industrialization. The case of Austria 1830–1995. *Population and Environment, 23*, 49-69.

Hathaway, M. J. (2010). Global environmental encounters in southwest China: Fleeting intersections and transnational work. *The Journal of Asian Studies, 69*(2), 427-451.

He, C. F. (2002). Information costs, agglomeration economies and the location of foreign direct investment in China. *Regional Studies, 36*(9),1029-1036.

He, C. F., Huang, Z. J., & Ye, X. (2014). Spatial heterogeneity of economic development and industrial pollution in urban China. *Stochastic Environmental Research and Risk Assessment, 28*(4), 767-781.

He, C. F., & Pan, F. H. (2010). Economic transition, dynamic externalities and city industry growth in China. *Urban Studies, 47*(1), 121-144.

He, C. F., Pan, F. H., & Yan, Y. (2012). Is economic transition harmful to urban environment? Evidence from industrial air pollution in Chinese cities. *Urban Studies*, *49*(8), 1767-1790.

He, C. F., & Wang, J. S. (2012). Does ownership matter for industrial agglomeration in China. *Asian Geographers*, *29*(1), 1-19.

He, C. F., Wei, Y. H.D., & Xie, X. Z. (2008). Globalization, institutional change and industrial location: Economic transition and industrial concentration in China. *Regional Studies, 42*(7), 923-945.

He, C. F., Zhang, T., & Wang, R. (2012). Air quality in urban China. *Eurasian Geography and Economics, 53*(6), 750-771.

He, J. (2006). Pollution haven hypothesis and environmental impacts of foreign direct investment: The case of industrial emission of sulfur dioxide (SO_2) in Chinese provinces. *Ecological Economics, 60*(1), 228-245.

Hornborg, A. (1998). Towards an ecological theory of unequal exchange: Articulating world system theory and ecological economics. *Ecological Economics, 25*, 127-136.

Hornborg, A. (2001). *The Power of the machine: Global inequalities of economy, technology, and environment*. Walnut Creek, CA: Alta Mira Press.

Hornborg, A. (2009). Zero-sum world: Challenges in conceptualizing environmental load displacement and ecologically unequal exchange in the world-system. *International Journal of Comparative Sociology, 50*, 237-262.

Huang, Z. J., Wei, Y.H.D., & He, C.F. (2015). Urban land expansion under economic transition in China: A multilevel modeling analysis. *Habit International, 47,* 69-82.

Janicke, M. (2008). Ecological modernization: New perspectives. *Journal of Cleaner Production, 16*, 557-565.

Jorgenson, A. K. (2006). Unequal ecological exchange and environmental degradation: A theoretical proposition and cross-national study of deforestation, 1990-2000. *Rural Sociology, 71*, 685-712.

Jorgenson, A. K. (2007). Does foreign investment harm the air we breathe and the water we drink? A cross-national study of carbon dioxide emissions and organic water pollution in less-developed countries, 1975-2000. *Organization & Environment,* *20*, 137-156.

Jorgenson, A. K. (2009a). The transnational organization of production, the scale of degradation, and ecoefficiency: A study of carbon dioxide emissions in less-developed countries. *Human Ecology Review, 16*, 64-74.

Jorgenson, A. K. (2009b). Foreign direct investment and the environment, the mitigating influence of institutional and civil society factors, and relationships between industrial pollution and human health: A panel study of less-developed countries. *Organization & Environment, 22*, 135-157.

Jorgenson, A. K. (2012). The sociology of ecologically unequal exchange and carbon dioxide emissions, 1960-2005. *Social Science Research, 41*, 242-252.

Jorgenson, A. K. (2014). Economic development and the carbon intensity of human well-being. *Nature Climate Change, 4*, 186-189.

Jorgenson, A. K., & Clark, B. (2009). The economy, military, and ecologically unequal exchange relationships in comparative perspective: A panel study of the ecological footprints of nations, 1975-2000. *Social Problems, 56*(4), 621-646.

Jorgenson, A. K., & Clark, B. (2010). Assessing the temporal stability of the population / environment relationship: A cross-national panel study of carbon dioxide emissions, 1960-2005. *Population & Environment, 32*, 27-41.

Jorgenson, A. K., & Clark, B. (2012). Are the economy and the environment decoupling? A comparative international study, 1960-2005. *American Journal of Sociology, 118*, 1-44.

Jorgenson, A. K., & Clark, B. (2013). Relationship between national-level carbon dioxide emissions and population size: An assessment of regional and temporal variation, 1960-2005. *PLoS ONE, 8*(2), e57107.

Jorgenson, A. K., Clark, B., & Kentor, J. (2010). Militarization and the environment: A panel study of carbon dioxide emissions and the ecological footprints of nations, 1970-2000. *Global Environmental Politics, 10*, 7-29.

Jorgenson, A. K., Dick, C., & Shandra, J. (2011). World economy, world society, and environmental harms in less-developed countries. *Sociological Inquiry, 81*(1), 53-87.

Jorgenson, A. K., & Kick, E. (2003). Globalization and the environment. *Journal of World-System Research, 9*, 195-203.

Jorgenson, A. K., & Kuykendall, K. (2008). Globalization, foreign investment dependence, and agriculture production: A cross-national study of pesticide and fertilizer use intensity in less-developed countries, 1990-2000. *Social Forces, 87*, 529-560.

Jorgenson, A. K., & Rice, J. (2005). Structural dynamics of international trade and material consumption: A cross-national study of the ecological footprint of less-developed countries. *Journal of World-Systems Research, 11*, 57-77.

Jorgenson, A. K., Rice, J., & Clark, B. (2010). Cities, slums, and energy consumption in less-developed countries, 1990-2005. *Organization & Environment, 23*, 189-204.

Kahn, M. E. (2004a). Domestic pollution havens: Evidence from cancer deaths in border counties. *Journal of Urban Economics*, *56*(1), 51-69.

Kahn, M. E. (2004b). *Green cities: Urban growth and the environment.* Washington, DC: Brookings Institution Press.

Kahn, M. E. (2009). Urban growth and climate change. *Annual Review of Resource Economics, 1,* 333-350.

Kahn, M. E., Li, P., & Zhao, D.X. (2015). Water pollution progress at borders: The role of changes in China's political promotion incentives. *American Economic Journal: Economic Policy, 7*(4), 223-242.

Kellenberg, D. K. (2009). An empirical investigation of the pollution haven effect with strategic environment and trade policy. *Journal of International Economics, 78*(2), 242-255.

Kentor, J., & Boswell, T. (2003). Foreign capital dependence and development: A new direction. *American Sociological Review, 68*, 301-313.

Kochin, M. S. (1996). Decollectivization of agriculture and the planned economy. *American Journal of Political Science, 40*(3), 717-739.

Konisky, D.M. (2007). Regulatory competition and environmental enforcement: Is there a race to the bottom? *American Journal of Political Science, 51*(4), 853-872.

Kuby, M., & He, C. F. (2011). The changing structure of energy supply, demand and CO_2 emissions in China. *Annals of Association of American Geographers, 101*(4), 795-805.

Kuhn, T. S. (1970). *The structure of scientific revolutions*. Chicago, IL: University of Chicago Press.

Kung, J. K., & Lin, J. Y. F. (2003). The causes of China's great leap famine, 1959-1961. *Economic Development and Cultural Change, 52*(1), Lei, Y., Zhang, Q., He, K. B., & Streets, D. G. (2011). Primary anthropogenic aerosol emission trends for China, 1990-2005. *Atmospheric Chemistry and Physics, 11,* 931-954.

Li, B. Q., & An, X.S. (2009). *Migration and small towns in China: Power hierarchy and resource allocation*. London: International Institute for Environment and Development.

Li, J., Wang, Z., Zhuang, G., Luo, G., Sun, Y., & Wang, Q. (2012). Mixing of Asian mineral dust with anthropogenic pollutants over east Asia: A model case study of a super-duststorm in march 2010. *Atmospheric Chemistry and Physics*, *12*(16), 7591-7607.

Liang, D. (2012). *Payment schemes for forest ecosystem services in China: policy, practices and performance*. Wageningen, Netherlands: Wageningen Academic Pub.

Lin, J. Y. F., Cai, F., & Li, Z. (2003). *The China miracle: Development strategy and economic reform*. Hong Kong: Chinese University Press.

Liu, J. G., & Diamond, J. (2005). China's environment in a globalizing world. *Nature, 435*, 1179-1186.

Liu, T., & Beattie, J. (Eds.) (2016). *Environment, modernization, and development in East Asia: Perspectives from environmental history*. Basingstoke, UK: Palgrave Macmillan.

Liu, X. P., Lovely, M. E., & Ondrich, J. (2010). The location decisions of foreign investors in china: Untangling the effect of wages using a control function approach. *The Review of Economics and Statistics, 92*(1), 160-166.

Liu, Z., Guan, D., Wei, W., Davis, S.J., Ciais, P., Bai, J., Peng, S., & He, K. (2015). Reduced carbon emission estimates from fossil fuel combustion and cement production in China. *Nature, 524*, 335-338,

Longhofer, W., & Schofer, E. (2010). National and global origins of environmental association. *American Sociological Review, 75*, 505-533.

Mauro, D. D., Dietz, T., & Rockwood, L. (2007). Determining the effect of urbanization on generalist butterfly species diversity in butterfly gardens. *Urban Ecosystems, 10*, 427-439.

McElroy, M. B. (2009). Potential for wind-generated electricity in China. *Science, 325*, 1378-1380.

McNally, C. A. (2002). China's state-owned enterprises: Thriving or crumbling? *Asia*

Pacific Issues, *59*, 1-8.

McNeill, J. (2000). *Something new under the sun: An environmental history of the world in the 20th century*. London: Allen Lane.

Merican, Y. (2007). Foreign direct investment and the pollution in five ASEAN nations. *International Journal of Economics and Management, 1*(2), 245-261.

Mol, A. P. J. (1997). Ecological modernization: Industrial transformations and environmental reform. In M. Redclift & G.Woodgate (Eds.), *The international handbook of environmental sociology* (pp. 138-149). Northampton, MA: Elgar.

Mol, A. P. J. (2002). Ecological modernization and the global economy. *Global Environmental Politics, 2*(2), 92-115.

Mol, A. P. J. (2006). From environmental sociologies to environmental sociology? A comparison of U.S. and European environmental sociology. *Organization & Environment, 19*(1), 5-27.

Mol, A. P. J., & Spaargaren, G. (2000). Ecological modernization theory in debate: A review. *Environmental Politics, 9*, 17-49.

Mol, A. P. J., & Spaargaren, G. (2002). Ecological modernization and the environmental state. In A. P.J. Mol & F. H. Buttel (Eds.), *The environmental state under pressure* (pp. 33-52*).* Amsterdam and Boston, MA: JAI Press.

Mol, A. P. J., & Spaargaren, G. (2005). From additions and withdrawals to environmental flows: Reframing debates in the environmental social sciences. *Organization & Environment, 18*, 91-107.

Mol, A. P. J., Spaargaren, G., & Sonnenfeld, D. (2009). Ecological modernization: Three decades of policy, practice and theoretical reflection. In A.P.J. Mol, D.A. Sonnenfeld, & G. Spaargaren (Eds.), *The ecological modernization reader* (pp. 3-14). London/New York: Routledge.

Molotch, H. (1976). The city as a growth machine: Toward a political economy of place. *American Journal of Sociology, 82*(2), 309-332.

Moore, T. (2002). *China in the world market: Chinese industry and international sources of reform in the post Mao era.* Cambridge, UK: Cambridge University Press.

Murphey, R. (1967). Man and nature in China. *Modern Asian Studies, 1*(4), 313-333.

Naughton, B. (2007). *The Chinese economy: Transitions and growth*. Boston, MA: MIT Press.

Nicholas, A. A., Bluestone, B., Freeman, P., J. McAteer, D., & Moomaw, W. R. (2002). Globalization and the environment. *Journal of Public Health Policy, 23*(2), 225-238.

Nolan, P. (1983). Decollectivization of agriculture in China, 1979-82: A long term perspective. *Cambridge Journal of Economics*, *8*, 381-403.

Oi, J. C. (1999). *Rural China takes off: Institutional foundations of economic reform*. Berkeley, CA: University of California Press.

Organization for Economic Co-operation and Development. (2002). *Indicators to measure decoupling of environmental pressure from economic growth*. Paris: OECD.

Paehlke, R. (2001). Environment, equity and globalization: Beyond resistance. *Global Environmental Politics, 1*(1), 1-10.

Pandey, K. D., Wheeler, D., Ostro, B., Deichmann, U., Hamilton, K., & Bolt, K. (2004). *Ambient particulate matter concentrations in residential areas of world cities: New estimates based on global model of ambient particulates (GMAPS)*. Washington, DC: World Bank.

Pellow, D., & Brehm, H. (2013). An environmental sociology for the twenty-first century. *Annual Review of Sociology, 39,* 229-250.

Peters, G. P., & Hertwich, E.G. (2008). CO_2 embodied in international trade with implications for global climate policy. *Environmental Science and Technology*, *42*(5), 1401-1407.

Piao, S. (2009). The carbon balance of terrestrial ecosystems in China. *Nature, 458,* 1009-1013.

Pomeranz, K. (2000). *The great divergence: China, Europe, and the making of the modern world economy.* Princeton, NJ: Princeton University Press.

Pope, C. A. (2009). Fine particulate air pollution and life expectancy in the United States. *New England Journal of Medicine, 360*, 376-386.

Pred, A. (1980). *Urban growth and city-systems in the United States, 1840-1860*. Boston, MA: Harvard University Press.

Rene, H. K. (2013). *China's sent-down generation. Public administration and the legacies of Mao's rustication program*. Washington, DC: Georgetown University Press.

Rice, J. (2009). The transnational organization of production and uneven environmental degradation and change in the world economy. *International Journal of Comparative Sociology, 50*(3-4), 215-236.

Roberts, J. T. (2001). Global inequality and climate change. *Society & Natural Resources, 14*, 501-109.

Roberts, J. T., & Grimes, P. E. (1997). Carbon intensity and economic development 1962-91: A brief exploration of the environmental Kuznets curve. *World Development, 25*(2), 191-198.

Roberts, J. T., Grimes, P. E., & Manale, J. L. (2003). Social roots of global environmental change: A world-systems analysis of carbon dioxide emissions. *Journal of World-Systems Research, 9*(2), 277-315.

Rohde, R., & Muller, R. (2015). Air pollution in China: Mapping of concentrations and sources. *PLoS ONE*, *10*, e0135749.

Rosa, E. A., & Dietz, T. (2012). Human drivers of national greenhouse gas emissions. *Nature Climate Change*, *2*, 581-586.

Rosa, E. A., York, R., & Dietz, T. (2004). Tracking the anthropogenic drivers of ecological impacts. *Ambio*, *33*(8), 509-512.

Rosen, S. (1982). Obstacles to educational reform in China. *Modern China*, *8*(1), 3-40.

Rudel, T. (2009). How do people transform landscapes? A sociological perspective on suburban sprawl and tropical deforestation. *American Journal of Sociology, 115*, 129-154.

Rudel, T., Roberts, T., & Carmin, J. (2011). The political economy of the environment. *Annual Review of Sociology, 37*, 221-237.

Schmidt, C.W. (2002). Economy and environment: China seeks a balance. *Environmental Health Perspectives, 110*, 516-522.

Schnaiberg, A. (1975). Social syntheses of the societal-environmental dialectic: The role of distributional impacts. *Social Science Quarterly, 56*, 5-20.

Schnaiberg, A. (1980). *The environment: From surplus to scarcity*. New York, NY: Oxford University Press.

Schnaiberg, A., & Gould, K. A. (1994). *Environment and society: The enduring conflict*. New York, NY: St. Martin's Press.

Schnaiberg, A., Pellow, D. N., & Weinberg, A. (2002). The treadmill of production and the environmental state. In A. P.J. Mol & F. H. Buttel (Eds.), *The environmental* *state under pressure* (pp. 15-32*).* Amsterdam and Boston, MA: JAI Press.

Shabad, T. (1972). *China's changing map: National and regional development, 1949-1971*. New York, NY: Praeger.

Shapiro, J. (2001). *Mao's war against nature: Politics and the environment in revolutionary China.* Cambridge, UK: Cambridge University Press.

Shen, J. Y. (2006). A simultaneous estimation of environmental Kuznets curve: Evidence from China. *China Economic Review*, *17*(4), 383-394.

Shi, H., & Zhang, L. (2006). China's environmental governance of rapid industrialization. *Environmental Politics*, *15*(2), 271-292.

Shi, Y. Z. (1998). *Chinese firms and technology in the reform era*. London, UK: Routledge.

Shin, S. (2004). Economic globalization and the environment in China: A comparative case study of Shenyang and Dalian. *The Journal of Environment & Development*, *13*(3), 263-294.

Sims, H. S. (1999). One-fifth of the sky: China's environmental stewardship. *World Development, 27*(7), 1227-1245.

Singh, B., Singh, A., & Dhingra, A.K. (2012). Drivers and barriers of green manufacturing practices: A survey of Indian industries. *International Journal of Engineer Science, 1*(1), 5-19.

Smith, D. (2006). *Globalization: The hidden agenda*. Cambridge, UK: Polity Press.

Song, L.G., & Woo, W.T. (2009). *China's dilemma: Economic growth, the environment and climate change*. Washington, DC: Brookings Institution Press.

Song, Tao., Zheng, T.G. & Tong, L.J. (2008). An empirical test of the environmental Kuznets curve in China: A panel cointegration approach. *China Economic Review*, *19*(3), 381-392.

Sonnenfeld, D., & Rock, M.T. (2009). Ecological modernization in Asian and other emerging economies. In A.P.J. Mol, D.A. Sonnenfeld & G. Spaargaren (Eds.), *The ecological modernization reader* (pp. 359-371). London/New York: Routledge.

Spaargaren, G. (2003). Sustainable consumption: A theoretical and environmental policy perspective. *Society & Natural Resources, 16*, 687-701.

Spaargaren, G., & Mol, A.P.J. (1992). Sociology, environment, and modernity:

Ecological modernization as a theory of social change. *Society and Natural Resources, 5*, 323-344.

Spapens, A., White, R., & Huisman, W. (2016). *Environmental crime in transnational context: Global issues in green enforcement and criminology*. London, UK: Routledge.

Spatareanu, M. (2007). Searching for pollution havens the impact of environmental regulations on foreign direct investment. *The Journal of Environment & Development, 16*(2), 161-182.

Stern, D. (2004). The rise and fall of the environmental Kuznets curve. *World Development, 32*, 1419-1439.

Sun, C., Zheng, S.Q., & Wang, R. (2014). Restricting driving for better traffic and clearer skies: Did it work in Beijing? *Transport Policy*, *32*, 34-41.

Tang, S., Selvanathan, E. A., & Selvanathan, S. (2008). Foreign direct investment, domestic investment and economic growth in China: A time series analysis. *The World Economy*, *31*(10), 1292-1309.

Torras, M., & Boyce, J. K. (1998). Income, inequality, and pollution: A reassessment of the environmental Kuznets curve. *Ecological Economics, 25*(2), 147-160.

UN Development Programme. (UNDP). (2015). *Human development report 2015: Work for human development*. Retrieved from http://hdr.undp.org/sites/default/files/2015_human_development_report.pdf

UN Development Programme. (UNDP). (2016). *Green is gold: The strategy and actions of China's ecological civilization.* Retrieved from http://web.unep.org/greeneconomy/sites/unep.org.greeneconomy/files/publications/greenisgold_en_20160519.pdf

United Nations. (2016). *Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015. Part one: Proceedings.* Retrieved from http://unfccc.int/resource/docs/2015/cop21/eng/10.pdf

Van Rooij, B. (2010). The people vs. pollution: Understanding citizen action against pollution in China. *The Journal of Contemporary China, 19*(63), 55-79.

Van Rooij, B. (2012). The people's regulation: Citizens and implementation of law in China. *Columbia Journal of Asian Law*, *25*(2), 116-180.

Van Rooij, B., & Lo, C. H. W. (2010). Fragile convergence, understanding variation in the enforcement of china's industrial pollution Law. *Law & Policy, 32*, 14-37.

Van Rooij, B., Lora-Wainwright, A., Wu, Y., & Zhang,Y. (2012). The compensation trap: The limits of community-based pollution regulation in China. *Pace Environmental Law Review, 29*, 701-745.

Wagner, U. J., & Timmins, C. D. (2009). Agglomeration effects in foreign direct investment and the pollution haven hypothesis. *Environmental and Resource Economics, 43*(2), 231-256.

Wallace, J. L. (2014). *Cities and stability: Urbanization, redistribution, and regime survival in China*. New York, NY: Oxford University Press.

Wang, G., Innes, J.L., Lei, J., Dai, S., & Wu, S.W. (2007). China's forestry reforms. *Science, 318*, 1556-1557.

Wang, H., & Jin, Y. H. (2002). Industrial ownership and environmental performance: Evidence from China. *Environmental and Resource Economics*, *36*(3), 255-273.

Wang, L.Y. (2010). The changes of China's environmental policies in the latest 30 years. *Procedia Environmental Sciences, 2*, 1206-1212.

Wang, S. S., Zhou, D.Q., Zhou, P., & Wang, Q.W. (2011). CO_2 emissions, energy consumption and economic growth in China: A panel data analysis. *Energy Policy*, *39*(9), 4870-4875.

Warner, M. (2004). Human resource management in China revisited: Introduction. *The International Journal of Human Resource Management, 15*(4), 617-634.

Warner, M. (2009). "Making sense" of HRM in China: Setting the scene. *The International Journal of Human Resource Management, 20*(11), 2169-2193.

Wei, Y. H. D. (2001). Decentralization, marketization, and globalization: The triple processes underlying regional development in China. *Asian Geographer*, *20*(1-2), 7-23.

Wei, Y. H. D., & Li, W.M. (2002). Reforms, globalization, and urban growth in China: The case of Hangzhou. *Eurasian Geography and Economics, 43*(6), 459-475.

Wei, Y. H. D., & Ye, X.Y. (2014). Urbanization, land use, and environmental change in China. *Stochastic Environmental Research and Risk Assessment, 28*, 757-765.

Wen, M., & Gu, D. D. (2012). Air pollution shortens life expectancy and health expectancy for older adults: The case of China. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 67*(11), 1219-1229

Williamson, A. (1965). Regional inequality and the process of national development. *Economic Development and Cultural Change*, *13*(4), 3-47.

World Bank. (1993). *The East Asian miracle: Economic growth and public policy.* New York, NY: Oxford University Press.

World Bank. (2007). *Cost of pollution in China : Economic estimates of physical damages*. Washington, DC: World Bank. Retrieved from http://documents.worldbank.org/curated/en/782171468027560055/Cost-of-pollution-in-China-economic-estimates-of-physical-damages.

World Bank. (2016). *What a waste: A global review of solid waste management*.Washington, DC: World Bank.

Wu, X. G., & Treiman, D.J. (2004). The household registration system and social stratification in China: 1955-1996. *Demography*, *41*(2), 363-384.

Xie, H. M., Shen, M.H., & Wang, R. (2014). Determinants of clean development mechanism activity: Evidence from China. *Energy Policy*, *67*, 797-806.

Xin, H., & Stone, R. (2010). China amasses war chest to confront its environmental nightmares. *Science, 327*, 1440-1441.

Yang, D. L. (1990). Patterns of China's regional development strategy. *The China Quarterly*, *122,* 230-257.

Yang, X., & He, C. (2015). Do polluting plants locate in the borders of jurisdictions? Evidence from China. *Habitat International, 50*, 140-148.

Ye, B. M. (2003). Concentration and chemical composition of $PM_{2.5}$ in Shanghai for a 1-year period. *Atmospheric Environment*, *37*, 499-510.

York, R. (2007). Structural influences on energy production in South and East Asia, 1971-2002. *Sociological Forum, 22*(4), 532-554.

York, R. (2012). Do alternative energy sources displace fossil fuels? *Nature Climate Change, 2*(6), 441-443.

York, R., Ergas, C., Rosa, E.A., & Dietz, T. (2011). It's a material world: Trends in material extraction in China, India, Indonesia and Japan. *Nature and Culture, 6*, 103-122.

York, R., & Rosa, E, A. (2003). Key challenges to ecological modernization theory: Institutional efficacy, case study evidence, units of analysis, and the pace of eco-efficiency. *Organization & Environment, 16*(3), 273-288.

York, R., & Rosa, E.A. (2012). Choking on modernity: A human ecology of air pollution. *Social Problems, 59*(2), 282-300.

York, R., Rosa, E. A., & Dietz, T. (2003). Footprints on the earth: The environmental consequences of modernity. *American Sociological Review, 68*, 279-300.

Yue, W.Z., Fan, P.L., Wei, Y.H.D., & Qi, J.G. (2014). Economic development, urban expansion, and sustainable development in Shanghai. *Stochastic Environmental Research and Risk Assessment, 28*(4), 783-799.

Zhang, C. H. (2011). Productivity growth and environmental regulations-accounting for undesirable outputs: Analysis of China's thirty provincial regions using the Malmquist-Luenberger index. *Ecological Economics, 70*(12), 2369-2379.

Zhang, J., & Fu, X.L. (2008). FDI and environmental regulations in China. *Journal of the Asia Pacific Economy, 13*(3), 332-353.

Zhang, K. M., & Wen, Z.G. (2008). Review and challenges of policies of environmental protection and sustainable development in China. *Journal of Environmental Management, 88*, 1249-1261.

Zhang, K. M., Wen, Z., & Peng, L.Y. (2007). Environmental policies in China: Involvement, features and evaluation. *China Population Resources Environment, 17*(2), 1-7.

Zhang, X., Zhang, P., Zhang, Y., Li, X., & Qiu, H. (2007). The trend, seasonal cycle, and sources of tropospheric NO_2 over China during 1997-2006 based on satellite measurement. *Science in China Series D: Earth Sciences*, *50*, 1877-1884.

Zheng, S. Q. (2009). Economic value of air quality: Estimating the willingness-to-pay for clean air in Beijing. *Journal of Environmental Economy and Policy, 1,* 36-47 (in Chinese).

Zheng, S. Q., Cao, J., Kahn, M. E., & Sun, C. (2014). Real estate valuation and cross-boundary air pollution externalities: Evidence from Chinese cities. *Journal of Real Estate Finance and Economics, 48*(3), 398-414.

Zheng, S. Q., & Kahn, M. E. (2013). Understanding China's urban pollution dynamics. *Journal of Economic Literature, 51*(3), 731-772.

Zheng, S. Q., Kahn, M. E., & Liu, H.Y. (2010). Towards a system of open cities in China: Home prices, FDI flows and air quality in 35 major cities. *Regional Science and Urban Economics, 40*(1), 1-10.

Zheng, S. Q., Kahn, M.E., Sun, W.Z., & Luo, D. L. (2014). Incentives for China's urban mayors to mitigate pollution externalities: The role of the central government and public environmentalism. *Regional Science and Urban Economics, 47*, 61-71.

Zheng, S. Q., Sun, C., Qi, Y., & Kahn, M. E. (2014). The evolving geography of China's

Industrial production: Implications for pollution dynamics and urban quality of life. *Journal of Economic Surveys, 28*(4), 595-774.

Zhou, Y. X., & Ma, L.J. C. (2003). China's urbanization levels: Reconstructing a baseline from the fifth population census. *The China Quarterly*, *173*, 176-196.

Zhu, S. J., He, C. F., & Ying, L. (2014). Going green or going away: Firm strategy and environmental regulation in china's pollution-intensive industries. *Geoforum, 55*, 53-65.

Zhu, C. J., & Nyland, C. (2004). Marketization and social protection reform: Emerging HRM issues in China. *The International Journal of Human Resource Management, 15*(4), 853-877.