MAINTAINING GROWTH, REDUCING EMISSIONS: AN ECONOMETRIC ANALYSIS OF INDUSTRIAL SULFUR DIOXIDE EMISSIONS AND ECONOMIC GROWTH IN CHINA

by

Matthew Baird Archer

A thesis submitted to the faculty of the University of Mississippi in partial fulfillment of the requirements for completion of the Bachelor of Arts degree in International Studies
Croft Institute for International Studies
Sally McDonnell Barksdale Honors College
The University of Mississippi

Oxford, Mississippi

May 2011

Approved by

Advisor: Dr. Gang Guo

Reader: Dr. Walter J. Mayer

Reader: Dr. William C. Schenck

© Matthew Baird Archer
2011
ALL RIGHTS RESERVED

ACKNOWLEDGEMENTS AND DEDICATION

First, I would like to thank the Croft Institute for International Studies and the Sally McDonnell Barksdale Honors College for their continued support over the last four years.

This thesis would never have taken shape without the help of my mentor, Professor Gang Guo, and my third reader, Professor Walt Mayer. Their contributions throughout the entire thesis-writing process were invaluable, and I am extremely grateful for their past and continued support. Outside of my thesis committee, I would also like to thank Dr. Micah Milinovich, Dr. Michael Belongia and Ms. Jing Zhang. It goes without saying that any mistakes contained in this thesis resulted from the author's own shortcomings and are in no way contributed to my advisors.

I would also like to thank my friends, those who I've been friends with since my first day at Ole Miss, as well as those who have come into my life more recently. Friends I made while studying abroad in Shanghai and friends who are still in China have also been very helpful over the past year. Pan A'yi and Zhou Shushu, my host parents in Shanghai, were also tremendously helpful, as they provided a glimpse into real China and encouraged me to look under the surface of China's environmental issues.

Finally, I would like to thank my mom, dad and sister, who have been unbelievably supportive throughout this entire process.

I dedicate this to my family.

TABLE OF CONTENTS

CHAPTER 1

Mankind thus inevitably sets itself only such tasks as it is able to solve, since closer examination will always show that the problem itself arises only when the material conditions for its solution are already present or at least in the course of formation.

Karl Marx, A Contribution to the Critique of Political Economy, *1859*

1.1. Introduction

The increasing prevalence of environmental degradation in the People's Republic of China parallels the country's rapid economic growth. Certainly, China's development has translated to higher standards of living for hundreds of millions of people and increased prosperity around the globe. But economic development requires a "gargantuan consumption of resources" (Economy E. , 2007), and China's economic expansion has, unfortunately, been followed by extraordinarily high levels of pollution. National accounts indicate that the absolute value of SO2 emissions has increased dramatically since 1996. A national analysis of these trends is not very useful because instances of pollution and other destructive environmental accidents are not spread evenly across provinces, nor do they correlate significantly with the national aggregate GDP per capita. This thesis seeks to explain these discrepancies by analyzing various provincial and municipal-level economic and industrial data over a period of 14 years (from 1996 – 2008) and three Five Year Plans (FYPs) to determine what type(s) of industrial and economic policies will allow China to maintain growth while curtailing environmental destruction. In the end, the author hopes to answer two questions: First, what factors have allowed some provinces and municipalities in China to develop thriving economies without sacrificing environmental quality? And second, what steps can sub-national governments take to obviate the threat of further environmental degradation while maintaining necessary economic growth?

The thesis is divided into four chapters: the first outlines China's demoralizing history of environmental devastation, from Mao Zedong's idea that "man must conquer nature" (*ren ding sheng tian*) to China's current dependency on coal and other forms of dirty energy, while noting the significant progress the Chinese government has made under the leadership of Hu Jintao and Wen Jiabao. Chapter one also discusses different theories in environmental economics, specifically the Environmental Kuznets Curve (EKC) theory and the pollution haven hypothesis (PHH), as they pertain to the relationship between China's growing economy and battered environment. The second chapter quantitatively analyzes economic and environmental data from China's National Bureau of Statistics from 1996 to 2008 on a subnational level. Utilizing simple panel data methods, the author determines what variables have significant impact on industrial SO2 emissions and what policies are best suited to maintain economic growth while mitigating environmental damage. In the third chapter, the author introduces various environmental and economic policy theories and discusses their relevance to the relationship between economic growth and environmental quality in China. In the concluding chapter, the author provides economic and environmental policy recommendations for both the Central Government in Beijing and lower-level government bodies in the various provincial capitals.

China's breakneck rise to international prominence – both economically and politically – puts it at the forefront of many of the world's most pressing affairs. Sandstorms originating in the Gobi Desert blow across China's eastern seaboard, Japan, Korea and even California, carrying harmful pollutants from China's industrial zones around the world. China's economic growth is bound to be mirrored by other developing regions like Africa and Southeast Asia. Jeffrey Sachs phrases it perfectly: "China's economic rise, while improving the well-being of hundreds of millions of people, exemplifies the kind of global stresses that will be pervasive in the coming decades" (Sachs, 2008).

The importance of this thesis and its results lies not only in the recommendations it will propose to the Chinese government, but also the data analysis contained within the quantitative section by which other researchers might model their own analyses. Moreover, this thesis addresses a topic that few economists have studied. While the relationship between economic growth and environmental quality has been studied on a broad, international level, few researchers have narrowed their focus to a specific country. Even fewer have sought to address a country that is as economically diverse as the People's Republic of China. Discrepancies in income, living standard, foreign investment and industrial output are only a few aspects of provincial differences, and the empirical analysis contained in this paper deviates from approaches found in existing literature by examining subnational data, as opposed to aggregate figures. This, perhaps, is its most significant contribution.

1.2. Brief history of environmental movements and policies

In rapidly industrializing regions, environmental quality is often ignored in favor of economic growth. In the 19th Century, smog and water pollution were killing residents of densely populated cities like London. In a letter to the editor in 1855, Michael Faraday noted the pollution in the Thames River and urged local government officials to work to correct it. The roots of the modern environmental movement are often attributed to the publication of Rachel Carson's book *Silent Spring* in the summer of 1962, which prompted the creation of a national committee on pesticides in the United States. By 1970, environmentalism was common, especially in America, where over 300,000 people participated in the first Earth Day. Since then, numerous international regulatory organs have been established to promote environmental protection (McCormick, 1991).

In China, however, it was not until the mid-1990s that civic environmentalism began to develop and flourish. This movement has by and large been very peaceful in China, and a vast network of NGOs, bolstered by popular support both at home and abroad, has allowed the movement to spread (Yang, 2010).

Now, the so-called climate change debate rages in public discourse, but in reality, “debate” is a bit of a misnomer. Hard science proves that there is little room for debating the fact that climate change is a serious issue. Recent research at NASA’s Jet Propulsion Laboratory concludes that the “Earth’s largest lakes have warmed during the past 25 years in response to climate change” (Buis & Cole, 2010). The report shows that climate change has impacted bodies of water ranging from the Great Lakes to the Caspian Sea to the lakes of Siberia, Mongolia and northern China. With that said, the fact that climate change is occurring will not be debated in this thesis, and its existence is an assumption in the analyses.

Whether humans are responsible for climate change is a more credible debate, but only slightly. While greenhouse gases like carbon dioxide, methane and nitrous oxide certainly occur naturally, human activities like agriculture, transportation, energy production, manufacturing and solid wastes disposal contribute significantly to environmental degradation. Fluorinated gases, on the other hand, are emitted only by human activities and include chemicals like hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride. The US Environmental Protection Agency (EPA) notes that human-generated greenhouses gas emissions will likely continue to increase in the near future, due in large part to continued dependence on fossil fuels (Greenhouse Gas Emissions, 2010). In the international scientific community, there is also a relatively stable consensus. According to the European Union, the United Nations, ASEAN, and many other international government organizations, climate change is obvious, and many place it at the forefront of their political agendas. Even the Chinese government recognizes the increasing importance of international climate change mitigation efforts based on scientific evidence (Xinhua News, 2011).

With this in mind, it is important to note that human-induced climate change is a result of environmental degradation, but not all environmental degradation contributes to climate change. Some harmful pollutants (among them sulfur dioxide) are not considered a greenhouse gas, yet there societal and economic impacts are more easily visible. SO2, for example, is responsible for acid rain and is one of the airborne particulates that contributes to higher rates of bronchitis, asthma, respiratory diseases, hospitalizations and morbidity (Pope, 2000).

Because of these palpable observations, environmental protection has become a ubiquitous issue in political dialogues around the world, and recently, China has been a central topic of conversation. As global powers begin to realize the exigency of mitigating the effects of climate change, national governments are beginning to take a proactive stance against various environmental hazards. And as the effects of human induced climate change become more and more visible, environmental regulations are being passed at every level of government (Rugman & Verbeke, 1998). Following the culmination of the 2009 Copenhagen summit, which was widely regarded as a failure[1], governments began propagating grandiloquent plans to save the planet from climate change. Environmental protection initiatives became a central theme in

---

[1] Environmental groups were overwhelmingly critical of the outcome of the Copenhagen summit on climate change. Activists at Greenpeace was especially displeased, dubbing the summit a “cop-out” that was “not fair, not ambitious and not legally binding” (Greenpeace, 2009). Academics were also unimpressed. “The Hartwell Paper: A New Direction for Climate Policy after the Crash of 2009,” coordinated by the MacKinder Program at the London School of Economics, discusses candidly the failure of world leaders to reach a meaningful consensus in Copenhagen. International media outlets, ranging from the People’s Daily to the New York Times to Le Monde, were also unabashedly critical of the outcome in Copenhagen.

political campaigns, but so far, Chinese leadership has been hesitant to accept many international mandates.

Recently, Beijing has been wont to use its new influence in global negotiations to urge developed nations to fund poorer countries' environmental efforts. National Development and Reform Commission vice-chairman Xie Zhenhua, one of the leading voices on environmental issues in China, has said that before China can be expected to play a significant role in international environmental efforts, the US and other western nations must take the lead in reducing emissions, funding research and development of green technologies, and helping developing nations meet their goals (Johnson, 2010). Xie reiterated this stance in a conference with various environmental NGOs on 25 November 2010, the first day of the UN's annual summit on climate change in Cancun, Mexico, which is a precursor for this year's summit in South Africa, where leaders hope to draft legislation similar to the Kyoto Protocol. But, Xie warns that Cancun talks will not be a solid foundation for South Africa unless developed countries set reasonable goals for the developing world, and then help those nations achieve them (Meng, 2010).

1.3. Economic growth versus environmental quality

The relationship between environmental quality and economic growth is obfuscated by the myriad aspects of each side. No single variable is a good indicator of economic well-being, nor is one variable a suitable representative of environmental quality. Moreover, neither economic growth nor environmental quality can be analyzed statically – one generation's actions can drastically affect future generations' well-being. Siebert (1987) characterizes the interaction between the economy and the environment almost as a parasitic relationship, i.e., the inputs required for production of consumer goods are extracted from the earth, and the harmful effects of emissions and other environmental pollutants are distributed as costs to both human welfare and the natural world (p. 8). Economically, this relationship is subject to a number of constraints, including various functions of human capital, physical capital, pollution, abatement technology and utility functions (Hettich, 2000).

The Environmental Kuznets Curve

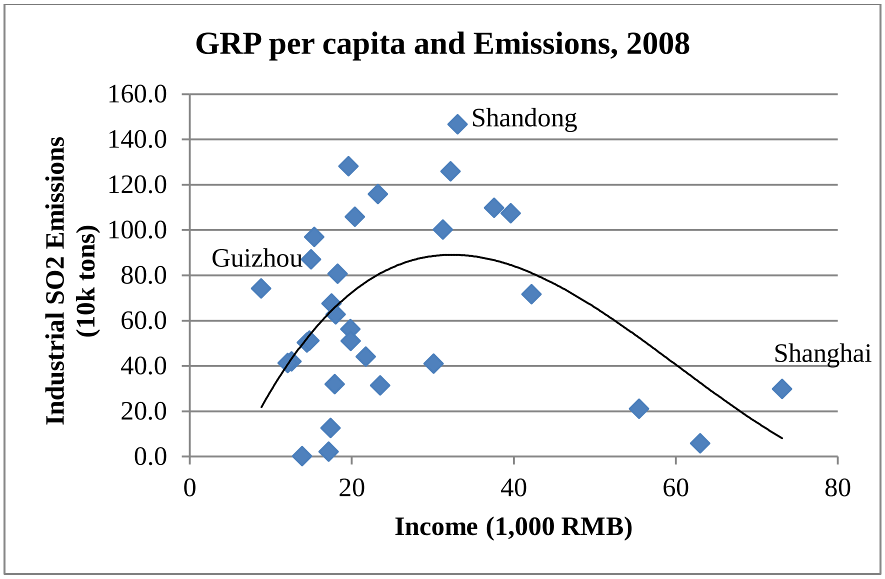
Scholarly publications on the relationship between economic growth and environmental quality are numerous. At the center of the literature is the Environmental Kuznets Curve, which is based primarily on Shafik (1994) and Grossman and Krueger (1995). Basically, the EKC explains the relationship between income and environmental quality as an inverted U-shaped curve. That is, as income rises from zero, environmental degradation becomes more severe, but at a certain point of economic development, people become wealthy enough to demand a cleaner and healthier environment, and some environmental quality indicators begin to improve. With the exception of nitrates and cadmium, Grossman and Krueger (1995) estimate that all pollutants will peak before GDP per capita reaches $10,000, which means that their slopes are negative after this level. At $12,000, all the pollutants have peaked, and some, e.g. total coliform and dissolved oxygen, have already began to increase as a result of the cubic relationship between GDP per capita and pollution.

The EKC theory has become widely accepted in many environmental economic circles, but it is certainly not infallible (see, for example, Andreoni and Levinson, 2001; Levinson, 2002; Stern, 2004). In China’s case, the EKC fails to take into account the government’s role in expediting the process of enhancing environmental quality. On an international level, the EKC fails to provide any realistic income levels where pollution might begin to decrease. In the United States, for example, emissions continue to rise as GDP per capita nears $40,000. In

China specifically, the EKC may not be a realistic indicator of the relationship between GDP per capita and pollution emissions (Guo, Fan and Wu, 2007).

Some critics also argue the EKC phenomenon is simply a spurious outcome of numerous tests and that it is impractical. A more realistic outcome, they suggest, is that emissions will eventually reach a plateau at a horizontal line of pollution levels in a globalization-induced "'race to the bottom' in emissions standards" (Dasgupta, Laplante, Wang, & Wheeler, 2002). Furthermore, many researchers are unable to replicate the results of earlier studies. Harbaugh *et al.* (2000), for example, are unable to attain the same results as Grossman and Krueger (1995), despite using the same variables and functional forms (although their emissions data were corrected for reporting errors). And, as Ekins (1997) points out, the inverted U-shape form of the results depends very heavily on functional forms of the tested data. Furthermore, the EKC fails to take into account a nation's economic composition, which is especially important in developing countries like China (Cole & Neumayer, 2009).

Regardless, it seems that China may be following the EKC trend after all. In 2008, for example, Guizhou's GRP per capita was less than 9,000 RMB, making it China's poorest province. That same year, it emitted over 740,000 tons of industrial sulfur dioxide. This is in stark contrast to Shanghai, whose GRP per capita exceeded 73,000 RMB, but whose industrial SO2 emissions were less than 300,000 tons. There were almost 1.5 million tons of industrial SO2 emitted in Shandong Province, the highest of any region in China, yet its GRP per capita was right between Shanghai and Guizhou, equaling just over 33,000 RMB in 2008. The scatter plot below illustrates this relationship in 2008, with a trend line included to demonstrate the inverted U-shaped curve hypothesized by the EKC theory:



Pollution Haven Hypothesis

The tradeoff between environmental quality and industrial competitiveness is also an important topic in any conversation about environmental policy. The pollution haven hypothesis (PHH) suggests that international corporations will move their production facilities to regions with lax environmental regulations. Support for the PHH exists in the relationship between foreign direct investment (FDI) of the US chemical industry and foreign countries' environmental laws. Kolstad and Yang (1998) show that "lax environmental policy tends to attract more capital inflow from the US for pollution intensive industries" and "tough environmental regulations would tend to impede or discourage FDI from these industries" (pg. 20). But, Porter and van der Linde (1995) suggest that stringent environmental policies might actually spur innovation and boost competitiveness, contrary to the decreasingly accepted PHH. They also point out the "early-mover advantage in international markets" (pp. 104-105), of which China, in its industrial capacity as a low cost solar-panel and windmill producer, has taken full advantage. Moreover, typical analyses of the PHH focus primarily on the relationship between income and pollution, neglecting other relevant factors (Eskeland & Harrison, 2003). As China continues to develop its domestic environmental policies, the country's industrial sector will likely adapt to these harsher regulations. These implications will be discussed in more detail in the third and fourth chapters.

1.4. A brief history of the modern Chinese economy

China's rise to international economic prominence is unprecedented. Mao Zedong's stifling development initiatives enervated the Chinese economy, which afforded his successor, Deng Xiaoping, the liberty to implement an array of progressive economic plans. Before Deng's 1978 reforms, China's productivity growth rate was much lower. This was due in part to strict pre-reform laws that established a collective farming system (as opposed to the household responsibility system) and restricted rural to urban migration (Lin, 1992). Between 1952 and 1978, GDP only grew by about 6.0% a year; between 1978 and 1998, on the other hand, growth rates averaged 9.7% per year (Chow & Li, 2002). In fact, it was the pre-Deng levels of poverty and underdevelopment that allowed such rapid growth in China. The overabundance of agricultural labor that shifted to industrial manufacturing jobs was a key part of the success of Deng's reforms. Furthermore, China's economic boom was, at least in the early stages, based on factor accumulation and huge levels of capital inputs (Bramall, 2000). The capital accumulation was complemented by technological innovation, which was missing before the 1978 reforms (Chow G. , 1993). These conditions allowed China's economy to flourish. By instituting an "open door" policy and decentralizing the economy, the Dengist reforms increased productivity, per capita income and quality of life for hundreds of millions of people (Hu & Khan, 1997). But, China's rapid growth, both before and after 1978, led to an array of serious environmental problems.

1.5. The environment of China

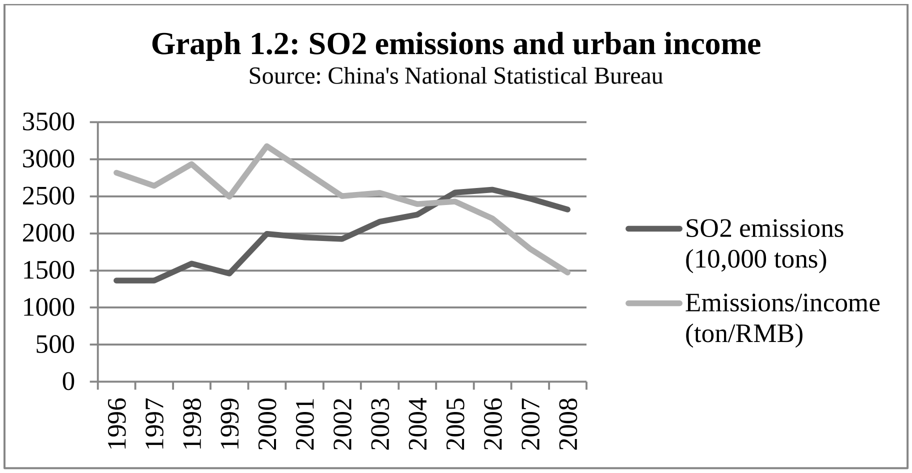
These environmental problems are based on a number of factors. Chinese economic growth has been "characterised by a reliance on labour and capital inputs rather than on productivity enhancement" (Fang & Yang, 2008, p. 227). This is apparent throughout China's environmental history since 1949. Under the guise of economic development, Mao Zedong effectively launched an attack on environment with the slogan "man must conquer nature" (*ren ding sheng tian*). Mao's agricultural campaigns, for example, ignored the laws of nature and wrought havoc on China's natural environment. Revolutionaries clear cut massive swaths of China's old growth forests to cultivate a variety of crops, but the Soviet agricultural "innovations" on which their planting techniques were based would ultimately prove unsuccessful. To Mao, nature was a mere obstacle that would yield to his socialist utopian ideology (Shapiro, 2001). Economically, Mao attempted to boost China's industrial output by encouraging the spread of "backyard steel mills." These furnaces were extremely inefficient and the wood needed to fuel them exacerbated the problem of deforestation. The most perceptible outcome of these economic and environmental travesties was the nationwide famine that killed millions of people during the Great Leap Forward (Shapiro, 2001). The backyard steel mills, rampant deforestation, unsustainable agricultural policies and wasteful energy consumption during Mao's reign, coupled with a shortage of arable land and a suffering population, created a dark backdrop against which Deng Xiaoping's economic reforms would be implemented.

Deng's reform and open up (*gaige kaifang*) policies of the late 1970s and early 1980s revitalized the Chinese economy, but not without taking a drastic toll on the environment. China's transition from an impoverished nation under Mao's economic centralization to its modern status as an international economic powerhouse depended on energy-intensive industrial development, and as China opened its doors to the world, more and more countries began importing inexpensive, Chinese-made goods (Fang & Yang, 2008). By granting provincial and select municipal governments more economic autonomy, encouraging merit-based rewards for agricultural output, fostering entrepreneurial endeavors, reducing the influence of state-owned enterprises and opening the country to foreign investment, Dengist reforms pulled millions of Chinese citizens out of poverty and increased the nation's standard of living (Economy, 2010).

As China's economy prospered, foreign companies took advantage of an abundance of cheap labor and lax environmental regulations (Economy, 2010). Today, air and water pollution in many of China's industrial zones have led to myriad social problems. Numerous scholarly publications have addressed the health impacts of pollution in China. For example, Wu *et al.* (1999) discuss the societal threats posed by water pollution. Air pollution has also taken its toll on the population's health, especially in densely-crowded urban areas. In Shanghai, for example, air pollution-related health costs exceeded US $625 million in 2004 (Kan & Chen, 2004).

China's Eleventh Five Year Plan (FYP) for 2006 through 2010 was a turning point from previous development strategies. While economic development is still the principle goal, the 11th FYP's promotion of "scientific development" (*kexue fazhan*), "harmonious socialist society" (*shehui zhuyi hexie shehui*) and "common prosperity" (*gongtong fuyu*) are markedly different from earlier FYPs characterized by the Dengist slogan "getting rich first" (*xianfu lun*), which emphasized coastal development (Fan, 2006). This new direction for economic development was reflected by a stronger emphasis on environmental protection and climate change mitigation. In a speech on 23 November 2010, National Development and Reform Commission Vice-Chairman Xie Zhenhua said that during the Eleventh FYP, China had invested over 200 billion yuan (approximately 30 billion USD) toward environmental causes, which had resulted in an estimated two trillion yuan (approximately 300 billion USD) shift of related funds from various social sectors to green industries (Xie, 2010). Moving forward, China has set ambitious goals for decreasing emissions and energy intensity, improving air and water quality, and investing in afforestation projects (NDRC, 2008). One outcome of these goals has been aggressive environmental policies. The government has promulgated a number of stringent regulations that mandate compliance and have encouraged international cooperation. The government has also implemented a "shutdown policy" that targets small, inefficient, typically coal-powered power plants. The Eleventh FYP also includes targets for national installation of flue-gas desulphurization apparatuses (Cao, Garbaccio, & Ho, 2009).

Although the absolute value of China's SO2 emissions has risen significantly since 1996, they have steadily decreased since 2006, according to China's National Statistical Bureau. However, as urban income has risen from RMB 4,839 in 1996 to RMB 15,781 in 2008, emissions intensity has decreased significantly, from 2,819 tons/RMB in 1996 to 1,471 tons/RMB in 2008. The graph below illustrates these points:



As China moves into its Twelfth FYP, environmental issues seem to be playing an even bigger role than they did in the Eleventh FYP. According to the *People's Daily Online,* current government research is exploring the possibility of including carbon taxes, emissions trading mechanisms and an “environmental protection tax” in China’s 12th FYP. As China continues developing its environmental policy, it plans to utilize the 1992 UN Framework Convention on Climate Change and the 1997 Kyoto Protocol as guides (China drafting law on dealing with climate change, 2010).

1.6. The rise of subnational power

Although environmental issues have certainly been addressed at the national level, provincial and even some municipal governments are enjoying increasing political and economic autonomy. In the past, interregional competition centered on national investment, but as Beijing continues to loosen its grip on subnational affairs, local governments are beginning to compete more directly for both domestic and foreign investment (Hendrischke, 1999).

This new level of political independence could have both positive and negative implications for environmental quality in China. On one hand, the pollution haven hypothesis suggests that provinces with less stringent environmental policies will attract more investment from foreign companies. Kolstad and Xing (1998) discover a positively-correlated relationship between the leniency of foreign countries’ environmental policies and the amount of foreign direct investment (FDI) they receive from the US chemical industry. The authors do admit, however, that since their models only test one indicator of environmental policy, “it would not be appropriate to conclude that environmental regulation alone can decide the direction of FDI flow for a polluting industry” (pg. 21).

On the other hand, decentralization has allowed subnational governments to establish policies that address region-specific challenges. It also means that local governments are increasingly responsible for their own economic and social development. By ceding some power to provincial governments, Beijing has allowed some provinces to specialize in certain industrial sectors, and competition for FDI has flourished as provinces find their own production niches (Montinola, Qian, & Weingast, 1995). A negative side effect of this, however, has been the widening income disparity that has plagued China's economic development for decades, and it seems that western provinces are fighting an uphill battle. For example, FDI stock is heavily concentrated in eastern provinces: in the 1990s, 87.6% of FDI was in the eastern region, compared with only 3.2 in western areas (Ögütçü & Taube, 2002).

CHAPTER 2

Mencius said, "The trees on Ox Mountain were lush and beautiful, but because it neighbored a large country, people came with axes to cut down the trees. How, then, could it remain beautiful? The rain and dew of the days and nights made the sprouts and shoots grow, but cows and sheep came to graze, and the mountain became bare. When people see the mountain's bareness, they think it was never lush, but is this the mountain's true nature?"

2.1. Introduction

Too many environmental policy proposals fail to utilize econometric and statistical methods in their background research. For example, Greenpeace is well-known for its environmental activism. The group's argument against, say, tuna farming may have scientific and social merit – overfishing can shatter fragile ocean ecosystems and threatens biodiversity – but they often ignore the economic implications of their suggestions, and they rarely consult empirical data to support their advocacy. As another example, the Nobel Prize-winning documentary *An Inconvenient Truth* (Guggenheim, 2006) makes a strong case against continued greenhouse gas emissions, but the movie fails to offer any economically feasible solutions to the problem. Moreover, its analysis of emissions trends is underwhelmingly simple, and despite graphs that depict steeply climbing GHG emissions, it offers little more than dramatic flair. Idealism is a necessary part of environmental protection, but alone, it is insufficient.

On the other end of the spectrum, many researchers often underemphasize the applicability of their econometric analyses of environmental quality in the policy world. Grossman and Krueger (1995), for example, discuss the vital relationship between income and environmental quality but only provide a glossed-over summary of this relationship's policy implications. Shafik (1994) is guilty of a similar offense, although she did test some indicators of political action in an earlier paper (Shafik & Bandyopadhyay, 1992). Mechanical analysis of environmental quality, no matter how complicated the models or robust the results, is a necessary part of environmental protection, but alone, it is insufficient.

A marriage of these two aspects, however, is sufficient. Thus, although the main goal of this thesis is to develop environmental policy ideas for the People's Republic of China, the author hopes to support his proposals with compelling empirical evidence. By shoring up qualitative analyses with econometric models that test a wide range of parameters, the thesis becomes a more credible source in the field of environmental economics and policy.

2.2. Methodology

The first chapter – which introduced the topic, defined the relationship between economic growth and environmental quality, and discussed the environmental history of China – provided a broad overview of the background to the current state of China's environment. Testable models are limited by the availability of variables, but they explain a lot about environmental quality, nonetheless. To make the most of each model, industrial SO2 emissions are tested via three different statistical methods – pooled ordinary least squares (OLS), fixed effects and random effects models. Comparing these different models is necessary to determine the true nature of the tested relationships. This is because the validity of OLS regression tests hinges on the assumption that the error term in a specified equation is not correlated with the independent variables, the x's. In reality, this is unlikely. For example, an unobserved variable from one time period, e.g. political pressure in period t to enforce environmental regulations, probably affects a region's environmental quality in period t. That same unobserved political pressure will probably be correlated with environmental quality in periods $t+1$, $t+2, \ldots, t+n$, as well. The fixed effects (FE) model effectively breaks the error term into two parts: one part that can be correlated with the independent variables (known as the unobserved effect, individual effect or heterogeneity term), and one part that is not. The random effects (RE) model, on the other hand, assumes that the individual effect of each panel i (province or municipality, in this case), is not correlated with the independent variables, i.e., the fact that Shanxi is Shanxi has nothing to do with its pollution output.

To determine which model is best, the author will employ a Hausman specification test. This test determines whether the random effects or fixed effects model has more explanatory power. If the individual effect is uncorrelated with each independent variable, then the random effects model is superior to the fixed effects model. However, if the Hausman test indicates that the individual effect is correlated with the independent variables, then the fixed effects model is preferred. In policy analysis, the fixed effects model is usually more convincing.[2]

2.3. Explanation of the dependent and independent variables

To analyze the relationship between economic growth and environmental quality, it is important that independent and dependent variables – as well as the models used to test them – exhibit some degree of parsimony; testing a multitude of environmental indicators is outside the scope of this thesis. The reduction of harmful pollutants serves as a useful gauge of environmental policies' efficacy (Sorsa, 1994), and because SO2 emissions reduction plays such a crucial role in China's recent FYPs, industrial sulfur dioxide emissions will be the primary focus of this thesis's econometric tests and analysis. Moreover, Grossman and Krueger (1995) point out that "in the case of SO2, the estimated relationship turns up again at very high levels of income" (pg. 366). This enigmatic relationship between SO2 emissions and economic growth is interesting, especially in China where GRP per capita is growing significantly, contributions

---

[2] For an expanded discussion of fixed effects versus random effects, see Wooldridge (2009), *Introductory Econometrics: A Modern Approach*, pg. 493.

from various sectors of industry are shifting and environmental protection is becoming a national priority.[3]

The dangers of SO2 further demonstrate its importance as the dependent variable. Sulfur dioxide is a highly reactive gas that causes acid rain and a number of respiratory illnesses. Around 73% of SO2 emissions are attributed to the burning of fossil fuels at power plants; 20% comes from "other" industrial activities, and the rest is due to ore extraction and the use of sulfur-rich fuels (U.S. EPA, 2011). Because of this, industrial SO2 emissions are the dependent variable of interest in this thesis, and it will be regressed in each model as an absolute value (10k tons), natural log and per capita (10k ton per person).

Independent variables are more difficult to choose. Shafik (1994, pp. 758-759) emphasizes four determinants of environmental quality:

i. *Endowment* – characteristics of a province or municipality that might affect environmental quality.

ii. *Income* – GRP per capita.

iii. *Technology* – the effect that technological developments have on various environmental characteristics.

iv. *Policy* – any government regulations that might influence environmental quality.

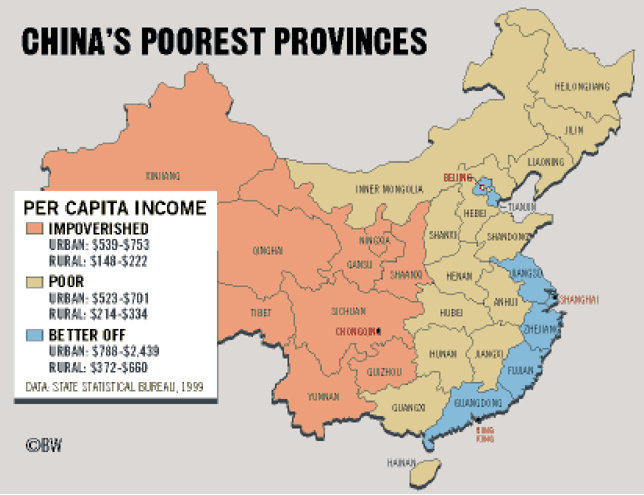
Fluctuations in environmental quality can be attributed to a number of factors. The composition of a region's GRP is categorized as an endowment characteristic that might affect that region's emissions. For example, secondary industries like manufacturing and mining are much more energy intensive than tertiary industries like finance and banking, and it is likely that increased output of secondary industries has a negative effect on environmental quality. Another example is foreign investment. Other endowment characteristics like average rainfall and temperature can

---

[3] In fact, all cubic functions approach either positive or negative infinity at very high levels, but Grossman and Krueger only mention sulfur dioxide emissions approaching infinity at high income levels.

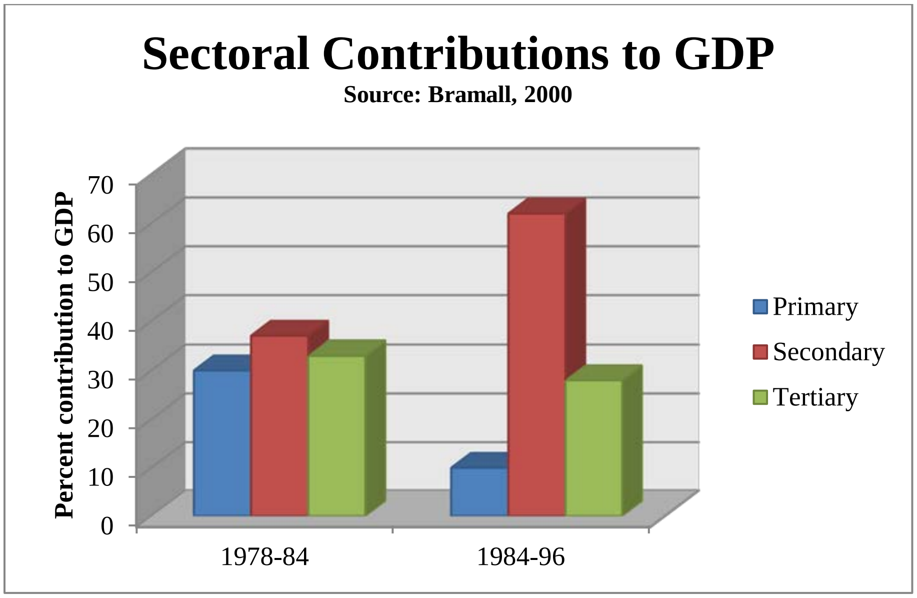
have an effect on the severity of industrial runoff (Ahuja & Lehman, 1982) and agricultural byproducts like nitrates and methane from rice patties (Sass, Fisher, Wang, Turner, & Jund, 1992), animal farming (Judd, et al., 1999), etc., but no relationship has been found between weather variables and industrial SO2 emissions. Moreover, rainfall and temperature are relatively stable from year to year, so their relationship with the dependent variable is likely controlled for in the individual effect. Technology is more difficult to quantify than endowment, but its effects on emissions rates can be estimated by including time trends in test models. Unfortunately, as Shafik (1994) points out, time series analyses also capture the effects of other variables that contribute to emissions growth and/or decline. In this paper, dummy variables will be used instead of time trends, which will allow for a more accurate interpretation of technology's impact on pollution rates. Government policies are also difficult to quantify, but data from China's statistical bureau on investment in environmental protection and pollution cleanup projects help elucidate the role of various environmental policies in reducing emissions. Five Year Plans are also a useful tool in examining changes in emissions, so dummy variables for the Ninth, Tenth and Eleventh FYPs will also be included in some regressions. Obviously, income, as the central aspect of existing Environmental Kuznets Curve literature, will be included in a number of different forms, including its linear, quadratic and cubic forms.

Theoretical support for the inclusion of certain independent variables is an important first step in specifying credible models. The first determinant of environmental quality is income. An array of research on the EKC has demonstrated the relationship between environmental quality and income, and even critics of the EKC recognize the environmental relevancy of GDP per capita as an indicator of economic growth. In China, GDP per capita is misleading since discrepancies between incomes in rural and urban areas can be vast. In 2008, for example, GRP per capita in Shanghai was a little over RMB 73,000. In the nearby province of Anhui, whose economy is largely based on primary and secondary industries, GRP per capita was a mere RMB 14,485. Therefore, GRP per capita is a much more useful gauge of development. The map below illustrates China's overwhelming income disparity:



Source: Newsweek, 2010

The second determinant of environmental quality is industrial composition. As Cole and Neumayer (2009) point out, many traditional analyses of this relationship ignore this variable, which they expect plays a huge role in determining pollution rates. Developed nations have exported their emissions-intensive industries abroad, something that helped China grow as an international economic power. This influx of dirty industries, while beneficial to China's economy, has been detrimental to the environment. Arrow *et al.* (1995) agree that economic composition is an important factor in determining the relationship between economic growth and environmental quality. Whether the bulk of a region's economic growth is based on relatively clean industries like banking, finance or tourism or dirty industries like manufacturing, carbon-intensive energy production and construction can either relieve or exacerbate preexisting environmental challenges. In China, sectoral contributions have fluctuated as GDP has grown over the past 30 years (Bramall, 2000), so it is likely that industrial strata play a significant role in determining emissions in a given region.[4]



The third determinant of environmental quality is foreign investment. According to the pollution haven hypothesis, lax environmental laws attract foreign investment, which in turn degrades environmental quality, and it is important to analyze the relationship between a province's foreign investment and its environmental quality. In China, foreign investment is highly concentrated in eastern provinces (Ögütçü & Taube, 2002). It has been shown that FDI in China depends on a number of factors, including market demand and size, i.e. GRP, quality of labor, and "degree of openness and progress of reform" (Na & Lightfoot, 2006). The relationship between this last variable and environmental policy is obvious, and it demonstrates the importance of analyzing foreign investment's relationship with industrial SO2 emissions.

The fourth determinant of environmental quality is environmental policy. Here, it is proxied by government investment in pollution control and environmental clean-up projects.

---

[4] In Chinese statistical reports, industrial sectors are often lumped into three strata of industry. In this regard, primary industry includes agriculture; second industry includes construction, manufacturing, mining and other labor-intensive services; and tertiary industry includes banking and finance, tourism, etc.

Many domestic environmental policies in China focus on sulfur dioxide emissions. The government’s Five Year Plans for economic development have grown more and more environmentally-focused, especially with the implementation of the Eleventh FYP in 2006 (Fan, 2006; Cao, Garbaccio, & Ho, 2009). While the broad implications of these more liberal strategies can be illustrated by simple graphs, econometric analyses are necessary to understand and quantify these policies’ actual impact. Variables that control for government investment in environmental protection and current FYP allow for a detailed analysis of China’s environmental policy.

2.4. Parameters of the test

The models tested in this section are based on a combination of previous research and the author’s own specifications. In each model, *E* denotes the tested environmental indicator in place *i* during time *t* (although these notations are only relevant in the fixed effects and random effects models). A stochastic error term is represented by ε, and individual effects, where they are included, are denoted by *F*. Income amounts are test as the natural log of one RMB per person. *Primary contributions, secondary contributions, and tertiary contributions* denote the values added by primary, secondary and tertiary industry strata, respectively. *Foreign investment* denotes the total investment by foreign-funded enterprises in units of $10,000 USD. *Investment* includes government investment in environmental protection campaigns. In some models, time is controlled for by including dummy variables for each year.

2.5. The Data

The data analyzed in this thesis were collected from the Chinese National Bureau of Statistics (NBS) online database. The data set includes yearly data for each province and some municipalities equaling 31 cases from 1996 through 2008 (where available) and spanning three consecutive Five Year Plans, the first two in their entireties and the current one for three years. Issues with the accuracy of Chinese statistical data are common in the West, but this criticism is likely a vestige of government propaganda campaigns during the revolutionary era, and now, claims of "data falsification" are rarely substantiated. Modern data are more or less reliable. China's National Bureau of Statistics has invested significant effort in improving its data collection and reporting apparatuses since the mid-1990s, and with the introduction of the online statistical yearbooks, from which the data in this thesis were taken, Chinese economic indicators have become increasingly transparent and reliable (Holz, 2003).

2.6. Econometric model specification

The models tested[5] are as follows:

2.1: $E_{it} = \beta_0 + \beta_1\ln(\text{GRP per capita})_{it} + \delta_1 D1997 + \delta_2 D1998 + \delta_3 D1999 + \delta_4 D2000 + \delta_5 D2001 + \delta_6 D2002 + \delta_7 D2003 + \delta_8 D2004 + \delta_9 D2005 + \delta_{10} D2006 + \delta_{11} D2007 + \delta_{12} D2008 + [a_i] + \varepsilon_{it}$

2.2: $E_{it} = \beta_0 + \beta_1\ln(\text{GRP per capita})_{it} + \beta_2(\ln(\text{GRP per capita})_{it})^2 + \delta_1 D1997 + \delta_2 D1998 + \delta_3 D1999 + \delta_4 D2000 + \delta_5 D2001 + \delta_6 D2002 + \delta_7 D2003 + \delta_8 D2004 + \delta_9 D2005 + \delta_{10} D2006 + \delta_{11} D2007 + \delta_{12} D2008 + [a_i] + \varepsilon_{it}$

2.3: $E_{it} = \beta_0 + \beta_1\ln(\text{GRP per capita})_{it} + \beta_2(\ln(\text{GRP per capita})_{it})^2 + \beta_3(\ln(\text{GRP per capita})_{it})^3 + \delta_1 D1997 + \delta_2 D1998 + \delta_3 D1999 + \delta_4 D2000 + \delta_5 D2001 + \delta_6 D2002 + \delta_7 D2003 + \delta_8 D2004 + \delta_9 D2005 + \delta_{10} D2006 + \delta_{11} D2007 + \delta_{12} D2008 + [a_i] + \varepsilon_{it}$

2.4: $E_{it} = \beta_0 + \beta_1\ln(\text{primary contributions})_{it} + \beta_2\ln(\text{secondary contributions})_{it} + \beta_3\ln(\text{tertiary contributions})_{it} + [a_i] + \varepsilon_{it}$

2.5: $E_{it} = \beta_0 + \beta_1(\text{primary contributions})_{it} + \beta_2(\text{secondary contributions})_{it} + \beta_3(\text{tertiary contributions})_{it} + \beta_4(\text{primary contributions})_{it}^2 + \beta_5(\text{secondary contributions})_{it}^2 + \beta_6(\text{tertiary contributions})_{it}^2 + [a_i] + \varepsilon_{it}$

2.6: $E_{it} = \beta_0 + \beta_1\ln(\text{foreign investment})_{it} + \beta_2(\ln(\text{foreign investment})_{it})^2 + [a_i] + \varepsilon_{it}$

2.7: $E_{it} = \beta_0 + \beta_1(\ln(\text{investment}_{i(t-1)})) + \beta_2(\ln(\text{investment}_{i(t-1)}))^2 + \delta_1(\text{FYP } 10) + \delta_2(\text{FYP } 11) + [a_i] + \varepsilon_{it}$

---

[5] Models 2.1 through 2.3 are modifications of the models tested in Shafik (1994). The rest were specified by the author, and include various transformations of the four determinants outlined in section 2.2 that are based on the four characteristics – income, policy, technology and endowment – that Shafik (1994) discusses.

2.7. Analysis of results

This thesis finds that almost all of the independent variables tested are significantly correlated with environmental quality. The results are summarized in Tables I-VIII in appendix II.

2.7.1 Income

The results of the econometric tests showed that GDP per capita is significantly correlated with environmental quality in almost every model, although their relationship is complicated. Models 2.1 through 2.3 all explain the effect of a change in GRP per capita on environmental quality, but because their functional forms are different, they express different relationships. Model 2.1, for example, shows that GRP per capita and industrial SO2 emissions are positively correlated, and that a ten percent increase of GRP per capita will cause emissions to increase by over 37,000 tons, holding time constant[6]. As a result of the Hausman test, it is likely that the random effects model is a better model of the actual relationship between these two variables. The relationship between GRP per capita and SO2 emissions per capita is also positively correlated, as expected; a one percent change in GRP per capita is associated with an increase of 110 tons of industrial SO2 emissions per million people, according to the random effects model, which was also favored by the Hausman test.

Model 2.2, while equally significant, illustrates a different relationship, that of an inverted U. These results are similar to those found by Shafik (1995), Grossman and Kreuger (1995) and many other researchers, and they fall in line with the EKC theory. Provinces with lower GRP per capita are at a disadvantage according to this model.

---

[6] In a linear model, the change in y for a change in x equal to some number a is calculated simply by multiplying the beta-coefficient of x times a. For quadratic and cubic functions, it is a bit more complicated. For an x that is raised to the second power, the change in y for a given change in x equal to a is calculated as $2a\beta2x + a\beta1 + a2\beta2$, where $\beta1$ is the coefficient for x and $\beta2$ is the coefficient for x2. The change in y given a change in x equal to a in the cubic model is equal to $a\beta_1 + \beta_2(2ax + a^2) + \beta3(ax^2 + a^2x + a^3)$, where $\beta1$, $\beta2$, and $\beta3$ represent the linear, quadratic and cubic transformations of x, respectively.

Model 2.3 is the most interesting model. Grossman and Krueger (1995) found an N-shaped relationship between SO2 emissions and income, noting that at high levels of income, SO2 emissions turn up and approach infinity. This is a discouraging forecast, especially considering China's continued rapid economic growth. However, Chinese data illustrate a different relationship: as income rises from low levels, industrial SO2 emissions also increase, but they peak around 49,000 RMB and descend indefinitely afterward, exhibiting an inverted N-curve. The data support this claim, and for the absolute value of industrial SO2 emissions, the coefficients are all statistically significant at $p < 0.01$. The natural log of industrial SO2 emissions and SO2 emissions per capita also exhibit a statistically significant inverted N-curve relationship with income.

2.7.2 Endowment

Models 2.4 and 2.5 illustrate the relationship between GRP makeup and environmental quality. As hypothesized, primary and secondary industries, most of which are energy intensive, are worse for the environment than tertiary industries. For example, a one percent change in the GRP contributions of primary industries will, on average, cause industrial SO2 emissions to increase by 120 thousand tons, holding secondary and tertiary contributions constant; that same increase of secondary industry contributions is associated with an increase of over 110 thousand tons of industrial SO2 emissions. In the random effects model, which was favored by the Hausman test for all the dependent variables except absolute value of emissions, the contribution of tertiary industries is not statistically significant; in the pooled OLS model, however, it is extremely significant, and suggests that a one percent increase in the GRP contribution of tertiary industries will lead to an industrial SO2 emissions decrease of almost 150,000 tons, and with an R-squared of over 0.53, this model has a good deal of explanatory power.

Another interesting result obtained from model 2.4 shows with a relatively high degree of statistical significance that a one percent increase in the tertiary industrial stratum's contribution to GRP will decrease industrial SO2 emissions by 170,000 tons per million people, ceteris paribus. In this case, the Hausman test favors the random effects model. In the pooled OLS model, that same change is analogous to a decrease in SO2 emissions of just under one ton per person, holding other factors constant.

Model 2.5 explores the quadratic relationship between environmental quality and sectoral contributions. The fixed effects model, which the Hausman test shows is more convincing, contradicts the idea that tertiary industries are better for the environment; in fact, it shows the exact opposite. But, even though the coefficients are statistically significant at over 99.9% (with the exception of the quadratic transformation of the contribution of tertiary industries to GRP, which is significant at $p>0.01$), their expected values are trivial. For example, an increase in the tertiary industrial stratum's contribution to GRP from 100 million yuan to 200 million yuan results in less than 100 additional tons of SO2 emissions. Despite that, model 2.5 shows that the relationship between environmental quality and primary and secondary industries can be described as an inverted-U, while the relationship between tertiary industries and environmental quality is concave up, i.e. a U-shaped curve. These results empirically support the theoretical implication in Section 2.3 that China's reliance on dirty industry as the bulk of its domestic income has exacerbated its environmental problems.

Model 2.6 analyzes the relationship between foreign investment and environmental quality. For the absolute value of industrial sulfur dioxide emissions, the relationship is defined by a U-shaped curve with a turning point at around $7.5 million USD. Unfortunately, the linear coefficient of foreign investment is statistically insignificant with a p-value of .218. For the natural log transformation of SO2 emissions, however, the beta-coefficients are all statistically significant at above 99%. The model exhibits an inverse-U shaped curve. This means that foreign investment causes environmental quality to decline up to around $81.6 billion USD, at which point the addition of foreign investment will be associated with an improvement of environmental quality. Unfortunately, that is about 212 times higher than the population mean for foreign investment, so it is safe to say that an increase in FDI will generally be associated with an increase in industrial SO2 emissions, although the marginal rate of increase will decline.

2.7.3. Policy

Model 2.7 explores the relationship between environmental policy in China and its actual effects on environmental quality. A dearth of relevant information limits the efficacy of some of these models; nonetheless, many of the results are statistically significant and illustrate quantitatively the implementation and enforcement challenges that Chinese legislators face. Nonetheless, model 2.7 shows that, holding Five Year Plan constant, which is an imperative aspect of environmental policy analysis in China, an increase in environmental protection and pollution abatement investment of 100 million RMB will be associated with a substantial decrease in industrial SO2 emissions per capita. For example, a 100 million yuan increase from the population average, which is equal to just over 1 billion yuan in each province, will result in an emissions decrease of over 1000 tons per person. The policy implications of these results are extensive.

Another interesting outcome is the relationship between Five Year Plans and emissions, and it highlights the challenges that Chinese policymakers must confront. The model, controlling for investment in environmental and pollution abatement projects, indicates that FYPs are generally ineffective. Although the results indicate in most of the pooled OLS models that industrial SO2 emissions decreased from the 9th FYP to later plans, both the random effects and fixed effects models illustrate very convincingly that subsequent FYPs have not been effective at reducing emissions. Considering the weight Beijing has placed on environmental protection in the last two plans, this policy failure is disheartening, and one cannot help but worry that Wang Jin's criticism of Chinese environmental policy (Wang J. , 2010) may be warranted.

2.7.4 Technology

As Shafik (1994) notes, technological innovation can be proxied by including a time trend in the model. In models 2.1 through 2.3, the "time trend" is included as a series of dummy variables with the base year set at 1996. The models paint two different pictures: one shows substantially decreasing emissions over time (holding GRP per capita constant), which suggests that technological advancements have improved environmental quality, holding other factors constant; the other suggests that industrial SO2 emissions have actually increased over time, but only very slightly. Obviously, challenges remain for environmental protection in China.

2.8. Conclusion

These results convincingly illustrate the relationship between industrial sulfur dioxide emissions and economic growth in the PRC from a number of perspectives. Despite the EKC's shortcomings, models 2.2 and 2.3 robustly support its relevance to the relationship between income and industrial sulfur dioxide emissions in China. The estimated turning point for industrial SO2 at around 49,000 RMB (approximately $7,500 USD) is significantly higher than the $4,053 turning point that Grossman and Krueger (1995) estimated for sulfur dioxide emissions.

The relationship between emissions and a region's endowment characteristics, i.e. industrial sector makeup and foreign investment, also was as hypothesized. An increase in tertiary sector contributions decreases the dependent variable in all forms, whereas an increase in secondary industries increases emissions. Generally, an increase in foreign investment is associated with an increase in industrial SO2 emissions. The models also demonstrate the challenges that Chinese legislators face. Indeed, Chinese investment has not been very efficient, according to model 2.7, and despite increasingly progressive environmental agendas in subsequent Five Year Plans, emissions have, for the most part, increased. Finally, technological improvements (proxied by time dummies in models 2.1 through 2.3) are generally associated with a decrease in emissions, although not always. Moreover, the coefficients are rarely statistically significant.

CHAPTER 3

You could cover the whole world with asphalt, but sooner or later green grass would break through.

Ilya Ehrenburg

3.1. Policymaking in the People's Republic of China

Creating, implementing and enforcing environmental regulations is an arduous task in China. In the past, China's authority structure suffered from factionalism among high-ranking officials whose support for certain policies was often based on an effort to maintain their own political power. The effective implementation of policy relies heavily on consensus building and *guanxi*, or relationships. The policymaking process is therefore characterized as "protracted," "disjointed," and "incremental" (Lieberthal & Oksenberg, 1988, p. 24).

However, as China continues to decentralize its control over provincial and municipal affairs, regional governments are becoming increasingly autonomous. The central government still maintains strict control over environmental policies, but it is up to local governments to ensure that they are enforced (Schwartz, 2004). For these policies to be successful, three conditions must be met: "all top leaders agree on the issue, all top leaders are willing to give the issue priority, and the degree of compliance of lower levels is manageable" (Lieberthal, 1997).

3.2. Environmental Policy in China

During the 1970s, China's leadership began to understand the environmental challenges associated with economic growth. Many of Deng Xiaoping's later reforms reflected this realization, and in 1979, the NPC Standing Committee implemented the *PRC Environmental Protection Law for Trial Implementation*. Ten years later, the trial run was over, and the aforementioned law became simply the *PRC Environmental Protection Law*. This powerful new legislation gave regulatory organs the political wherewithal to develop and enforce newer and more stringent environmental policies (Ma & Ortolano, 2000). Results of these laws include the Environmental Impact Assessment (EIA) system and “polluter-pays” principle, and in 1983 the Chinese government declared environmental protection as one of two “national fundamental policies,” the other being population control (Shi, 2008).

China’s biggest step forward came in 2008, when the former State Environmental Protection Administration (SEPA) was renamed the Ministry of Environmental Protection (MEP), effectively raising it to cabinet-level status (Economy, 2010). This also represented the government’s increasing obligation to environmental protection, as well as the importance of environment issues in China’s domestic affairs, and the MEP’s new status gave it more resources, autonomy, political influence and authority. That is, the new MEP not only has the power to create and implement environmental legislation from atop its ministerial perch in Beijing, it also has the resources to enforce them and the authority to punish those not in compliance.

3.2.1. Implementation and Enforcement Challenges

Despite this exceptional progress, enforcement challenges surrounding environmental policies abound in China, and conflicting interests pose one of the most serious threats to effective regulation. Laws that cater to both sides, i.e. society and polluters, usually become inefficient, a phenomenon that is apparent in China. Sustained market growth is also an important issue, and Beijing places economic growth at the forefront of every policy decision, including environmental policy (Tian & Whalley, 2008; China's National Climate Change Programme, 2007). Furthermore, environmental regulation in China is typically the result of intense negotiations, and ultimately, otherwise strong legislation becomes “watered down” and inefficient. The effectiveness of these regulations is even further diluted by what some scholars have dubbed “local protectionism,” i.e., a scenario in which provincial and municipal governments abandon environmental protection in favor of economic development (van Rooij, 2006).

This obsession with economic growth has been central to the country's provincial and municipal organization since *gaige kaifang*. Chinese leaders understood that governing directly from Beijing was ineffective, so they created a *de facto* system where "each level of government will grant the level just below it sufficient flexibility to enable the lower level to grow its economy rapidly enough to maintain social and political stability" (Lieberthal, 1997, pp. 4-5). Because of this system, provincial and municipal leaders' tenure is based almost entirely on their regions' economic growth and social stability, and performance is often based on the performance of a leader's immediate predecessor. In this sense, China's promotion system has been especially effective at encouraging provincial economic growth (Chen, Li, & Zhou, 2005), and China's local leaders see themselves as "entrepreneurs" that are strongly encouraged to promote economic growth by any means necessary. Because of this power paradigm, these entrepreneurial officials often interfere with and ignore lower-level regulatory agencies, which explains the "paradox of good environmental laws and poor environmental performance that is pervasive throughout China" (Lieberthal, 1997, p. 5). Therefore, despite rigid regulations and increasing investment, environmental protection policies in China are relatively ineffective, and simply put, there is little incentive to change that (Chen, Li, & Zhou, 2005).

The government's heavy-handed economic planning has been oft criticized as a barrier to free market growth. Theoretically, centralized state-owned enterprises (SOEs) should be more concerned with social welfare – and thus more environmentally friendly – than their privatized counterparts (POEs), but it China, this is not the case. In fact, Wang and Jin (2002) find that in China, "the best [environmental] performers are foreign companies which have the lowest pollution discharge intensities" (pg. 20). The rationale behind this phenomenon is simple to grasp: SOEs face even less pressure from enforcement agencies than POEs, and despite theoretical suggestions that SOEs should have good environmental performance, in China, they are actually the worst (Wang & Jin, 2002).

As evidenced above, environmental protection in China faces a number of challenges, but recently, the Ministry of Environmental Protection has shown its commitment to rectifying these shortcomings:

> In 2008, local Party Committees and governments were conscientious in implementing the important instruction on special environment campaign made by Vice Premier Li Keqiang. The special campaign was carried out intensively in line with the arrangement of the eight ministries of the State Council. 1.6 million law enforcer/times (sic) were sent to inspect over 700,000 companies, which put 15,000 illegal companies on record, 100 ore people under prosecution and blacklisted 3,500 cases…The special environmental campaign helped to solve a string of pollution problems affecting health, promoted pollution reduction and improved environmental quality dramatically in part of the country (Ministry of Environmental Protection, 2008).

While these progressive ideals can be seen writ large in China's more environmentally-stringent Five Year Plans and ministry reorganization, Wang Jin, a professor at Peking University School of Law, believes China's environmental regulations, while effective on paper, are "useless" because of implementation failures (Wang, 2010). In the past, China's local promotion scheme has been based on economic performance. Provincial and municipal leaders' tenure is based almost entirely on their regions' economic growth. In this sense, China's promotion system has been especially effective at encouraging provincial economic growth (Chen, Li, & Zhou, 2005). However, because performance is evaluated almost solely on economic performance and political cohesion, local leaders still have relatively few incentives to adhere to national environmental regulations. Local environmental protection bureaucrats are often demoted or fired for enforcing national laws that might threaten economic growth. In the courts, environmental issues are often ignored in favor of maintaining “social stability,” and criminal charges are rarely brought against polluters (Wang J., 2010).

3.3. Implications of Environmental Regulation

Critics of state environmental protection often argue that strict regulation hinders economic development, decreases industrial competitiveness and interferes with the market. But, these accusations are only true to a certain extent, and some theories even suggest that environmental regulation can encourage growth and competitiveness.

3.3.1. On competitiveness

The “internationalization of regulation” (Vogel, 1995, p. 12) is of immense macroeconomic significance, most notably its effect on international trade and competitiveness. Decreased industrial competitiveness as a result of overly stringent environmental regulations is a common fear of governments, industries, individual firms and consumers. It has been posited that environmental policies are ineffective because, instead of decreasing overall emissions, polluters simply move their dirty business overseas, which creates a “pollution haven.” In fact, the pollution haven hypothesis has been central to the debate on environmental legislation, especially among opponents of tough regulation (Sorsa, 1994).

This perception seems like common sense; however, research suggests that just the opposite actually occurs. Sorsa (1994) finds that the correlation between industrial competitiveness and the amount of resources allocated toward environmental protection is statistically insignificant. This is likely due to the fact that those resources make up only a tiny fraction of an industry’s total expenditures. Moreover, international environmental expenditure discrepancies are small, especially among industrialized nations, and only a few industries are dramatically affected by environmental legislation. Even in industries where environmental policies can have a dramatic effect on production, tougher regulations actually serve as an impetus for innovation (Porter & van der Linde, 1995).

In the long run, multi-national corporations also enjoy a number of advantages as a result of environmental policy, which contradicts both the pollution haven hypothesis and the idea that these regulations decrease competitiveness. Environmental protection policies force enterprises to rapidly develop new technologies and production systems. These “firm specific advantages,” in turn, actually increase international competitiveness (Rugman & Verbeke, 1998). Although the environmental regulation in specific locations is also a broad determinant of entry, firms must also consider both capital and labor resources. Enforcing environmental regulation in China might force some enterprises to migrate to less-developed regions like sub-Saharan Africa, but it is unlikely that losing the vast resources of China would be a sensible cost for most enterprises to simply circumvent a few environmental policies. Judge and Douglas (1998) find that firms that can adapt to environmental regulations are better financial performers. They go on to suggest that those firms that ignore the costs of environmental degradation – both real and perceived – are not as competitive as their counterparts who integrate an environmental strategy into their financial plans.

3.3.2. On growth

Perhaps even more frightening to the Chinese government than a weakened industrial presence in international markets is the potential slow-down of domestic economic growth. Previous sections analyzed China’s unabashed – and often unchecked – support of economic development. Certainly, any regulatory policy will to some degree impose an economic burden on firms that are affected by the policy. Environmental policies by definition lead to an improvement in environmental quality, “but this improvement is accompanied by a smaller capital stock and a smaller national product” (Siebert, 1987).

However, the extent of this burden is debatable, and despite China’s concern that harsh regulatory actions might drastically impede growth, almost no empirical or theoretical support exists to support this qualm. In fact, evidence from US gross national product growth rates contradicts it. Jorgensen and Wilcoxen (1990) show that environmental regulations slowed US GNP growth by only 0.191% between 1974 and 1985. About 40% of that slowdown was attributed to investment in pollution abatement technologies; less than 20% of the slowdown resulted from the operating costs associated with environmental protection (Jorgensen & Wilcoxen, 1990). Twenty years later, however, pollution abatement technologies are significantly more accessible and the cost of abatement has decreased dramatically, so the economic slowdown produced by environmental regulation in China would likely be even more inconsequential as the one observed in the US in the 1970s and 1980s. Furthermore, in its capacity as a major influence in its domestic industrial markets, China could “encourage” inexpensive production of these technologies at home, which, in theory, could even create a new export market.

This discussion among Chinese leaders on the environment’s role in the market is shifting. Recently, Zhou Shengxian, the Minister of Environmental Protection and one of China’s most powerful bureaucrats, admitted that environmental issues threaten the nation’s economic growth. Moreover, air and water pollution are having increasingly severe effects on society and are beginning to threaten social stability, which is very important to the central government (Martin, 2011). This is not a recent phenomenon. Over the past 20 years, “the losses from pollution and ecological damage ranged from 7% to 20 % of GDP every year” (Liu

& Diamond, 2005, p. 1183). The acknowledgement of this unfortunate consequence of environmental degradation by a top official is a good sign for China's environmental movement, and the fact that high-level bureaucrats are admitting that pollution is having a negative effect on growth could be a turning point from previous, inefficient policies.

3.4. China's systematic advantages

Although some aspects of policymaking in China make the development and implementation of environmental legislation a challenge, the centralized political system, coupled with the ministerial status of the MEP, allows the government to expedite the regulatory process. But still, the Chinese government's lax enforcement of environmental regulations in favor of promoting and sustaining economic development seems contradictory: why would a government ignore its own laws? As backwards as it may seem to outsiders, this system of political push and pull actually creates an environment conducive to NGO activity. In China, despite relatively strict monitoring of NGOs (which has led to the popularity of the term GONGO (government-organized NGO) when discussing Chinese social movements), organizations are becoming increasingly autonomous. Furthermore, the Chinese government has historically relied on different social organizations to carry out its social policies, a relationship which "creates a bridge between non-state, even grassroots, organizations and the official state agencies over which information, policy ideas, and advocacy can travel" (Knupp, 1997). Understanding this complex sociopolitical dynamic has allowed environmental NGOs to flourish in China, and because so much relies on relationships (or *guanxi*), NGOs and GONGOs are able to bypass the culture of politics that so often inhibits environmental activism in the West.

This political process is further truncated in China, where technocratic politicians understand and more readily accept the science that human-induced climate change is real. For example, eight of the nine members on the CCP Politburo's standing committee are university-trained engineers (The Economist, 2009). Moreover, Chinese people are better informed about climate change and are relatively willing to sacrifice jobs in favor of environmental improvement. For example, 96% of Chinese people believe that humans have been a factor in global warming, compared with only 73% of Americans. Only 4.5% of Chinese people deny global warming, compared with 24.3% of Americans. In the United States, 40.3% of people think the government should "prioritize environmental improvements, even if we lose jobs." In China, the number was 76.7%, almost twice as high (Carlsson, et al., 2010).

With politicians who are very technically educated, a populace that supports environmental protection and a political system that provides inherently direct access to the highest strata of government for environmental organizations, China's environmental future looks bright. For now, the most substantial challenge by far is convincing the government that strict enforcement of environmental regulations is necessary to maintain economic growth. But as a developing nation, the Chinese government still has time to incorporate stringent environmental regulations into their development strategy, instead of facing the challenge of backtracking like the West has had to do.

As China continues to grow at a very rapid, albeit declining, rate, much of its output will rely on technological advancements. In simple growth theory, technology is usually represented as a scalar multiplier of some function that combines capital (both human and physical) and labor. Of course, more complicated models take into account various levels of population and labor force growth, interest rates and depreciation, but conceptually, the impact of technological innovation on economic growth remains positive (Barro, 2010). The Chinese government understands this aspect of growth theory and is already investing heavily in "green jobs." These significant investments have helped spur innovation throughout Asia, and China has already surpassed the United States in production of green technologies like windmills and solar panels. Moreover, as the clean energy sector continues to grow, foreign companies will seek out business opportunities in nations whose economic atmospheres and physical infrastructures already support green industries (Atkinson, et al., 2009). This gives China a significant comparative advantage over, for example, the United States.

CHAPTER 4

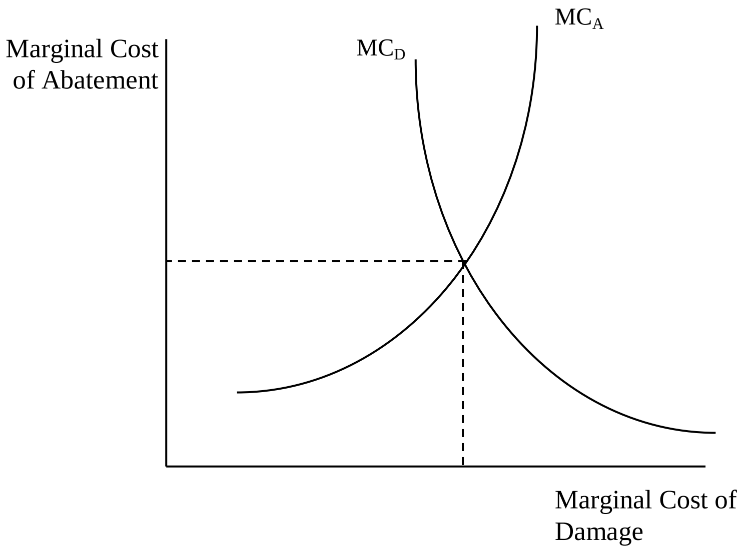
"But the environmental crisis rises closer to home. Every time we draw a breath, every time we drink a glass of water, every time we eat a bite of food we are suffering from it. And more important, every time we indulge in, or depend on, the wastefulness of our economy – and our economy's first principle is waste – we are causing *the crisis. Nearly every one of us, nearly every day of his life, is contributing* directly *to the ruin of this planet. A protest meeting on the issue of environmental abuse is not a convocation of accusers, it is a convocation of the guilty. That realization ought to clear the smog of self-righteousness that has almost conventionally hovered over these occasions, and let us see the work that is to be done."*

-Wendell Berry "Think Little"

Economic policies that seek to control emissions outputs and mitigate the effects of environmental damage can be efficient both economically and environmentally. In China, environmental policy has been largely ineffective, due in no small part to the central government's perpetual desire for rapid economic growth. Econometric tests that analyze the relationship between environmental regulation (insofar as it can be quantified) and environmental quality (represented by various forms of industrial sulfur dioxide emissions) support this theory (see Chapter 2).

4.1. Environmental economics and regulation

Effective responses to environmental degradation must be efficient, which is "achieved when the marginal cost of control is equal to the marginal damage caused by the pollution for each emitter" (Tietenberg, 2007, p. 263). Graphically, this is where the marginal cost of abatement intersects the marginal cost of damage:



Siebert (1987) outlines three benchmarks for optimization. Economic output is Koopmans-efficient if, for a given output, environmental quality cannot be increased, i.e., a producer is doing as little damage to the environment possible at a certain level of output. Output levels where resources are wasted are inefficient, and production is not optimized (see Porter & van der Linde, 1995), so Koopmans efficiency implies that these "inefficient allocations" of capital all lie under or within the transformation space, where competing uses of the environment (e.g. as a public good and as a pollution receptacle) are properly balanced. The second criterion of optimality is the social-welfare function, in which a society's well-being rests in part on the quality of its natural environment. Mathematically, this is where the welfare function, whatever it may be, is maximized; graphically, it is where the indifference cap (a higher cap represents a higher level of social welfare) is tangent to the aforementioned transformation space. A third measure of optimality is Pareto optimality, which measures individual utility instead of aggregate social welfare. This criterion is met if the utility of one person cannot increase or decrease, holding the utility of everyone else constant. Pareto optimality is closely associated with value optimality, which takes into account the value of the environment compared with the value of, for example, a polluting car factory (Siebert, 1987).

As important as these criteria are, their application is broad, and in the real world, perfect optimization is rarely achieved. Understanding the concepts of “utility” and “optimization” and “efficiency” is relatively straightforward, but defining the actual utility of a clean environment and finding the real-world level of efficient, optimized output verges on impossible. Another incalculable aspect of cost-benefit analyses associated with environmental policy is the risk of ignoring climate change, which Weitzman (2007) suggests very convincingly will diverge, i.e., the “estimates of expected damages” are infinite (Stern, 2008). It can also be shown mathematically that the worst possible outcomes should be emphasized in policy analysis – “a mathematical embodiment of the precautionary principle” (Stern, 2008, p. 20).

Crafting environmental policies that satisfy these efficiency and optimality requirements, even to a small degree, is rife with challenges, not least of which is the economic uncertainty that surrounds environmental valuation. How much is biodiversity worth? What makes a city park more valuable than a car factory? Will the costs of environmental regulations pay off in the long run? These uncertainties are another huge challenge policymakers face when developing progressive environmental legislation. Uncertainty, loosely defined, is the inability to predict future utility of a given economic choice based on present indicators. Varian’s (2006) “contingent consumption plans” support the idea that a healthy environment is worth more to people when it is not available. The adage “You don’t know what you’ve got ‘til it’s gone” sums up this idea perfectly. Because the benefits of environmental policies are often seen generations after their implementation, uncertainty’s impact on these kinds of policy decisions is exacerbated, and this increased uncertainty plays a huge role in crafting and implementing environmental policies. Pindyck (2006) points to three challenges specifically: the nonlineararity of environmental cost and benefit functions, irreversibilities associated with environmental policies, and the protracted time spans involved with environmental policy assessment.

Unfortunately, the uncertainty inherent in economic forecasting is only one of the challenges policy makers face. As Portney notes, “All forecasting is fraught with a risk of future embarrassment, but environmental forecasts may be among the diciest of all” (2000, pg. 199). He points to the 1984 report by Coates, Coates and Heinz that predicted carbon dioxide would be a “*potential* second order problem, the effects of which ‘are unlikely to be important by 2020’” (ibid.). Portney predicts that environmental quality in the United States and other Western countries will improve in the future, which “represents a triumph of technology” (2000, pg. 203). Fortunately, many of these analytical shortcomings can be rectified by quantitative analyses that demonstrate statistically significant relationships between dependent and independent variables.

4.2. Policy options

Despite these challenges, policies that can effectively mitigate the impact of pollution without fatally decelerating the Chinese economy do exist. Siebert (1987, pg. 120) suggests seven policy instruments: a moral reevaluation of the private sector’s impact on society, publically-funded abatement schemes, government subsidies that discourage pollution, strict regulations, emissions taxes, tradable permits, and public associations that distribute the cost of polluting to polluters. No matter what shape environmental policies take, however, their primary purpose should be to “facilitate the development and implementation of novel approaches to climate change control” (Tietenberg, 2007, pg. 481).

Emissions taxes are levied against polluters to “introduce a scarcity price for emissions.” Taxes make it more costly to pollute and can encourage firms to utilize cleaner production techniques. If environmentally-damaging inputs are taxed, producers will adapt and use their resources more efficiently in order to minimize costs (Siebert, 1987). These taxes are quite popular internationally, and China is no exception. To combat emissions, Beijing has developed a two-tiered tax system. Emissions below a certain level are taxed less than emissions that have exceeded that given level, a concept that makes economic sense. In China, and certainly in other countries, as well, imposing high taxes on pollution will not only decrease emissions but will also provide funding for environmental agencies and projects (Tietenberg, 2007). However, Li (2001) suggests that in China, environmental taxes actually attract polluting industries. This paradox could be due to the fact that the demand for energy is relatively inelastic, and regulations that impose taxes on polluters are rarely strong enough to curb energy usage. The authors of the Hartwell Paper (2010) suggest that tax policies that address long term goals rather than short term emissions targets would be more effective by encouraging innovation and creating government income for R&D. These kinds of policies would be particularly effective in provinces where secondary industries contribute significantly to GRP.

Encouraging the continued development of circular economies, in which inputs are “reduced, reused and recycled” whenever possible, could also be beneficial in provinces where a large portion of GRP is made up of secondary industries. In Guangdong province, for example, eco-parks and other examples of sustainable industrial practices have already been successfully implemented and are becoming increasingly important in the local economy. But, for progress to continue, subnational governments must work closely with private enterprises to create and maintain an efficient implementation system for this economic model (Wang J. , 2002).

Emissions trading programs are also popular in industrialized and rapidly industrializing nations, and their effectiveness is apparent. In the United States, for example, emissions trading schemes diminished the cost of compliance under the Clean Air Act (Tietenberg, 2007). Another successful example from the US is the Acid Rain Program, which significantly reduced SO2 emissions. China has also implemented emissions trading schemes in certain cities and provinces, with broad success, by developing an emissions allotment system and expanding its emissions trading markets (Li, 2001). Creating these markets for emissions trading is more cost-effective than developing a system of emissions reduction credits, which requires an extensive network of bureaucratic regulators (Tietenberg, 2007).

Incentive-based approaches are another viable option for Chinese policymakers. Public recycling, for example, could be incentivized by increasing the cost of garbage disposal. On an industrial level, environmental costs could be translated into a monetary amount and shifted to the polluter. These higher costs would encourage cleaner production and waste disposal techniques (Tietenberg, 2007). In China, the role of incentive-based regulations could be expanded by further developing the polluter-pays principle.

4.3. Conclusions

Looking ahead, Chinese policymakers will undoubtedly face many challenges surrounding the development, implementation and enforcement of environmental regulations. But there is hope. The econometric analysis in this thesis shows that there is a strong link between the makeup of gross regional product and emissions output. By encouraging the expansion of tertiary industries like finance, banking and tourism, China could significantly reduce its industrial sulfur dioxide emissions. One way China could implement such a policy is by increasing education funding, which would not only increase environmental awareness, but would also create a more educated labor force (Liu & Diamond, 2005). In turn, this would raise

GRP per capita, which, according to models 2.2, 2.3 and the EKC theory, is necessary before environmental quality can improve.

The tests also showed that investment in pollution abatement and environmental protection can have a substantial impact on industrial SO2 emissions per capita, although it is often ineffective. The population average of investment between 1997 and 2008 was just under one billion yuan in each province. Increasing that by 10 percent would decrease industrial SO2 emissions by over 1000 tons per person. As optimistic as these results are, they also reveal some of the shortcomings of Chinese environment policy, specifically its ineffectiveness. Environmental protection was a central theme in the Eleventh Five Year Plan and represented a departure from previous FYPs (Cao, Garbaccio, & Ho, 2009). Unfortunately, models 2.6 and 2.7 both show that during the 11th FYP, industrial SO2 emissions have actually increased. Perhaps as China moves into the 12th FYP this year, the government will try to resolve the enforcement challenges that have beleaguered past environmental policies.

Chinese lawmakers must understand the importance of implementing progressive environmental protection policies domestically, and recent actions, including increasing attention to environmental problems in Five Year Plans, show a growing commitment to producing tangible results. With that said, the Chinese government must also focus on closing the gap between rural and urban areas, as well as the increasing disparities between inland and coastal regions. These inequalities must be addressed; otherwise, China’s development will continue to progress unevenly, and environmental damage will be exacerbated by misguided “catch-up” policies.

On an international stage, implementing and enforcing more stringent environmental policies will give China the legitimacy it needs as it continues to rocket toward superpower status. International treaties and environmental mandates affect domestic legislation at many levels, and in order for China to keep up with its Western counterparts, its legislators must realize the importance of actively participating in and adhering to international negotiations (Vogel, 1995). China's environmental quality affects everyone on the planet. This thesis clearly demonstrates the relationship between environmental quality and a number of economic growth factors. Now, it is up to the Chinese government to develop, implement and enforce pragmatic policy solutions for a global environmental problem.

BIBLIOGRAPHY

Ahuja, L. R., & Lehman, O. R. (1982). The Extent and Nature of Rainfall-soil Interaction in the Release of Soluble Chemicals to Runoff. *Journal of Environmental Quality*, 34-40.

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C., et al. (1995). Economic Growth, Carrying Capacity, and the Environment. *Science*, 520-521.

Atkinson, R., Shellenberger, M., Nordhaus, T., Swezey, D., Norris, T., Jenkins, J., et al. (2009). *Rising Tigers, Sleeping Giant: Asian Nations Set to Dominate the Clean Energy Racce by Out-Investing the United States*. Breakthrough Institute.

Barro, R. J. (2010). *Intermediate Macro.* Mason, OH: Cengage Learning.

Bramall, C. (2000). *Sources of Chinese Economic Growth, 1978-1996.* New York: Oxford University Press.

Bréchet, T., & Jouvet, P.-A. (2008). Environmental innovation and the cost of pollution abatement revisited. *Ecological Economics*, 262-265.

Buis, A., & Cole, S. (2010, November 23). *NASA Study Finds Earth's Lakes are Warming.* Retrieved November 23, 2010, from Jet Propulsion Laboratory: http://www.jpl.nasa.gov/news/news.cfm?release=2010-393

Cao, J., Garbaccio, R., & Ho, M. S. (2009). China's 11th Five-Year Plan and the Environment: Reducing SO2 Emissions. *Review of Environmental Economics and Policy*, 231-250.

Carlsson, F., Kataria, M., Krupnick, A., Lampi, E., Lofgren, A., Qin, P., et al. (2010). *Paying for Mitigation: A Multiple Country Study.* Washington, DC: Resources for the Future.

Chen, Y., Li, H., & Zhou, L.-A. (2005). Relative performance evaluation and the turnover of provincial leaders in China. *Economics Letters*, 421-425.

Chen, Y., Li, H., & Zhou, L.-A. (2005). Relative performance evaluation and the turnover of provincial leaders in China. *Economics Letters*, 421-425.

Chow, G. (1993). Capital Formation and Economic Growth in China. *The Quarterly Journal of Economics*, 809-842.

Chow, G. C., & Li, K.-W. (2002). China's Economic Growth: 1952–2010. *Economic Development and Cultural Change*, 247-256.

Cole, M., & Neumayer, E. (2009). Economic growth and the environment in developing countries: what are the implications of the Environmental Kuznets Curve? In P. Dauvergne (Ed.), *International Handbook of Environmental Politics* (pp. 298-318). Cheltenham and Northampton: Edward Elgar Publishing.

Dasgupta, S., Laplante, B., Wang, H., & Wheeler, D. (2002). Confronting the Environmental Kuznets Curve. *Journal of Economic Perspectives*, 147-168.

Economy, E. (2007, October). The Great Leap Backward: The Costs of China's Environmental Crisis. *Foreign Affairs*, pp. 38-59.

Economy, E. C. (2010). *The River Runs Black: The Environmental Challenges to China's Future.* Ithica: Cornell Univ. Press.

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

Fan, C. (2006). China's Eleventh Five-Year Plan (2006–2010): From "Getting Rich First" to "Common Prosperity". *Eurasian Geography and Economics, 47*(6), 708-723.

Fang, C., & Yang, D. (2008). The political economy of emissions reduction in China: Are incentives for low carbon growth compatible? In L. Song, & W. T. Woo (Eds.), *China's Dilemma: Economic Growth, the Environment and Climate Change* (pp. 226-242). Brookings.

Grossman, G., & Krueger, A. (1995). Economic Growth and the Environment. *The Quarterly Journal of Economics*, 353-377.

Guggenheim, D. (Director). (2006). *An Inconvenient Truth* [Motion Picture].

Hendrischke, H. (1999). Provinces in competition: region, identity and cultural construction. In H. Hendrischke, & C. Feng (Eds.), *The Political Economy of China's Provinces: Comparitive and Competitive Advantage* (pp. 1-30). New York: Routledge.

Hettich, F. (2000). *Economic Growth and Environmental Policy: A Theoretical Approach.* Cheltenham: Elgar.

Holz, C. A. (2003). *China's Statistical Problems in Transition: Challenges, Data Problems, and Innovations.* Hong Kong: HKUST.

Hu, Z. F., & Khan, M. S. (1997). Why Is China Growing So Fast? *Staff Papers - International Monetary Fund*, 103-131.

Johnson, I. (2010, November 23). China Sets Tough Line in Climate Talks. *The New York Times*.

Jorgensen, D. W., & Wilcoxen, P. J. (1990). Environmental Regulation and US Economic Growth. *The Rand Journal of Economics*, 314-340.

Judd, M., Kellier, F., Ulyatt, M., Lassey, K., Tate, K., Shelton, I., et al. (1999). Net methane emissions from grazing sheep. *Global Change Biology*, 647-657.

Judge, W. Q., & Douglas, T. J. (1998). Performance Implications of Incorporating Natural Environmental Issues into the Strategic Planning Process: An Empirical Assessment. *Journal of Management Studies*, 241-262.

Kan, H., & Chen, B. (2004). Particulate air pollution in urban areas of Shanghai, China: health-based economic assessment . *Science of the Total Environment*, 71-79.

Knupp, E. (1997). Environmental NGOs in China: An Overview. *China Environment Series*, 9-15.

Kolstand, C. D., & Xing, Y. (1998). *Do Lax Environmental Regulations Attract Foreign Investment?* Santa Barbara: Department of Economics, UC Santa Barbara.

Li, J. (2001). 环境保护的经济手段及其应用 (Three Economic Methods for Environmental Protection and Their Application). *财经理论与实践 (The Theory and Practice of Financial Economics)*, 104-108.

Lieberthal, K. (1997). China's Governing System and Its Impact on Environmental Policy Implementation. *China Environment Series*, 3-8.

Lieberthal, K., & Oksenberg, M. (1988). *Policy Making in China: Leaders, Structures, and Processes.* Princeton: Princeton.

Lin, J. Y. (1992). Rural Reforms and Agricultural Growth in China. *The American Economic Review*, 34-51.

Liu, J., & Diamond, J. (2005). China's Environment in a Globalizing World. *Nature*, 1179-1186.

Ma, X., & Ortolano, L. (2000). *Environmental Regulation in China: Institutions, Enforcement, and Compliance.* Lanham: Rowman and Littlefield.

Martin, D. (2011, February 28). *Chinese growth threatened by pollution: minister.* Retrieved February 28, 2011, from Yahoo! Green: http://green.yahoo.com/news/afp/20110228/sc_afp/chinaeconomyenvironmenthealth.html

McCormick, J. (1991). *Reclaiming Paradise: The Global Environmental Movement.* Bloomingdale: Indiana University Press.

Meng, S. (2010, November 29). *解振华：中国希望以开放消除误解 (Xie Zhenhua: China hopes to start being transparent).* Retrieved November 29, 2010, from 中国对话 (China Dialogue): http://www.chinadialogue.net/article/show/single/ch/3966--China-will-be-transparent-

Ministry of Environmental Protection. (2008). *2008 Report on the State of the Environment in China.* Beijing: MEP.

Montinola, G., Qian, Y., & Weingast, B. R. (1995). Federalism, China Style: The Political Basis for Economic Success in China. *World Politics*, 50-81.

Na, L., & Lightfoot, W. (2006). Determinants of foreign direct investment at the regional level in China. *Journal of Technology Management in China*, 262-278.

NDRC. (2007). *China's National Climate Change Programme.* National Development and Reform Commission.

NDRC. (2008). *The National Eleventh Five Year Plan for Environmental Protection.*

Ögütçü, M., & Taube, M. (2002). Getting China's regions moving. *Observer*, 13-15.

Pope, C. A. (2000). Risk?, Epidemiology of Fine Particulate Air Pollution and Human Health: Biologic Mechanisms and Who's at. *Environmental Health Perspectives*, 713-723.

Porter, M. E., & van der Linde, C. (1995). Toward a New Conception of the Environment-Competitiveness Relationship. *Journal of Economic Perspectives*, 97-118.

Prins, G., Galiana, I., Green, C., Grundmann, R., Hulme, M., Korhola, A., et al. (2010). *The Hartwell Paper: A new direction for climate policy after the crash of 2009.* London: The London School of Economics.

Rugman, A. M., & Verbeke, A. (1998). Corporate Strategies and Environmental Regulations: An Organizing Framework. *Strategic Management Journal*, 363-375.

Sachs, J. (2008). *Common Wealth: Economics for a Crowded Planet.* New York: Penguin.

Sass, R., Fisher, F., Wang, Y., Turner, F., & Jund, M. (1992). Methane emission from rice fields: The effect of floodwater management. *Global Biochemical Cycles*, 249-262.

Schwartz, J. (2004). Environmental NGOs in China: Roles and Limits. *Pacific Affairs*, 28-49.

Shafik, N. (1994). Economic Development and Environmental Quality: An Econometric Analysis. *Oxford Economic Papers*, 757-773.

Shafik, N., & Bandyopadhyay, S. (1992). *Economic Growth and Environmental Quality: Time-Series and Cross-Country Evidence.* World Bank Policy Research Working Papers.

Shapiro, J. (2001). *Mao's War against Nature: Politics and the Environment in Revolutionary China.* Cambridge: Cambridge University Press.

Shi, X. (2008). Can China's coal industry be reconciled with the environment? In L. Song, & W. T. Woo (Eds.), *China's Dilemma: Economic Growth, the Environment and Climate Change* (pp. 367-391). ANU E, Asia Pacific, Brookings Institute, Social Sciences Academic Press (China).

Siebert, H. (1987). *Economics of the Environment: Theory and Policy.* Berlin: Springer-Verlag.

Sorsa, P. (1994, February). Competitiveness and Environmental Standards.

Stern, N. (2008). The Economics of Climate Change. *The American Economic Review*, 1-37.

The Economist. (2009, April 16). There was a lawyer, an engineer and a politician... *The Economist.*

Tian, H., & Whalley, J. (2008). *China's Participation in Global Environmental Negotiations.* Cambridge: National Bureau of Economic Research.

Tietenberg, T. (1990). Economic Instruments for Environmental Regulation. *Oxford Review of Economic Policy*, 17-33.

Tietenberg, T. (2007). *Environmental Economics and Policy, Fifth Edition.* Boston: Pearson Education.

U.S. EPA. (2011, March 30). *Sulfur Dioxide*. Retrieved April 18, 2011, from Environmental Protection Agency: http://www.epa.gov/air/sulfurdioxide/

US EPA. (2010, October 19). *Greenhouse Gas Emissions*. Retrieved November 23, 2010, from US Environmental Protection Agency: http://www.epa.gov/climatechange/emissions/index.html

van Rooij, B. (2006). Implementation of Chinese Environmental Law: Regular Enforcement and Political Campaigns. *Development and Change*, 57-74.

Vogel, D. (1995). *Trading Up: Consumer and Environmental Regulation in a Global Economy.* Cambridge: Harvard University Press.

Wang, H., & Jin, Y. (2002). Industrial Ownership and Environmental Performance: Evidence from China. *World Bank Policy Research Working Paper Series.*

Wang, J. (2002). 发展循环经济是 21 世纪环境保护的战略选择 (Developing a Circular Economy is the Strategic Choice for Environmental Protection in the 21st Century). *环境科学研究 (Research of Environmental Sciences)*, 34-37.

Wang, J. (2010, September 23). *中国环境法治为何失败？*. Retrieved February 6, 2011, from China Dialogue: http://www.chinadialogue.net/article/show/single/ch/3831--China-s-green-laws-are-useless-

Wu, C., Maurer, C., Wang, Y., Xue, S., & Davis, D. L. (1999). Water Pollution and Human Health in China. *Environmental Health Perspectives*, 261-256.

Xie, Z. (2010, November 23). *我委解振华副主任出席国新办举行的新闻发布会，介绍中国应对气候变化的政策与行动和联合国气候变化坎昆会议情况 (News conference with NDRC Vice-Chairman Xie Zhenhua on the state of China's climate change policies).* Retrieved November 29, 2010, from 中国发改委新闻中心 (China's NDRC News Center): http://xwzx.ndrc.gov.cn/wszb/t20101123_381781.htm

Xinhua News. (2010, November 07). *China drafting law on dealing with climate change.* Retrieved November 23, 2010, from Xinhua: http://news.xinhuanet.com/english2010/china/2010-11/07/c_13594459.htm

Xinhua News. (2011, January 14). *"十二五" 中国环境保护面临四大挑战 The Four Big Environmental Protection Challenges China Will Face during the 12th Five Year Plan.* Retrieved January 25, 2011, from 中华人民共和国环境保护部 Ministry of Environmental Protection of the PRC: http://www.mep.gov.cn/ztbd/gzhy/2011gzh/mtbd/201101/t20110114_199844.htm

Yang, G. (2010). Civic Environmentalism. In Y.-t. Hsing, & C. K. Lee (Eds.), *Reclaiming Chinese Society* (pp. 119-139). New York: Routledge.

Yang, G., & Calhoun, C. (2007). Media, Civil Society, and the Rise of a Green Public Sphere in China. *China Information*, 211-236.

Appendix I: Descriptive Statistics

	Industrial SO2 Emissions (10k tons)	GRP per capita (1k RMB)	Foreign Investment (10k USD)	Investment in environmental and pollution projects (10k RMB)	Primary Industry Contributions (100 million RMB)	Secondary Industry Contributions (100 million RMB)	Tertiary Industry Contributions (100 million RMB)
Maximum	176.0	73.124	41,590,000	844,159.4	3,002.65	18,402.64	15,323.59
Minimum	0.1	2.093	19,113	128.9	27.15	11.39	26.22
Mean	56.2	12.7151	3,834,373	102,948.9	629.1338	2,406.105	1,868.644
Median	50.7	9.1335	1,368,370	63,365.5	507.995	1,558.505	1,249.44

Appendix II: Output Tables

Table I: $E_{it} = \beta_0 + \beta_1 \ln(\text{GRP per capita})_{it} + \beta_{2-13}(\text{d98-d08}) + \varepsilon_{it}$

	industrial SO2 emissions			ln(industrial SO2 emissions)			industrial SO2 emissions per capita		
	Pooled	FE	RE	Pooled	FE	RE	Pooled	FE	RE
ln_aGDP	1.43861 (3.646895)	37.10237*** (7.272664)	28.63957*** (6.400882)	.2233144* (.1344983)	-.0187543 (.1600839)	.0042258 (.1520768)	1246.822 (887.3854)	17836.64*** (2516.009)	10987.59 (1982.072)
d97	-1.621734 (10.04975)	-5.379138* (2.799352)	-4.515689 (2.790023)	-.0640546* (.3706369)	-.0590263 (.0616186)	-.0613283 (.0612877)	-234.5893 (2445.368)	-2115.043** (968.4477)	-1414.269 (974.9237)
d98	5.720406 (10.06095)	-.4310137*** (2.966022)	1.000521 (2.920321)	.0488778 (.3710501)	.0701555 (.0652873)	.0663109 (.0646243)	934.6052 (2448.094)	-2059.48** (1026.108)	-898.9472 (1010.833)
d99	1.359366 (10.07355)	-6.625123** (3.13931)	-4.758612 (3.057381)	-.03823 (.3715145)	-.0045102 (.0691016)	-.009536 (.0681092)	-250.3603 (2451.158)	-4097.14*** (1086.058)	-2584.575** (1048.96)
d00	5.296455 (10.10162)	-5.687066 (3.49125)	-3.108902 (3.339886)	.0123657 (.3725498)	.0664414 (.0768485)	.0594833 (.0752274)	115.0691 (2457.989)	-5126.779*** (1207.813)	-3038.266*** (1128.523)
d01	2.512264 (10.13956)	-11.51803*** (3.914784)	-8.216882** (3.685678)	-.0606679 (.373949)	.0140879 (.0861712)	.0051665 (.0838489)	-823.1026 (2467.221)	-7482.225*** (1354.336)	-4808.596*** (1227.381)
c02	2.643637 (10.19264)	-14.7673*** (4.439544)	-10.66395** (4.120652)	-.0701541 (.3759068)	.0275479 (.097722)	.0164482 (.0945912)	-760.2589 (2480.138)	-8991.965*** (1535.879)	-5669.1*** (1353.514)
d03	11.46375 (10.28706)	-10.72647** (5.246815)	-5.489022 (4.799622)	.0865056 (.379389)	.2166471* (.1154915)	.2024678* (.111205)	1767.897 (2503.112)	-8687.005*** (1815.158)	-4446.302*** (1553.28)
d04	14.44195 (10.44741)	-14.12663** (6.397213)	-7.375635 (5.780302)	.1208898 (.3853028)	.2943246** (.1408137)	.2760354** (.1349947)	2115.026 (2542.13)	-11306.91*** (2213.143)	-5841.28*** (1845.93)
d05	23.13498** (10.62494)	-11.20402 (7.480516)	-3.083736 (6.712431)	.2290775 (.3918501)	.4416792*** (.1646591)	.4196718*** (.1574709)	4595.694* (2585.328)	-11510.49*** (2587.916)	-4936.677** (2126.96)
d06	25.00896** (10.81017)	-14.53336* (8.478731)	-5.17836 (7.576045)	.2296429 (.3986814)	.4775623** (.1866315)	.4522021** (.1782213)	5137.542* (2630.399)	-13389.09*** (2933.253)	-5816.002** (2388.953)
d07	21.76345** (11.05543)	-23.86534** (9.663385)	-13.06606 (8.604886)	.1526465 (.4077267)	.4418779** (.2127078)	.4125958** (.20288)	4127.646 (2690.077)	-17230.24*** (3343.089)	-8488.281*** (2702.46)
d08	16.72395 (11.33391)	-35.08198*** (10.87858)	-22.8169** (9.663329)	.0493649 (.4179968)	.3805237 (.2394564)	.3472614 (.2282)	2610.842 (2757.837)	-21620.48*** (3763.492)	-11692.24*** (3026.096)
constant	43.03408*** (9.411169)	-16.27198* (12.27011)	-2.144976 (12.91228)	2.978332*** (.3470859)	3.399821*** (.2700864)	3.362807*** (.3679087)	10357.51*** (2289.985)	-17107.34*** (4244.897)	-5677.944 (3750.133)
R-squared	0.0591			0.0236			0.0703		
Hausman prob>chi^2		0.0560			0.8235			0.0001	
n	402	402	402	402	402	402	402	402	402

The number in parentheses is the standard error.
***p<0.01, **p<0.05, *p<0.1

Table II: $E_{it} = \beta_0 + \beta_1\ln(\text{GRP per capita})_{it} + \beta_2(\ln(\text{GRP per capita})_{it})^2 + \beta_{3\text{-}14}(d98\text{-}d08) + \varepsilon_{it}$

	industrial SO2 emissions			ln(industrial SO2 emissions)			industrial SO2 emissions per capita		
	Pooled	FE	RE	Pooled	FE	RE	Pooled	FE	RE
ln_aGDP	49.29922*** (17.03442)	49.95344*** (8.784986)	42.83915*** (8.199864)	1.279182** (.6325268)	.5467052*** (.1879575)	.5737377*** (.1826046)	1481.5 (4188.936)	28772.97*** (2894.262)	23181.24*** (2602.545)
ln_aGDP^2	-9.593708*** (3.336869)	-2.93989** (1.146029)	-3.121655*** (1.147116)	-.2116497* (.1239055)	-.129358*** (.0245196)	-.1291569*** (.0244206)	-47.04154 (820.5698)	-2501.862 *** (377.5655)	-2545.849*** (382.9821)
d97	-2.967459 (9.967948)	-5.597689** (2.779091)	-4.804291* (2.767642)	-.093743 (.3701326)	-.0686427 (.0594595)	-.0714371 (.0591025)	-241.1879 (2451.219)	-2301.031** (915.5869)	-1712.467* (921.5679)
d98	3.555246 (9.996459)	-.7788151 (2.946292)	.5374913 (2.899986)	.0011115 (.3711913)	.0548519 (.0630368)	.0501928 (.0623905)	923.9886 (2458.231)	-2355.46** (970.6722)	-1380.565 (958.0921)
d99	-1.3471 (10.02482)	-7.045498** (3.119431)	-5.327174* (3.038298)	-.0979382 (.3722445)	-.0230071 (.0667412)	-.0290959 (.0658069)	-263.6311 (2465.206)	-4454.881*** (1027.714)	-3183.78*** (996.481)
d00	1.85333 (10.07974)	-6.18053* (3.469689)	-3.801656 (3.321478)	-.0635942 (.3742835)	.0447286 (.0742351)	.0362977 (.0727486)	98.18613 (2478.709)	-5546.719*** (1143.108)	-3790.324*** (1075.704)
d01	-1.699829 (10.1522)	-12.09205*** (3.891063)	-9.042502** (3.667704)	-.1535921 (.3769741)	-.0111697 (.0832505)	-.0219795 (.0811472)	-843.7561 (2496.528)	-7970.722*** (1281.932)	-5721.402*** (1173.742)
c02	-2.25945 (10.24151)	-15.38099*** (4.411831)	-11.5842*** (4.101139)	-.1783226 (.3802906)	.0005448 (.0943925)	-.0129082 (.0915734)	-784.3005 (2518.491)	-9514.222*** (1453.502)	-6717.217*** (1297.684)
d03	5.891314 (10.37473)	-11.30201** (5.211224)	-6.443002 (4.774558)	-.0364297 (.3852372)	.1913227* (.1114957)	.1741268 (.107644)	1740.573 (2551.25)	-9176.794*** (1716.867)	-5604.104*** (1492.127)
d04	8.389886 (10.56282)	-14.52449** (6.349821)	-8.240017 (5.744834)	-.0126265 (.3922215)	.2768186** (.1358564)	.2546187* (.1306218)	2085.351 (2597.504)	-11645.49*** (2091.984)	-7035.688*** (1775.058)
d05	16.9812 (10.74223)	-11.33933 (7.423071)	-3.75897 (6.66694)	.0933171 (.3988835)	.4357255*** (.1588189)	.4089915*** (.152339)	4565.52* (2641.623)	-11625.64*** (2445.572)	-6076.052*** (2045.928)
d06	19.37418* (10.88819)	-14.24477* (8.41416)	-5.484313 (7.521707)	.1053324 (.4043034)	.4902603*** (.1800235)	.4594251*** (.1724187)	5109.912* (2677.517)	-13143.5*** (2772.092)	-6743.684*** (2297.885)
d07	17.21175 (11.06717)	-22.93505** (9.59579)	-12.78517 (8.544572)	.0522302 (.4109492)	.4828115** (.2053049)	.447169** (.1963872)	4105.328 (2721.529)	-16438.56*** (3161.386)	-9042.03*** (2600.457)
d08	13.74805 (11.27685)	-33.35438*** (10.81576)	-21.78536 (9.60424)	-.0162873 (.4187353)	.4565396** (.2314064)	.4160082* (.2211603)	2596.25 (2773.092)	-20150.29*** (3563.311)	-11740.01*** (2914.97)
constant	-7.626558 (19.93568)	-28.78007** (13.11561)	-16.35094** (13.84173)	1.860693** (.7402571)	2.849453*** (.2806124)	2.805002*** (.3799029)	10109.11 (4902.385)	-27751.79*** (4321.01)	-18284.52*** (4053.581)
R-squared	0.0788			0.0309			0.0703		
Hausman prob>chi^2		0.1162			0.8913			0.0005	
n	402	402	402	402	402	402	402	402	402

The number in parentheses is the standard error.
***p<0.01, **p<0.05, *p<0.1

Table III: $E_{it} = \beta_0 + \beta_1\ln(\text{GRP per capita})_{it} + \beta_2(\ln(\text{GRP per capita})_{it})^2 + \beta_3(\ln(\text{GRP per capita})_{it})^3 + \beta_{4\text{-}15}(\text{d98-d08}) + \varepsilon_{it}$

	industrial SO2 emissions			ln(industrial SO2 emissions)			industrial SO2 emissions per capita		
	Pooled	FE	RE	Pooled	FE	RE	Pooled	FE	RE
ln_aGDP	-145.7904** (63.56026)	-42.75068* (22.4177)	-52.93135** (21.80647)	-3.608363 (2.376953)	-2.626451*** (.4581201)	-2.56285*** (.4525198)	-39144.54** (15688.04)	-5014.785 (7339.003)	-12359.89* (7082.47)
ln_aGDP^2	74.00796*** (26.47071)	33.44389*** (8.20798)	35.15905*** (8.177044)	1.882807* (.9899207)	1.116017*** (.1677353)	1.107275*** (.1669671)	17362.41*** (6533.539)	10758.89*** (2687.091)	11924.65*** (2693.176)
ln_aGDP^3	-11.09393*** (3.485287)	-4.787053*** (1.069892)	-5.033164*** (1.065152)	1.882807** (.9899207)	-.1638553*** (.0218639)	-.1626486*** (.0217589)	-2310.232*** (860.2435)	-1744.731*** (350.2564)	-1902.011*** (350.6977)
d97	-1.549782 (9.862445)	-4.254581 (2.724481)	-3.575066 (2.705253)	-.0582262 (.3688242)	-.0226697 (.0556765)	-.027237 (.0553589)	54.03338 (2434.263)	-1811.51** (891.928)	-1316.01 (889.5724)
d98	5.655963 (9.90258)	1.353914 (2.910113)	2.476256 (2.852067)	.0537404 (.3703251)	.1278528** (.05947)	.1202786** (.0588812)	1361.448 (2444.169)	-1578.147* (952.6995)	-760.7112 (930.7482)
d99	1.143284 (9.93944)	-4.368474 (3.097841)	-2.90877 (3.001818)	-.035547 (.3717036)	.0686243 (.0633064)	.0587591 (.0624536)	254.9737 (2453.267)	-3479.189*** (1014.157)	-2416.966** (972.9238)
d00	4.657185 (10.00174)	-2.757636 (3.466272)	-.7510078 (3.298819)	.0066503 (.3740334)	.1618903** (.0708355)	.1483066** (.0694892)	682.0692 (2468.644)	-4299.181*** (1134.772)	-2840.761*** (1057.032)
d01	1.439903 (10.08286)	-7.903235** (3.905252)	-5.34089 (3.658572)	-.074933 (.377067)	.1322087* (.0798063)	.1148462 (.0779149)	-189.9292 (2488.665)	-6444.03*** (1278.483)	-4582.901*** (1160.005)
c02	.9527599 (10.17295)	-10.4771** (4.436322)	-7.302438* (4.098876)	-.0978477 (.3804362)	.1683995* (.0906591)	.1468708* (.0881447)	-115.3807 (2510.902)	-7726.906*** (1452.343)	-5422.865*** (1286.976)
d03	8.887853 (10.29757)	-5.534388 (5.238785)	-1.496676 (4.771678)	.038642 (.3850964)	.3887419*** (.1070579)	.3613467*** (.1036544)	2364.581 (2541.66)	-7074.675*** (1715.049)	-4148.367*** (1482.487)
d04	10.63207 (10.46409)	-7.818795 (6.366072)	-2.633603 (5.727193)	.0435465 (.3913239)	.5063467*** (.1300948)	.4711578*** (.125512)	2552.269 (2582.762)	-9201.475*** (2084.095)	-5450.474*** (1762.385)
d05	17.96202* (10.62216)	-4.045497 (7.414326)	2.169795 (6.622883)	.1178892 (.3972351)	.6853849*** (.1515165)	.6431959*** (.1458842)	4769.768* (2621.777)	-8967.266*** (2427.268)	-4477.708** (2026.393)
d06	19.56367* (10.76212)	-6.290974 (8.389104)	.8697377 (7.459435)	.1100796 (.4024693)	.7625098*** (.1714367)	.7139485*** (.164852)	5149.372* (2656.323)	-10244.59*** (2746.386)	-5082.909** (2273.824)
d07	16.83231 (10.93951)	-14.0707 (9.557545)	-5.789273 (8.466062)	.042724 (.409103)	.786228*** (.1953146)	.7301567*** (.1876128)	4026.311 (2700.106)	-13207.78*** (3128.905)	-7253.885*** (2572.503)
d08	13.26539 (11.14715)	-23.37668** (10.77202)	-13.94039 (9.515911)	-.0283794 (.4168679)	.7980649*** (.2201331)	.7343027*** (.2112928)	2495.739 (2751.354)	-16513.73*** (3526.494)	-9748.124*** (2884.895)
constant	130.4876*** (47.65476)	44.09936** (20.70333)	57.36149*** (20.67346)	5.320841*** (1.782137)	5.344032*** (.4230859)	5.258435*** (.4931983)	38870.4*** (11762.22)	-1189.524 (6777.762)	8475.253 (6417.408)
R-squared	0.1024			0.0422			0.0874		
Hausman prob>chi^2		0.2322			0.7497			0.0122	
n	402	402	402	402	402	402	402	402	402

The number in parentheses is the standard error.
***p<0.01, **p<0.05, *p<0.1

Table IV: $E_{it} = \beta_0 + \beta_1\ln(\text{primary contributions})_{it} + \beta_2\ln(\text{secondary contributions})_{it} + \beta_3\ln(\text{tertiary contributions})_{it} + [\beta_4 F_i] + \varepsilon_{it}$

	industrial SO2 emissions			ln(industrial SO2 emissions)			industrial SO2 emissions per capita		
	Pooled	FE	RE	Pooled	FE	RE	Pooled	FE	RE
pri_cont	14.01898*** (2.018197)	11.81957** (5.533153)	13.50642*** (4.275123)	.2245419*** (.0589456)	.4596212*** (.1141451)	.4811873*** (.1008572)	-5368.957*** (642.9345)	5269.493*** (1878.252)	-399.2197 (1396.45)
sec_cont	24.63512*** (4.281051)	11.28361*** (4.013581)	11.08838*** (3.586973)	1.797701*** (.125037)	.2162418*** (.0827974)	.2567701*** (.0801732)	12331.04*** (1363.809)	3304.583** (1362.427)	5952.359*** (1228.2)
ter_cont	-14.7866*** (4.328472)	-.5224039 (2.632406)	-.9961697 (2.602488)	-1.24573*** (.126422)	-.1303157** (.0543047)	-.1615435*** (.0562847)	-9194.183*** (1378.916)	-1496.374* (893.5813)	-1775.209* (914.1578)
Constant	-101.0442*** (9.243613)	-91.96797*** (15.95196)	-97.36985*** (13.62742)	-1.972222*** (.2699789)	.140874 (.329078)	-.0589872 (.3255441)	22928.23*** (2944.726)	-30179.72*** (5414.961)	-13117.86*** (4459.174)
R-squared	0.5339			0.6966			0.2105		
Hausman prob>chi^2		0.5363			0.0000			0.0000	
n	402	402	402	402	402	402	402	402	402

The number in parentheses is the standard error.
***p<0.01, **p<0.05, *p<0.1

Table V: $E_{it} = \beta_0 + \beta_1(\text{primary contributions})_{it} + \beta_2(\text{secondary contributions})_{it} + \beta_3(\text{tertiary contributions})_{it} + \beta_4(\text{primary contributions})_{it}^2 + \beta_5(\text{secondary contributions})_{it}^2 + \beta_6(\text{tertiary contributions})_{it}^2 + [\beta_7 F_i] + \varepsilon_{it}$

	industrial SO2 emissions			ln(industrial SO2 emissions)			industrial SO2 emissions per capita		
	Pooled	FE	RE	Pooled	FE	RE	Pooled	FE	RE
pri_cont	.0473528*** (.008355)	.0483929*** (.0095899)	.0516564*** (.0089176)	.0027646*** (.0003634)	.0015371*** (.0002154)	.0015942*** (.000212)	-15.83837*** (2.998582)	23.84614*** (3.578878)	17.22688*** (3.392814)
pri_cont^2	-8.17e-06* (4.20e-06)	-.0000125*** (3.08e-06)	-.0000133*** (2.95e-06)	-1.02e-06*** (1.82e-07)	-4.54e-07*** (6.92e-08)	-4.71e-07*** (6.86e-08)	.0038041** (.001506)	-.007115*** (.0011503)	-.0053969*** (.0011221)
sec_cont	.0191487*** (.0035886)	.0133822*** (.0022902)	.0133919*** (.0022572)	.0002947* (.0001561)	.0001946*** (.0000514)	.0001918*** (.0000513)	6.507902*** (1.287934)	2.11868** (.8546891)	2.710057*** (.8596594)
sec_cont^2	-6.10e-07** (2.39e-07)	-5.67e-07*** (1.31e-07)	-5.58e-07*** (1.29e-07)	-4.86e-09 (1.04e-08)	-4.99e-09* (2.94e-09)	-4.76e-09 (2.94e-09)	-.0002501*** (.0000857)	-.0000343 (.0000488)	-.0000674 (.0000493)
ter_cont	-.0135474*** (.004213)	-.0091269*** (.0024753)	-.0093475*** (.0024633)	-4.32e-06 (.0001832)	-.0001912*** (.0000556)	-.0001902*** (.0000556)	-4.737296*** (1.512026)	-2.31118** (.9237733)	-2.39983** (.9383305)
ter_cont^2	3.70e-07 (3.73e-07)	5.31e-07*** (1.93e-07)	5.27e-07*** (1.93e-07)	-1.51e-08 (1.62e-08)	5.51e-09 (4.34e-09)	5.28e-09 (4.34e-09)	.0001816 (.0001339)	.0000254 (.0000721)	.000043 (.0000734)
Constant	16.6717*** (2.864224)	22.68502*** (3.049614)	21.49597*** (5.18686)	1.962762*** (.124572)	2.789915*** (.0685053)	2.770354*** (.2191777)	17373.18*** (1027.955)	3907.594*** (1138.096)	6016.647*** (1961.826)
R-squared	0.5886			0.4062			0.1156		
Hausman prob>χ^2		0.5380			.0990			0.0000	
n	331	331	331	331	331	331	331	331	331

The number in parentheses is the standard error.
***p<0.01, **p<0.05, *p<0.1

Table VI: Eit = β0 + β1ln(foreign investment)it + β2(ln(foreign investment)it)2 + [β_3Fi] + εit

	industrial SO2 emissions			ln(industrial SO2 emissions)			industrial SO2 emissions per capita		
	Pooled	FE	RE	Pooled	FE	RE	Pooled	FE	RE
ln(foreign investment)	40.19436*** (14.69128)	-11.94158 (9.687252)	-9.903593 (9.562851)	4.899015*** (.4631357)	.7487843*** (.1934471)	.8023256*** (.1945209)	8457.671** (3925.546)	14708.71*** (3067.884)	14766.74*** (3042.976)
ln(foreign investment)^2	-1.087953** (.5280609)	.901404** (.3546885)	.8180158** (.3496417)	-.1612591*** (.0166469)	-.0177755** (.0070829)	-.0195501*** (.0071179)	-301.4063** (141.0992)	-404.486*** (112.3273)	-420.5087*** (111.1823)
Constant	-291.2726*** (101.4908)	43.36628 (66.19831)	31.44171 (65.71309)	-33.05933*** (3.19945)	-3.43387** (1.32193)	-3.829942*** (1.344998)	-43882.12 (27118.59)	-111197.3*** (20964.54)	-108783.3*** (20885.09)
R-squared	0.1704			0.3710			0.0116		
Hausman prob>chi^2		0.3569			0.0051			0.0037	
n	402	402	402	402	402	402	402	402	402

The number in parentheses is the standard error.
***p<0.01, **p<0.05, *p<0.1

Table VII: $E_{it} = \beta_0 + \beta_1(\ln(\text{investment } i_{(t-1)})) + \beta_2(\ln(\text{investmenti}_{(t-1)}))^2 + \delta_1(\text{FYP 10}) + \delta_2(\text{FYP 11}) + [\beta_3 F_i] + \varepsilon_{it}$

	industrial SO2 emissions			ln(industrial SO2 emissions)			industrial SO2 emissions per capita		
	Pooled	FE	RE	Pooled	FE	RE	Pooled	FE	RE
ln(investment)	-50.98698*** (10.38557)	-14.02847* (7.985651)	-10.1477 (7.805021)	2.761001*** (.2395919)	.5181368*** (.1649943)	.9924591*** (.1815097)	12938.09*** (3388.931)	8189.475*** 2910.257	8491.067*** (2727.513)
ln(investment) ^2	3.567341*** (.5195823)	.9064904** (.3757376)	.8203844** (.3717633)	-.0996368*** (.0119866)	-.0216278*** (.0077632)	-.0397583*** (.0086326)	-583.5498*** (169.5458)	-327.1185** 136.9323	-342.9871*** (129.9996)
FYP 10	-8.346319* (4.409472)	1.817652 (1.766812)	.6871252 (1.809941)	-.2722887*** (.1017252)	.0663643* (.0365047)	.0135858 (.0418429)	227.3509 (1438.862)	-102.9305 643.8898	-87.70581 (634.1387)
FYP 11	-16.56062*** (5.023253)	12.21755*** (2.481594)	9.534728*** (2.505397)	-.380125*** (.115885)	.3421776*** (.0512731)	.2378503*** (.0580281)	4974.964*** (1639.146)	3802.633*** 904.3818	3863.922*** (877.0867)
Constant	194.2594*** (52.21051)	97.52684** (42.88478)	66.39095 (41.56676)	-14.14125*** (1.204481)	.4875164 (.886057)	-2.514*** (.9688655)	-57203.78*** (17036.9)	-35806.85** 15628.75	-37239.93** (14512.23)
R-squared	0.4977			0.7157			0.1143		
Hausman prob>chi^2		0.0000			0.0000			0.9305	
n	335	335	335	335	335	335	335	335	335

The number in parentheses is the standard error.
***p<0.01, **p<0.05, *p<0.1