ABSTRACT

QIN, JIN. A Test of the Relationship between Air Pollution and Exports: The Case of China (Under the direction of Dr. Ivan Kandilov and Dr. Roger von Haefen).

This dissertation consists of three essays. The first essay (Chapter II) estimates the effects of exports on the air pollution in China. To avoid endogeneity issues, I use an instrumental variable strategy, which relies on the exogenous shock to exports brought about by the Great Recession and the fact that most exports from China are produced in coastal provinces. In my empirical work, I employ data collected by the National Bureau of Statistics of the People's Republic of China. Sulfur dioxide, nitrogen oxides and smoke & dust at the province level over 13 years from 2003 to 2015 are used to measure the air pollution, and are related to the measures of provincial exports such as export intensity (exports as a fraction of GDP). The econometric model utilizes a two-stage IV regression. In the first stage, export intensity is instrumented using the exogenous variation from the Great Recession and coastal location. Then, the predicted export intensity from the first stage is used as the regressor in the second stage regression explaining air pollution. For all three air pollutants, the results show that pollution decreases more for coastal provinces following the Great Recession than inland provinces. Hence, the air pollution in China improves as export intensity declines.

The second essay (Chapter III) estimates the effects of exports on wages in China. In my empirical work, I use data from the China Health and Nutrition Survey (CHNS). My difference-in-difference-in-differences econometric model utilizes data on individual workers to estimate the differences in the college wage premium between manufacturing and service sectors, before and after the Great Recession, between coastal and inland locations in China. The results suggest that a reduction in trade (exports) during the Great Recession lowers the relative wage of college-

educated individuals working for the manufacturing sector in coastal China more than the relative wage for individuals working for the service sector in non-coastal locations.

The third essay (Chapter IV) investigates the link between air pollution and income in China, a rapidly developing country that has experienced significant environmental problems in recent years. Per capita emissions of sulfur dioxide, nitrogen oxides and smoke & dust for each province in China are utilized to measure air pollution, and real GDP per capita for each province is used to measure income. A two-way, fixed effects panel data model is employed, and two specifications are considered: 1) a pooled model where the relationship between income and pollution is assumed stable across provinces, and 2) a disaggregated specification where the income-pollution relationship is allowed to vary across three geographic regions. The regression results are consistent with the environmental Kuznets hypothesis in some specifications but reject the hypothesis in others.

A Test of the Relationship between Air Pollution and Exports: The Case of China

by
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DEDICATION

To my loved family and friends in the Name of God.

BIOGRAPHY

Jin Qin, originally from China, did his undergraduate studies at Shanghai Normal University (SHNU) with an economics major. In his junior year, he was selected as one of two students from SHNU to study overseas at Indiana University of Pennsylvania (IUP) as an exchange student with Full-Tuition Scholarship. During his studies at IUP, in addition to being on the Dean's List for the academic year, he published an article entitled "An Analysis of Trade Openness and Economic Growth: The Case of Malaysia" in *The Inkwell* (Annual Scholar Journal of IUP), 2012, Vol. 9, 1 – 14, and he gave a presentation of this paper at the 2012 IUP Undergraduate Scholars Forum. Jin Qin earned his bachelor's degree of economics in July 2013, and he started his doctoral studies of economics in the following fall semester at North Carolina State University (NCSU). Additionally, since August 2015, Jin Qin had taught at NC State University for seven semesters, teaching undergraduate courses including EC 205 (Fundamentals of Economics), ARE 201 (Introduction to Agricultural & Resource Economics), and ARE 301 (Intermediate Microeconomics). In March 2017, Jin Qin won the Excellence in Teaching Award at NC State University. Meanwhile, in July 2016, Jin Qin was selected as the President of the Graduate Student Association for the Department of Economics, as well as, the Economics Department representative at the University Graduate Student Association. He served in this position until December 2018. Furthermore, Jin Qin's doctoral dissertation research at NC State University has been focused on international trade and environmental economics under the guidance of Dr. Ivan Kandilov and Dr. Roger von Haefen. He had done several presentations of his dissertation research at conferences including the American Economic Association Annual Meeting in January 2018 in Philadelphia, PA, and the 87th Southern Economic Association Annual Meeting in November 2017 in Tampa, FL.

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CHAPTER 1

Introduction

Over the past few decades, the world has witnessed the "Chinese miracle" – the tremendous speed of economic growth in China. Since the start of economic reforms in December 1978, China has experienced an average annual GDP growth rate of 8.6 percent per capita from 1979 to 2015, compared to a 3.2 percent rate from 1961 to 1978. Following the accession to the World Trade Organization in December 2001, China has reached an even higher average annual GDP growth rate of 9.2 percent per capita from 2002 to 2015, while the average annual GDP growth rate for the world was only 1.6 percent per capita in this period.[1] During this incredible economic expansion, exports have played a significant role (Qiao, 1998; Chen and Feng, 2000; Heshmati and Sun, 2012). Between 2003 and 2015, about 18.4 percent of China's GDP growth is due to expansion in exports.[2] Many countries around the globe now import goods that are "Made in China." However, the incredibly rapid economic growth has been accompanied by notorious pollution problems. More recently, as people in China have grown wealthier and public awareness of the importance of health has increased, environmental pollution issues have come into focus.

Research on questions related to the Chinese economy has always been important. In my dissertation research, I address three main issues: 1) the effects of exports on the air pollution in China; 2) the effects of exports on wages in China; and 3) the link between air pollution and income in China. For the first question, I use an instrumental variable strategy to avoid endogeneity problems, which relies on the exogenous shock to exports brought about by the Great Recession and the fact that most exports from China are produced in coastal provinces. For the second

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[1] Data source: World Development Indicators, February 1, 2017 version.
[2] Data source: *China Statistical Yearbook*, 2017.
Calculated using arithmetic mean of $\frac{\text{Real Exports}_{\text{Year i}} - \text{Real Exports}_{\text{Year i}-1}}{\text{Real GDP}_{\text{Year i}} - \text{Real GDP}_{\text{Year i}-1}} * 100\%$.

question, I employ a difference-in-difference-in-differences econometric model to estimate the differences in the college wage premium between manufacturing and service sectors, before and after the Great Recession, between coastal and inland locations in China. For the third question, I employ a two-way, fixed effects panel data model with two specifications, one is a pooled model where the relationship between income and pollution is assumed stable across provinces, and the other one is a disaggregated specification where the income-pollution relationship is allowed to vary across three geographic regions.

CHAPTER 2

A Test of the Relationship between Air Pollution and Exports: The Case of China

2.1. Introduction

Over the past few decades, the world has witnessed the "Chinese miracle" – the tremendous speed of economic growth in China. Since the start of economic reforms in December 1978, China has experienced an average annual GDP growth rate of 8.6 percent per capita from 1979 to 2015, compared to a 3.2 percent rate from 1961 to 1978. Following the accession to the World Trade Organization in December 2001, China has reached an even higher average annual GDP growth rate of 9.2 percent per capita from 2002 to 2015, while the average annual GDP growth rate for the world was only 1.6 percent per capita in this period.[3] During this incredible economic expansion, exports have played a significant role (Qiao, 1998; Chen and Feng, 2000; Heshmati and Sun, 2012). Between 2003 and 2015, about 18.4 percent of China's GDP growth is due to expansion in exports.[4] Many countries around the globe now import goods that are "Made in China." However, the incredibly rapid economic growth has been accompanied by notorious pollution problems. More recently, as people in China have grown wealthier and public awareness of the importance of health has increased, environmental pollution issues have come into focus. For example, due to increasingly severe air pollution in China since 2013, people and the news media have been paying particular attention to air quality.

There has been a heated debate whether exports have improved or worsened the air quality in China. On one hand, a significant percentage of the products exported from China are produced in heavily polluting industries. For instance, from 2003 to 2015, an average of 94.4 percent of total

[3] Data source: World Development Indicators, February 1, 2017 version.
[4] Data source: *China Statistical Yearbook*, 2017.
Calculated using arithmetic mean of $\frac{\text{Real Exports}_{\text{Year i}} - \text{Real Exports}_{\text{Year i}-1}}{\text{Real GDP}_{\text{Year i}} - \text{Real GDP}_{\text{Year i}-1}} * 100\%$.

exports from China are associated with industrial products[5]. In addition, chemical products, rubber products, mineral products, metal and machinery products, which are industries that generate severe air pollution, account for 72.9 percent on average of industrial products exported from China between 2003 and 2015[6]. As the pollution haven hypothesis states, polluting activities for tradable products will move to poorer countries with lower environmental regulations (Christmann and Taylor, 2001; Eskeland and Harrison, 2003), and these types of industries in China have grown exceedingly in a short period of time. On the other hand, foreign plants are known to be significantly more energy efficient and users of cleaner types of energy than their peers (Eskeland and Harrison, 2003), which may lead to an improvement in local environmental conditions. Meanwhile, Christmann and Taylor (2001) suggest that exports to developed countries would increase self-regulation of environmental performance in China. Besides, according to the environmental Kuznets curve hypothesis, a nation's environmental quality will first decrease and then improve with the level of economic development, as people value environmental protection more in the later stages of economic growth (Dinda, 2004). Taking both views into account, this study aims at finding out what are the real effects of exports on the air pollution in China.

The two main challenges in this line of research are: 1) the availability of reliable air pollution data for China; and 2) finding plausibly exogenous variation in trade (exports or imports) to credibly identify its effects on the air pollution. To solve the first problem, my study uses a reliable data source on the pollution statistics in China from the *China Statistical Yearbook*. In the data set, the annual quantity of sulfur dioxide, nitrogen oxides, and smoke & dust of each province in China are reported. I use all three air pollutants that are available in the data set. In existing

[5] Data source: *China Statistical Yearbook*, 2016.
[6] Data source: *China Statistical Yearbook*, 2016.

studies, carbon dioxide (Cole et al., 1997; Bruyn et al., 1998; Jalil and Mahmud, 2009; etc.) and sulfur dioxide (Selden and Song, 1994; Cole et al., 1997; Panayotou, 1997; etc.) are commonly used measures of air pollution. However, carbon dioxide is not reported as an air pollutant in the data set I use. Besides, as pointed out by Gill et al. (2018), carbon dioxide is a global pollutant, and is therefore not necessarily detrimental to the country where it is generated. Thus, I did not exploit carbon dioxide in this study. Nitrogen oxides (Selden and Song, 1994; Cole et al., 1997; Bruyn et al., 1998; etc.) and suspended particulate matter (Selden and Song, 1994; Cole et al., 1997; Harbaugh et al., 2002; etc.) are also widely used measures of air pollution. As reported by the Pan American Health Organization and the World Health Organization (2018), particulate matter, or PM, represents particles found in the air, including dust, dirt, soot, smoke, and liquid droplets. Thus, the smoke & dust data could serve as a good proxy of suspended particulate matter. To sum up, in this study, the air pollution is measured by sulfur dioxide, nitrogen oxides, and smoke & dust for each province in China. Meanwhile, the levels of GDP and exports of each province in China over the same time period in the data set are used to construct a measure of export intensity, which is exports as a fraction of GDP. For the second issue, I use a quasi-experiment, the Great Recession of 2007-2008, to identify the impact of exports on the air pollution in China. In my study, I interact the plausibly exogenous decline in demand for Chinese exports after the Great Recession with the geographic location (coastal vs. inland) of the province to show that after the Great Recession, coastal provinces, where export production is concentrated because of proximity to navigable water, experienced a larger decline in exports and the air pollution.

There have been many studies in the literature that particularly look into the relationship between trade and pollution (e.g. Frankel and Rose, 2005; Managi et al., 2009), but a key difference of this study from existing work is the careful focus on the estimation strategy. I do not simply correlate export intensity (exports as a share of provincial GDP) and the air pollution across Chinese provinces over time, but estimate the difference in export intensity brought about by the Great Recession before and after 2008 between coastal and inland provinces. In my empirical analysis, the first stage regression shows that the Great Recession brought about a decline in export intensity, especially for coastal provinces. In the second stage, I estimate the reduced-form regression, using the Great Recession and coastal location to infer that provinces along the coast, where disproportionately higher production of exports occurs, experienced a greater decline in the air pollution following the Great Recession. The regression results reveal this same relationship for all three pollutants.

The chapter proceeds as follows: the second section reviews the literature, the third section describes the data and the econometric model, including descriptive statistics, the fourth section presents the empirical results, and conclusions are presented in the last section.

2.2. Literature Review

Frankel and Rose (2005) estimate the effects of trade on the environment by sorting out causality. They specifically consider the endogeneity of trade, and they use exogenous geographic determinants of trade as instrumental variables, while also control for income and other relevant factors. They employ the three air pollutants I have discussed, i.e., sulfur dioxide, nitrogen dioxide, and total suspended particulate matter, all measured as concentrations in micrograms per cubic meter, and they find that trade tends to reduce air pollution: statistical significance is high for concentrations of sulfur dioxide, moderate for nitrogen dioxide, and lacking for particulate matter. They conclude that there is little evidence supporting the detrimental effects of trade on the environment, and trade appears to have a beneficial effect on some measures of environmental quality. Their work focuses on the same issue as my study, but they perform a cross country analysis, whereas my study particularly looks at China alone and my instrumental variable strategy, unlike theirs, is time-variant. Additionally, their conclusions contradict the regression results from my analysis. This may be because I focus on one country or because my instrumental variable strategy is time-variant. Also, I focus on exports, while they assess the impact of trade, which combines exports and imports.

Managi et al. (2009) also ask if trade openness (the ratio of aggregate exports and imports to GDP) improves environmental quality. They treat trade and income as endogenous and estimate the overall impact of trade openness on the environmental quality. They employ data of 80 countries from 1970 to 2000, and conclude that whether trade openness has a beneficial effect on the environment depends on the pollutant and the country: trade openness would benefit the environment in OECD countries, but has detrimental effects on sulfur dioxide and carbon dioxide emissions in non-OECD countries, which is consistent with the results from my study.

Another related paper is Dean et al. (2009). Their analysis tests if foreign investors are attracted to weak environmental regulations in China under the assumption of the pollution haven hypothesis. They derive a model using foreign direct investment location choice in the presence of inter-provincial differences in environmental stringency, and find that equity joint ventures in highly-polluting industries funded through Hong Kong, Macao, and Taiwan were related to weak environmental standards, whereas equity joint ventures funded from non-ethnically Chinese sources were not significantly related to weak standards, regardless of the pollution intensity associated with the industry. Their findings are consistent with the pollution haven behavior, but not by investors from high income countries, and only in industries that were highly polluting.

2.3. Data and Econometric Model

2.3.1. Data

For this study, the data are collected from the *China Statistical Yearbook*, published by the National Bureau of Statistics of the People's Republic of China. My data set is a panel across the 31 provinces of mainland China from 2003 to 2015 (13 years in all). This research is testing the effects of international trade on the air pollution in China, while China gets involved significantly more with global trade after its accession to the World Trade Organization (WTO) in December 2001, when 2002 served more as a transition period. Thus, to control for the influence of the shocks in international trade brought about by China's accession to WTO, this study exploits data starting from 2003. Meanwhile, the Global Financial Crisis in 2008 is used as a natural experiment in this study. Therefore, in the data set, years from both before 2008 and afterward are needed. For other variables, trade openness is represented by the ratio of exports over GDP, as well as, imports over GDP. The real value of GDP[7], exports and imports[8] are obtained in constant 2000 trillion Yuan (also from the *China Statistical Yearbook*). In addition, one variable is included to measure location, i.e., whether the province is coastal. If a province is coastal, the variable *Coast* would be equal to 1, otherwise, it equals 0. Furthermore, the variable *GreRec* is equal to 1 after the Great

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[7] In the recent publications of the *China Statistical Yearbook*, some corrections are made with GDP reported from the publications in earlier years. Thus, GDP in this research is obtained from the newest publication of the *China Statistical Yearbook*. For instance, GDP for 2003 and 2004 is obtained from the 2008 publication, while GDP for 2005 to 2009 is obtained from the 2010 publication.

[8] According to the data documentation in the *China Statistical Yearbook*, the data for international trade are collected by the General Administration of Customs of the People's Republic of China based on the rules from the United Nations. In the *China Statistical Yearbook*, there are two measures of trade: by the location of trade agency, and by the initial position (for exports) or the final destination (for imports) of the traded goods in China. However, there is no clear definition or instruction of each measure in the data documentation, and the two measures are highly correlated ($\rho = 0.997$). Both measures of trade are attempted in the model, and there is no significant difference in the results. Thus, the measure by the location of trade agency is used in this study, while the other measure is used in a robustness check.

Recession (2009 and later) and 0 otherwise.[9] I also construct a measure of total consumption in China by adding up GDP and imports net of exports, also measured in constant 2000 trillion Yuan. Moreover, industries in China produce outputs for domestic consumption and outputs for exports, while the air pollution intensity could be different between the two production. Therefore, one extra variable is employed trying to reveal this difference, which is *DomesConsum*, and it equals GDP minus exports, measured in constant 2000 trillion Yuan as well.

To measure the air pollution in China[10], I use concentrations of sulfur dioxide, nitrogen oxides, and smoke & dust. In the regression, I adopt both the quantity of air pollution emissions, as well as a measure of intensity, which is the ratio of air pollution emissions over GDP. Total emissions of sulfur dioxide and nitrogen oxides are obtained by adding up respective industry emissions and household consumption emissions in the data set. Total emissions of smoke & dust[11] are obtained by adding up industrial soot, consumption soot and industrial dust. More detailed information is provided in the appendix. Additionally, for sulfur dioxide, according to a report from the U.S. Environmental Protection Agency (2018), the largest source in the atmosphere is the burning of fossil fuels by power plants and other industrial facilities, while other sources include industrial processes such as extracting metal from ore, natural sources such as volcanoes, and locomotives, ships, as well as other vehicles and heavy equipment that burn fuel with a high

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[9] As for 2008, it does not matter whether this year is included as a pre- or post- recession period. Both approaches are attempted, and there is no significant difference in the regression results.

[10] Since this study is investigating the effects of exports on the air pollution in China, and a high percentage of the air pollution comes from industrial production, so a best measure of the air pollution would be given by the industry emissions. However, the availability of data from the industry emissions is much less than the total emissions. Meanwhile, as reported in Table 2.3, the industry emissions and the total emissions are highly correlated, and thus the total emissions are used in the regression.

[11] In the *China Statistical Yearbook*, the item name *smoke & dust* is used since 2011. Before 2011, the same item is reported separately by industrial soot, consumption soot and industrial dust. I continue to use the item name *smoke & dust*, and the data of total smoke & dust before 2011 are obtained by adding up industrial soot, consumption soot and industrial dust.

sulfur content. Meanwhile, for nitrogen oxides, as reported by the U.S. Environmental Protection Agency (2018), it primarily enters the air from the burning of fuel, including emissions from cars, trucks and buses, power plants, and off-road equipment. Furthermore, according to the Pan American Health Organization and the World Health Organization (2018), large concentrations of particulate matter are typically emitted by sources such as diesel vehicles, waste and crop burning, and coal-fired power plants.

2.3.2. Descriptive Statistics

As shown in Table 2.2, for sulfur dioxide and smoke & dust, the mean is higher before the Great Recession than afterward for each category. By contrast, for nitrogen oxides, the mean is higher after the Great Recession than before for both the total emissions and the industry emissions. Meanwhile, for air pollution intensity, the mean is higher before the Great Recession for all three pollutants. On the other hand, for trade openness and growth, the mean for exports, imports, GDP, as well as domestic consumption, is higher after the Great Recession. For the ratio of exports over GDP, the mean is higher before the Great Recession.

In addition, as reflected in Figure 2.1, Chinese GDP was growing steadily over the sample period except that the growth rate was lower from 2008 to 2009. Also, exports and imports were growing steadily except from 2008 to 2009, during which time both decreased. Meanwhile, domestic consumption was growing steadily over the sample period as well, and the growth rate was increased from 2008 to 2009. The trends for the ratios of exports over GDP, exports over total consumption and imports over total consumption are presented in Figure 2.2. The three ratios were all increasing before 2007 and started to drop in 2008, then reached their respective minimum in 2009. After 2009, they were increasing slowly again but started to decrease slightly after 2012.

Next, statistics for the three air pollution emissions are displayed in Figure 2.3. From 2003 to 2015, Chinese air pollution emissions of sulfur dioxide, nitrogen oxides and smoke & dust increased initially and then decreased later in general, with some fluctuations in sulfur dioxide emissions between 2010 and 2011 and in smoke & dust emissions after 2012. On the other hand, as shown in Figure 2.4, air pollution intensity was decreasing steadily over the sample period in general, except some fluctuations of nitrogen oxides from 2010 to 2011 and smoke & dust from 2013 to 2014.

2.3.3. Econometric Model

How is air pollution influenced by exports from China? To answer this question, one can use the panel data described in the previous section and the following econometric equation:

$$\text{Air Pollution}_{it} = \alpha_0 + \alpha_1 * \text{Exports/GDP}_{it} + \text{Year}_t + \text{Province}_i + \varepsilon_{it}. \quad (1)$$

The dependent variable, $Air\ Pollution_{it}$, denotes the air pollution in province *i* in year *t*, and it is measured either by one of the emissions from sulfur dioxide, nitrogen oxides, and smoke & dust, or by one of the emission intensity from sulfur dioxide, nitrogen oxides, and smoke & dust, which is the ratio of emissions over GDP for a given province and year. Meanwhile, export intensity is measured by the ratio of exports over GDP in a given province and year. It is important to normalize exports by GDP because the air pollution is expected to rise with GDP even when the ratio does not change. If China has a comparative advantage in heavily polluting industries, i.e., the industrial composition of exports is skewed towards sectors that are heavy polluters, then an increase in provincial exports as a share of GDP will bring about greater amount of pollution.

Additionally, to control for time-invariant province-specific characteristics, I include province fixed effects, and I employ year dummies to control for aggregate economy-side shocks that affect all industries.

The main coefficient of interest is α_1, which estimates the effects of increased export intensity on the provincial-level air pollution. One potential problem with regression equation (1) above is endogeneity in the form of omitted variable, hidden in the error term, that may affect both export intensity and the air pollution simultaneously. To alleviate endogeneity concerns, I implement an instrumental variable strategy, which relies on the interplay between the temporal export demand shock brought about by the Great Recession of 2007-2008 that sharply reduced global demand for Chinese exports, and the geographic variation of provincial location that afford provinces along the Chinese coastline an exporter advantage. To this end, I estimate the following reduced-form econometric model:

$$\text{Air Pollution}_{it} = \alpha_0 + \alpha_1 * \text{Great Recession}_t * \text{Coastal\_Province}_i + \text{Year}_t + \text{Province}_i + \varepsilon_{it}. \quad (2)$$

The Great Recession of 2007-2008 started in the United States and Europe, and it led to a severe job loss and thus a drop in consumption there. Meanwhile, exports from China are mainly targeting these western countries. Therefore, exports from China declined following the Recession. Furthermore, a considerable percentage of exporting oriented business in China are clustered in coastal provinces because of easy access to ports on navigable water, and hence, the greatest negative impact of the decline in exports was experienced in coastal provinces.

The first-stage regression that corresponds to my IV strategy is given by the following econometric equation:

$$\text{Exports/GDP}_{it} = \alpha_0 + \alpha_1\text{*Great Recession}_t\text{*Coastal\_Province}_i + \text{Year}_t + \text{Province}_i + \varepsilon_{it}. \quad (3)$$

This model provides evidence for the impact of the Great Recession on export intensity in coastal provinces (compared to inland ones).

In addition, the model is estimated using the log-level form, as well as, the level-level form, which is given by equations (1), (2) and (3). In the log-level form of the model, the dependent variables in equations (1) and (2) are given in a (natural) log form. Also, several robustness checks are performed. First, as described in the data section, in the *China Statistical Yearbook*, there are two measures of trade: by the location of trade agency, and by the initial position (for exports) or the final destination (for imports) of the traded goods in China. The measure by the location of trade agency is used in this study, while the other measure is used in a robustness check. Second, the 31 provinces in China are differing in size and population, which might lead to heterogeneity in the effects of exports on the air pollution across different provinces. Thus, the regression is also estimated using province population weights as a robustness check. Meanwhile, two measures of population weights are attempted: by the population in each year, and by the average population over the 13 years in the sample. The two forms of weighting yield almost identical results, so the weighting by average population is reported in the results section. Furthermore, to get the most flexible specification, real GDP is added into the main model as an additional regressor for a robustness check. The log form of real GDP for every province in each year is added to the log-level model, while the level form of real GDP for every province in each year is added to the level-level model.

2.4. Results

Provinces with different trade linkages are affected differently by the Great Recession. First, Table 2.4 provides the regression results of the first-stage process by showing the impact of the instrumental variable on different outcome variables I have tried. As shown in this table, after the Great Recession, exports decreased by 22.3 percent[12] more for coastal provinces than inland, imports decreased by 11.7 percent more for coastal provinces than inland, and GDP decreased by 7.9 percent more in coastal provinces than inland. Also, after the Great Recession, the ratio of exports over GDP, i.e., the export intensity, decreased by about 9.5 percent more for coastal provinces than inland, the ratio of exports over total consumption decreased by 11.7 percent more for coastal provinces than inland, and the ratio of imports over total consumption decreased by 8.1 percent more for coastal provinces than inland. As for statistical significance, generally speaking, the significance level is higher when the dependent variable is a ratio. When regressed on the instrumental variable, the ratios of exports over GDP and exports over total consumption are statistically significant at the 1 percent level; the ratio of imports over total consumption and the log of GDP are statistically significant at the 5 percent level; the log of exports is statistically significant at the 10 percent level and the log of imports is not statistically significant.

Second, the regression results of two robustness checks for the first-stage process are given in Table 2.4 as well. Robustness check using trade measured by the initial position or the final destination of the traded goods yields a consistent result with the main model in general, except for imports that generate an opposite sign for the coefficient, but it demonstrates no statistical significance. Also, the magnitudes of the coefficients for this robustness check are lower than the

[12] In the regression, as hereinafter defined, a continuous variable is on the left-hand side, while a dummy variable is on the right-hand side, so the coefficient needs to be interpreted as exp(x)-1.

main model in general. On the other hand, robustness test with weights by the province average population over the entire sample also yields a consistent result with the main model. This robustness check demonstrates a higher level of statistical significance than the main model for the most part, and the magnitudes of the coefficients are greater than the main model as well.

Next, I present the results from the reduced-form model (2) and the two-stage model, where I first predict exports using equation (3) and then use the predicted values for export intensity in place of the actual export intensity in equation (1). Detailed results of the log-level model are shown in Tables 2.5, 2.7 and 2.9, while results of the level-level model are given in Tables 2.6, 2.8 and 2.10. The log-level model and level-level model develop almost identical level of statistical significance for sulfur dioxide and smoke & dust, but for nitrogen oxides, the level of statistical significance for the log-level model strongly dominates. Thus, the log-level model demonstrates a more precise estimation in general, so the regression results for the log-level model will be explained in detail here.

First, the regression results for sulfur dioxide are presented in Table 2.5. The estimates indicate that increased export intensity brought about greater sulfur dioxide emissions. In particular, the results suggest that when export intensity grows by 10 percent, the emissions of sulfur dioxide increase by about 20 percent. The endogenous regression in column (1), on the other hand, suggests that the impact is about half as small, which indicates an increase in the emissions of sulfur dioxide around 9 percent thanks to 10 percent higher expert intensity, and this regression is not statistically significant. Second, the regression results for nitrogen oxides are very similar. According to Table 2.7, when export intensity grows by 10 percent, provincial emissions of nitrogen oxides increase by about 24.4 percent. The coefficients from the IV results here are also larger in magnitude than the OLS estimate (impact of about 14.6 percent) in column (1), but both are statistically significant. Finally, the regression results for smoke & dust, reported in Table 2.9, are smaller in magnitude for the coefficients and statistically insignificant. In particular, a 10 percent increase in export intensity leads to only about a 5.3 percent increase in the emissions of smoke & dust. Note that in this case, the OLS estimate is actually negative, but also imprecisely estimated.

Furthermore, the regression results for robustness checks are given in the tables as well. First, for the robustness check using trade measured by the initial position or the final destination of the traded goods, the results show that there is no significant difference between the robustness check and the main model, except for the level-level model of sulfur dioxide that yields an opposite sign in the coefficient of the OLS estimate, but this estimation demonstrates no statistical significance. Second, the regression results from the robustness check with province weights using average population are consistent with the main model in general, except that the log-level model of smoke & dust yields opposite signs for the coefficients of the IV regression. The level of statistical significance here is consistent with the main model in general as well. Third, the regression results for the robustness check with GDP added as an additional regressor are overall consistent with the main model, except for the level-level model of sulfur dioxide which has an opposite sign in the coefficient of the OLS estimate, but this estimation demonstrates no statistical significance, either. For the robustness check with GDP included as an additional regressor and weighted by average population of each province, the regression results are consistent with the main model, except the level-level model of sulfur dioxide that yields an opposite sign in the coefficient of the OLS estimate and log-level model of smoke & dust which have opposite signs for the coefficients of the IV regression. The outcome variables with opposite signs in the coefficients, just like the main model with the same outcome variables, are not statistically significant. In addition, the level-level model of sulfur dioxide develops a lower level of statistical significance, while the level-level model of smoke & dust demonstrates a higher level of statistical significance. However, there is one issue with this specification that GDP itself is highly likely to be affected by the Great Recession. As shown in Table 2.4, after the Great Recession, the coastal provinces had a greater reduction in GDP by about 7.9 percent. Thus, this specification has an endogenous problem since GDP as a regressor is correlated with the instrumental variable on the right-hand side. Overall, adding GDP as a control variable leads to broadly similar conclusions for the effects of the Great Recession on the air pollution in China.

Before I conclude, I re-estimate equation (1) using air pollution intensity (the province-level air pollution as a share of GDP) as the dependent variable. One can think of this specification as an alternative to controlling for GDP on the right-hand side. The results, which are presented in Tables 2.11, 2.12, and 2.13, suggest that following the Great Recession, sulfur dioxide intensity rises by 91.0 percent more in coastal provinces compared to inland provinces, and smoke & dust intensity grows by 86.8 percent more in coastal provinces compared to inland provinces. Both of the estimates are statistically significant at the 5 percent level. On the other hand, the estimate for nitrogen oxides is close to zero, and it is not statistically significant. As I showed in Table 2.4, following the Great Recession, domestic consumption grows by 17.9 percent more in coastal provinces vis-a-vis inland provinces, and the result is statistically significant at the 10 percent level. In fact, industries in China produce output for both domestic consumption and for exports, and the air pollution intensity associated with the production for the two markets could be different. My results indicate that following the Great Recession, exports as a share of GDP decline, domestic consumption grows, and so does the air pollution intensity. Taken together, these estimates imply that the air pollution intensity associated with the production for domestic market is greater than the pollution intensity associated with the production for exports in China.

2.5. Conclusion

This study estimates the effects of exports on the air pollution in China. Since exports have been playing an essential role for the incredible economic growth in China, it is natural to ask if the air pollution in China is affected by exports. To answer this question, I use provincial-level panel data on the emissions of sulfur dioxide, nitrogen oxides, and smoke & dust to empirically assess if they increase with export intensity. The instrumental variable strategy I employ uses the temporal variation in export demand for Chinese manufacturing goods brought about by the Great Recession and geographic variation in provincial location (on the coast vs. inland) that affords coastal areas an exporter advantage to provide an estimate for the effects of exports on the air pollution. I find that a decrease in export intensity decreases the emissions of sulfur dioxide and nitrogen oxides, implying that greater export intensity leads to higher levels of air pollution in China.

As previously mentioned, the pollution haven hypothesis states that polluting activities for tradable products will move to poorer countries with lower environmental regulations (Christmann and Taylor, 2001; Eskeland and Harrison, 2003). The conclusion from this study is consistent with the pollution haven hypothesis, which indicates that western countries are exporting pollutions and importing personal goods, while China is becoming a "pollution haven." By exporting a large scale of personal goods, China generates considerable income and creates abundant jobs for its citizens, but it also results in severe pollutions. At this point, it is hard to determine whether the benefits exceed the costs of export driven growth. The welfare gains from trade, as well as, the social costs from pollution need to be quantified to resolve the real effects of trade. Future research might collect data from Chinese citizens about their willingness to pay for cleaning up the air pollution in a reliable survey.

CHAPTER 3

The Impact of Exports on the Skill Premium: Evidence from China in the aftermath of the Global Recession

3.1. Introduction

Over the past few decades, the world has witnessed the "Chinese miracle" – the tremendous speed of economic growth in China. Since the start of economic reforms in December 1978, China has experienced an average annual GDP growth rate of 8.6 percent per capita from 1979 to 2015, compared to a 3.2 percent rate from 1961 to 1978. Following the accession to the World Trade Organization in December 2001, China has reached an even higher average annual GDP growth rate of 9.2 percent per capita from 2002 to 2015, while the average annual GDP growth rate for the world was only 1.6 percent per capita in this period.[13] During this incredible economic expansion, exports have played a significant role (Qiao, 1998; Chen and Feng, 2000; Heshmati and Sun, 2012). Between 2003 and 2015, about 18.4 percent of China's GDP growth is due to expansion in exports.[14] Many countries around the globe now import goods that are "Made in China," a majority of which are perceived to be mass-produced, labor-intensive techniques.

According to Heckscher-Ohlin (H-O) model of international trade, each country will export the good that uses its abundant factors intensely, which for China is low-skilled labor. In other words, China gains its comparative advantage from its abundant low-cost labor. Meanwhile, based on the Stolper-Samuelson Theorem, as well as, the Factor Price Equalization (FPE) Theorem, free and frictionless trade will equalize factor prices (Deardorff and Hakura, 1994). Hence, higher trade (exports of low-skilled intensive goods) will drive up the demand for low-skilled labor and

[13] Data source: World Development Indicators, February 1, 2017 version.
[14] Data source: *China Statistical Yearbook*, 2017.
Calculated using arithmetic mean of $\frac{\text{Real Exports}_{\text{Year i}} - \text{Real Exports}_{\text{Year i}-1}}{\text{Real GDP}_{\text{Year i}} - \text{Real GDP}_{\text{Year i}-1}} * 100\%$.

enhance its return. Some studies based on other countries have tested this relationship before, such as, Beyer et al. (1999) who look into labor markets in Chile, Robertson (2004) who analyzes Mexico, and Gonzaga et al. (2006) who consider Brazil. Beyer et al. (1999) implement an empirical test of the relation between trade liberalization and wage inequality in Chile, and conclude that openness widens the wage gap between skilled and unskilled labors, while Robertson (2004) examines the link between relative goods prices and relative wages during two periods of Mexico's trade liberalization, and discovers a positive long-run relationship between them. Gonzaga et al. (2006) investigate the role of trade liberalization in explaining the reduction of skilled labor earning differentials in Brazil, and find that trade liberalization can account for the changes of observed relative earnings. Taking these instances into consideration and referring to the standard H-O model, a question arises: Does an increase in trade (exports) decrease the skill premium in China? Using the Great Recession as a natural experiment, which brought about an exogenous, negative export shock for coastal locations in China, I investigate the impact of lower exports on the wage premium in China over the last 15 years.

The chapter proceeds as follows: the second section will review the literature, the third section describes the data and the econometric model, including descriptive statistics, the fourth section presents the results, and conclusions are in the last section.

3.2. Literature Review

There are a number of papers that have investigated the effects of international trade on the wage inequality in other countries using a natural experiment as their identification strategy. For instance, Verhoogen (2008) studies the case of the Mexican manufacturing sector using the Peso crisis period in the 1990s as a natural experiment, and finds that plants that were more productive in the beginning increased the export share of sales, white-collar wages, blue-collar wages, the relative wage of white-collar workers more than plants that were less productive initially during the peso crisis period. Verhoogen (2008) supports the hypothesis that quality upgrading induced by the exchange-rate shock increases within-industry wage inequality. Comparing to my paper, I also use a natural experiment and a similar econometric method to come to a similar conclusion, yet in an entirely different country, China, and for a different time period.

Further, there are additional papers that have studied the effects of international trade on the wage inequality in China but using different natural experiments. First, Han et al. (2012) examine the impact of globalization on the wage inequality in China using the Chinese Urban Household Survey data from 1988 to 2008 by exploring two trade liberalization shocks, which include Deng Xiaoping's Southern Tour in 1992, as well as, the accession of China to the World Trade Organization (WTO) in 2001. Han et al. (2012) analyze whether regions that are more exposed to globalization experienced larger changes in wage inequality than less-exposed regions, and conclude that the accession to the WTO was associated with rising wage inequality in China, which is contrary to the predictions of the H-O model. In addition, Han et al. (2012) further show that the two trade liberalization shocks had contributed to a higher within-region inequality by raising the returns to education. Comparing to my research, Han et al. (2012) uses a different data set, but a similar econometric technique. Yet, I use a different natural experiment that functions as a trade liberalization shock (the Great Recession in 2008), while Han et al. (2012) have chosen Deng Xiaoping's Southern Tour in 1992, as well as, China's accession to the WTO in 2001. Above all, the results of my research are consistent with Han et al. (2012).

Second, Wang (2015) also uses a difference-in-differences (DD) econometric method, to estimate the influence of China's accession to the WTO on the wage inequality, as well as, to compare the differing effects between urban and rural areas in China. In her empirical analysis, she uses the China Household Nutrition and Health Survey data from both urban and rural areas, which helps to control for the effects of firm ownership (state vs. private), as well as, the occupation of a worker. In her study, Wang (2015) finds that the ownership of a firm and the specific occupation of a worker have statistically and economically significant effects on the wage of workers, while the wage inequality declines in urban China following the accession to the WTO, which supports the H-O model of trade, as well as, the Stolper-Samuelson theory. While Wang (2015) has investigated a similar issue as the focus of my study, she takes a different perspective. Wang (2015) compares the differences in the changes of the wage inequality between urban and rural areas in China, while my study inspects the differential changes in the wage premium between manufacturing and service sectors before and after the Great Recession. The conclusions in Wang (2015) are somewhat opposite to my conclusions here.

3.3. Data and Econometric Model

3.3.1. Data

This study employs data from the China Health and Nutrition Survey (CHNS), which are collected by the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute for Nutrition and Health (NINH, former National Institute of Nutrition and Food Safety) at the Chinese Center for Disease Control and Prevention (CCDC). This is a widely used data set, especially popular with health economists. Some of the most recent studies involving these data include: 1) Peng and Conley (2016), who investigate the implication of health insurance for child development and maternal nutrition in China; 2) Qin and Pan (2016), who look into the medical costs attributable to obesity in China; and 3) Huang and Gan (2017), who study the impact of China’s urban employee basic medical insurance on healthcare expenditures and health outcomes.

According to the data documentation, these survey data are gathered by questionnaires of household individuals across 15 provinces in China for 9 years, including 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011 (up to February 2018). About 4,400 households participated in the overall survey, covering roughly 19,000 individuals. Information collected includes health status, education, employment, wages, etc. Since the same individuals were surveyed over years, whenever that was possible, during the sample period, the data set is in the form of an unbalanced panel. While my main specification does not include individual fixed effects, I do perform a number of robustness checks that include them. On the other hand, the primary sample is not all consistent over years. Some individuals were replaced because they were not participating in the survey any longer. Thus, to mitigate the effects of the sampling change, the econometric model is run with individuals who participated in all four years’ survey as a robustness check. To be more specific, overall, 43.8 percent of individuals participated in all four years’ survey, while for males, the proportion is 41.9 percent, and for females, it is 45.7 percent.

This study exploits part of the overall survey data. Spatially, due to some changes in the survey areas, 12 provinces are used in this research, including Beijing, Chongqing, Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, Shandong and Shanghai. As shown in Figure 3.3, among those 12 provinces, 5 provinces are coastal (i.e., Guangxi, Jiangsu, Liaoning, Shandong and Shanghai). This is important for my study as I seek to examine the difference in the effects of the Great Recession on the skill premium between coastal and inland provinces. Temporally, because this study investigates the effects of international trade on China, and the country is involved significantly more with global trade after its accession to the World

Trade Organization (WTO) in 2001, my sample period is years 2004, 2006, 2009 and 2011. In addition, the Global Financial Crisis in 2008 is used as a natural experiment in this study. Hence, the years 2004 and 2006 will serve as the pre-change period, while the years 2009 and 2011 are considered the post-change period.

In the econometric models, several variables are employed to control for distinctive features of individuals and provinces. To begin with, one of the most important characteristics that affects the individual's wage is the level of education. The data distinguish across many different levels of education including none, elementary, elementary not complete, junior high school, junior high school not complete, senior high school, senior high school not complete, technical school, technical school not complete, college, college not complete, master and above. Using the data, I create an indicator variable called *College and Above*, which equals 1 if an individual has earned a college degree or higher and equals 0 otherwise. In addition, an individual's employment can be classified either as a manufacturing sector job or a service sector job. Thus, a variable *Manufacture* is generated, and it is equal to 1 if an individual works in the manufacturing sector, while it equals 0 if this individual works in the service sector. As for the province features, one variable is included to measure its location, i.e., whether the province is on the coast. If a given province is on the coast, the variable *Coastal* is equal to 1, while it equals 0 if the province is inland. Furthermore, a dichotomous variable *Great Recession* is included to measure changes in trade. It is equal to 1 after the Great Recession started, i.e., 2009 and later, otherwise, it equals 0.

3.3.2. Descriptive Statistics

To begin with, not surprisingly, as exhibited in Table 3.2, the monthly real wage had grown from 2004 until 2011. Also, as indicated in Table 3.4, while the average wage in inland provinces was lower at the beginning of the sample, it grew faster and reached a higher level than the average wage in coastal provinces by the end of the sample in 2011. In addition, Table 3.5 shows that the college premium increased slightly from 60.4 percent before the Great Recession to 63.1 percent afterward. This comparison, of course, does not control for any individual-specific characteristics, whose distributions may have changed in the wake of the Recession.

Next, Tables 3.6, 3.7, 3.8 and 3.9 show some features of individuals participated in the survey. The total number of individuals participated in the survey as displayed in the four tables are consistent in general, but with some minor variation given some missing data. First, Table 3.6 shows the number of individuals surveyed in each year. Generally speaking, more individuals participated in later years as the survey continued. For the entire sample, there were a total of 12,683 individuals participated, when 2,590 individuals participated in 2004, 2,725 individuals participated in 2006, 2,899 individuals participated in 2009 and 4,469 individuals participated in 2011. Second, Table 3.7 displays the number of individuals by their location. In the entire sample, for the total 12,669 individuals participated in the survey, 6,554 (51.7 percent) of them are in the coastal provinces, while 6,115 (48.3 percent) are in the inland regions. Third, Table 3.8 exhibits the number of individuals by their working positions. In the entire sample, for the total 12,683 individuals participated in the survey, 6,188 (48.8 percent) of them work in the manufacturing sector, while 6,495 (51.2 percent) work in the service sector. Also, more males work in the manufacturing sector than service sector, and more females work in the service sector than manufacturing sector. Last but not least, Table 3.9 displays the number of individuals by their education. In the entire sample, for the 12,669 individuals participated in the survey, 2,110 (16.7 percent) of them have a college degree or above, while 10,559 (83.3 percent) do not have a college degree.

3.3.3. Econometric Model

To assess the effects of a decline in trade (exports) brought about by the Great Recession on the college (skill) premium, I estimate the following econometric equation:

$$
\begin{aligned}
\text{Log (Monthly Wage)}_{it} = {} & \alpha_0 + \alpha_1 * \text{Age}_{it} + \alpha_2 * \text{Age}_{it}^2 + \alpha_3 * \text{Education}_{it} \\
& + \alpha_4 * \text{Great Recession}_t * \text{Coastal\_Province}_j \\
& + \alpha_5 * \text{College and Above\_Education}_{it} * \text{Coastal\_Province}_j \\
& + \alpha_6 * \text{College and Above\_Education}_{it} * \text{Great Recession}_t \\
& + \alpha_7 * \text{Great Recession}_t * \text{Manufacture\_Job}_{it} \\
& + \alpha_8 * \text{Coastal\_Province}_j * \text{Manufacture\_Job}_{it} \\
& + \alpha_9 * \text{College and Above\_Education}_{it} * \text{Manufacture\_Job}_{it} \\
& + \alpha_{10} * \text{College and Above\_Education}_{it} * \text{Coastal\_Province}_j * \text{Great Recession}_t \\
& + \alpha_{11} * \text{Great Recession}_t * \text{Coastal\_Province}_j * \text{Manufacture\_Job}_{it} \\
& + \alpha_{12} * \text{Great Recession}_t * \text{College and Above\_Education}_{it} * \text{Manufacture\_Job}_{it} \\
& + \alpha_{13} * \text{College and Above\_Education}_{it} * \text{Coastal\_Province}_j * \text{Manufacture\_Job}_{it} \\
& + \alpha_{14} * \text{College and Above\_Education}_{it} * \text{Coastal\_Province}_j \\
& \quad * \text{Great Recession}_t * \text{Manufacture\_Job}_{it} \\
& + \text{Province}_j + \text{Year}_t + \varepsilon_{it}, \quad (1)
\end{aligned}
$$

where *i* is an individual indicator, *j* is a province indicator, and *t* indexes the year. Robust standard errors clustered by province are computed. In addition, the econometric model is estimated using data on all individuals first and then separately for male and female workers.

In the econometric model, the dependent variable, $Monthly\ Wage_{it}$, denotes the real monthly wage for person *i* in year *t*, and it is measured in constant (year 2000) Chinese Yuan. The independent variables include the interaction among *Great Recession*, *Coastal*, *College and Above*, as well as, *Manufacture*. Following the Mincer earnings function, a variable *Age* is employed to represent the skills an individual develops over years, as experience is potentially gained with extra time in working. To control for time-invariant province-specific characteristics, as well as, aggregate economy-wide shocks, province fixed effects and year dummies are included.

The main coefficient of interest is α_{14}, which estimates the (double) difference in the change of the college premium after the Great Recession between coastal and inland provinces in the manufacturing sector vs. the service sector in China. This unbalanced panel regression serves as the baseline specification. Furthermore, since repeated individual observations are involved over time, individual fixed effects are added to control for individual-specific features in the robustness checks.

The econometric strategy seeks to compare the wage premium between manufacturing and service sectors, before and after the Great Recession, across coastal and inland China. The variable of interest is the college (skill) wage premium, which is the monthly wage for individuals with a college degree or higher compared to those with lower education. Also, individuals are engaged with differing types of jobs including manufacturing sectors, which should be affected more by international trade, as well as, service sectors, which is less affected by trade. Therefore, when a change in trade arises, individuals in varying sectors should be influenced differently. The Great Recession of 2007-2008 started in the United States and Europe, and it led to a severe job loss and thus a drop in consumption there. Meanwhile, exports from China are mainly targeting these western countries. Thus, exports from China declined following the Recession. Additionally, a considerable percentage of exporting oriented business in China are clustered in coastal provinces because of easy access to ports on navigable water, and hence, the greatest negative impact of the decline in exports was experienced in coastal provinces.

3.4. Results

Provinces with different trade linkages, as well as individuals who work for different sectors, are affected differently by the Great Recession. The term of primary interest in the regression is the interaction between *College and Above*, *Coastal*, *Great Recession*, and *Manufacture*. According to the main model, as shown in Table 3.10, after the Great Recession, individuals with a college degree or higher who work for the manufacturing sector in coastal China saw their average monthly wage decrease by 27.8 percent[15] more, and it demonstrates statistical significance at the 5 percent level. Table 3.10 also exhibits the results for the specification with individuals separated by gender. As displayed, after the Great Recession, the monthly wage was reduced by 32.7 percent more for male individuals with a college degree or above who work for the manufacturing sector in coastal areas of China, while the monthly wage shrank by 25.2 percent more for female individuals with a college degree or above who work for the manufacturing sector in coastal areas of China, which indicates that the decline in average monthly wage was lower in magnitude for females than males. In addition, this interaction term for the male group is statistically significant at the 1 percent level, which exhibits higher level of statistical significance than the pooled model, while the female group is not statistically significant. For other specifications, this interaction term fails to demonstrate enough statistical significance.

Table 3.10 also displays the results for other terms of interests in the pooled model. First, as expected, based on previous work using Mincerian regressions, age has a positive coefficient and age square a negative one (close to 0), implying that age (i.e. experience) has a positive impact on wages that is increasing at a decreasing rate. Second, interactions of variables provide some interesting implications. For instance, after the Great Recession, the average monthly wage for individuals in coastal areas decreased by 13.7 percent more than wages for individuals in inland areas. Meanwhile, individuals with a college degree and above who work for the manufacturing

[15] In the regression, as hereinafter defined, a continuous variable is on the left-hand side, while a dummy variable is on the right-hand side, so the coefficient needs to be interpreted as exp(x)-1.

sector in coastal China earn 41.8 percent higher wages. Yet, after the Great Recession, individuals with a college degree or higher who work in the manufacturing sector saw their average monthly wage decline by 10.5 percent more. Additionally, the level of statistical significance for the pooled model is high in general. Referring to Table 3.10, variables of interest, such as *Age*, *Age Squared*, the interaction of *Great Recession* and *Coastal*, as well as, the interaction of *College and Above*, *Coastal*, and *Manufacture*, exhibit statistical significance at the 1 percent level.

In addition, the results from the models with male and female being separated are consistent with the pooled model for the most part. Males and females are presumably functioning in different jobs or occupations in the manufacturing sector, and thus some variation is expected from the regression results. As reflected in Table 3.10, for the term *Age*, both males and females have a positive coefficient, which implies that both males and females will have their wage grown with additional experience. However, the magnitude of increase in payment is much larger for males than for females. Additionally, after the Great Recession, the reduction in average monthly wage rate was different between males and females. To be more specific, after the Great Recession, the average monthly wage decreased by 19.7 percent more in coastal areas of China compared to inland parts for males, while the average monthly wage declined by 8.2 percent more in coastal areas than inland areas for females. Also, as previously mentioned, after the Great Recession, the monthly wage was reduced by 32.7 percent more for male individuals with a college degree or above who work for the manufacturing sector in coastal areas of China, while the monthly wage shrank by 25.2 percent more for female individuals with a college degree or above who work for the manufacturing sector in coastal areas of China. In sum, the decline in average monthly wage was lower in magnitude for females than males. The difference in the roles/occupations between males and females hold may account for the difference in magnitude.

Also, the statistical significance of the grouped model is consistent with the pooled model. Based on Table 3.10, for the linear and quadratic terms of *Age*, both the male and female group demonstrate a 1 percent level statistically significant result. Meanwhile, for several terms of interest, such as the interaction of *Great Recession* and *Coastal*, as well as, the interaction of *College and Above*, *Coastal*, and *Manufacture*, the statistically significant level for the female group is lower than the pooled model and the male group. As pointed out previously, the difference in the occupations between males and females may account for the difference in the statistical significance, or the fact that the number of females in the regression is smaller than the number of males. However, a formal t-test reveals that the regression results for males and females are not significantly different from one another[16].

Finally, in a robustness check, individual fixed effects are added to control for individual-specific, time-invariant features. As shown in Table 3.11, for this model, the signs of the coefficients are consistent with the main model in general, but they are smaller in magnitude and lower in statistical significance. Meanwhile, regression results for the other robustness check with identical sampling over years are given in Tables 3.12 and 3.13. For this regression, the statistically significant levels are lower than the main model in general, while the signs and magnitudes of the coefficients are not all consistent with the main model either. This might be attributed by the fact that the percentage of individuals who participated in all four years' survey is not significantly high (43.8 percent overall, 41.9 percent for males, 45.7 percent for females).

[16] H_0: $\widehat{\beta^F} - \widehat{\beta^M} = 0$. H_1: $\widehat{\beta^F} - \widehat{\beta^M} \neq 0$. t-statistic = $\frac{-0.291-(-0.396)}{\sqrt{0.214^2+0.109^2}}$ = 0.437

3.5. Conclusion

This study estimates the effects of exports on the wage premium of high-skilled workers with a college degree in China. To avoid endogeneity, an instrumental variable strategy is employed, which uses the temporal variation in export demand for Chinese manufacturing goods brought about by the Great Recession and geographic variation in provincial location, i.e., on the coast vs. inland. Since the export-oriented industries are clustered in coastal provinces in China, and those industries are highly condensed into the labor-intensive manufacturing sector, when the demand for exported products from China declines due to the Great Recession, coastal areas in China are expected to be affected more than inland regions, and the manufacturing sector is also expected to be affected more than the service sector.

The results show that a reduction in trade (exports) lowers the average monthly wage of individuals with a college degree, which is the opposite of what Heckscher-Ohlin model predicts if China is a low-skill labor abundant country. However, this result is consistent with the recent evidence in the literature (e.g. Verhoogen, 2008) showing that exports are complementary with high-skill (or college education). In China, there has been an intense debate whether people should invest in education. The results from this study indicate that exports in China increase the returns to higher education, even if China is exporting mass-produced, labor-intensive goods. Thus, the results from this study could inform this long standing and intense debate.

CHAPTER 4

The Relationship between Air Pollution and Income in a Rapidly Developing Country: The Case of China

4.1. Introduction

In recent decades, China has grown at an unprecedented rate, leading to substantially higher living standards for much of the country's population. However, this extraordinary growth has been accompanied by notoriously high levels of industrial pollution. As a result, concerns about pollution's effects on human health have grown substantially, leading to calls for the Chinese government to pursue more aggressive environmental policies. These developments raise an important question: what is the relationship between income and air pollution in China? In past studies, researchers have discovered that the relationship between economic growth and air pollution follows an inverse-U relationship, which has been labeled the environmental Kuznets curve (Song et al., 2008) – see Figure 4.1. This relationship suggests that pollution and environmental degradation rise during the early stage of economic development up to a threshold of per-capita income, and afterward decreases as incomes continue to grow (Landrigan et al., 2017). According to Dinda (2004), in the early stage of industrialization, rapid growth results in increased pollution emissions and more intensive use of natural resources. At this stage of development, people value economic growth more than environmental protection, implying a low willingness to pay for the environment. But as a nation continues to grow, the tradeoff between growth and environmental protection tilts more towards the latter, implying a larger willingness to pay for the environment. Therefore, once income reaches a minimum threshold, people demand more environmental protections and environmental quality improves.

As discussed in Landrigan et al. (2017), the inverse-U relationship between income and pollution is similar to the relationship that Simon Kuznets (1901–85) identified nearly a century ago when examining the relationship between economic inequality and income. Kuznets observed that as a society transitions from a primarily agrarian to an urban, industrialized economy, economic inequality first increases and then decreases with economic development. More recently, a similar inverse-U relationship was identified between pollution and income, and recognizing this, Grossman and Krueger (1993) label it the environmental Kuznets curve. Since then, many researchers have used the hypothesized relationship to frame empirical investigations of pollution and per capita income, and a large literature has resulted that finds mixed evidence supporting the stability of the relationship.

Table 4.1 reports the most widely cited studies investigating the environmental Kuznets curve hypothesis[17]. As shown, past studies have tested the environmental Kuznets curve hypothesis across different countries. Fixed and random effects, panel data models are the most widely used econometric tool, where multiple years of national data and cross-country variation are used. For instance, Selden and Song (1994) employ a cross-country panel data analysis to test the environmental Kuznets curve hypothesis for air pollutants such as suspended particulate matter, sulfur dioxide, nitrogen oxides and carbon monoxide, and Stern and Common (2001) carry out a cross-country panel data study to check the environmental Kuznets curve hypothesis for sulfur dioxide. By contrast, some studies employ city-level panel. For example, Panayotou (1997) finds evidence supporting the environmental Kuznets curve hypothesis for sulfur dioxide, while Harbaugh et al. (2002) reject the environmental Kuznets curve hypothesis for sulfur dioxide, smoke and total suspended particulates. In terms of the type of pollution emissions investigated, carbon dioxide (Cole et al., 1997; Bruyn et al., 1998; Jalil and Mahmud, 2009; etc.) and sulfur

[17] These papers are identified using Google Scholar according to their frequency of being cited. Table 4.1 reports the studies with the highest ranking in the frequency of being cited.

dioxide (Selden and Song, 1994; Cole et al., 1997; Panayotou, 1997; etc.) are the most common. Meanwhile, nitrogen oxides (Selden and Song, 1994; Cole et al., 1997; Bruyn et al., 1998; etc.) and suspended particulate matter (Selden and Song, 1994; Cole et al., 1997; Harbaugh et al., 2002; etc.) are widely used measures of air pollution as well.

Although the hypothesis has received considerable attention from economists, Landrigan et al. (2017) identify several empirical and theoretical shortcomings. On one hand, some empirical studies have found uneven evidence supporting the hypothesis, where, for instance, only about half of the cited papers in Table 4.1 find evidence that supports the environmental Kuznets Curve hypothesis, and the statistical methods employed are not always convincing. Moreover, Landrigan et al. (2017) point out that evidence in favor of the hypothesis does not necessarily imply that pollution and environmental degradation is an unavoidable consequence of economic development. In particular, countries that adopt aggressive environmental laws, policies and regulations can grow on a greener path than countries have historically without necessarily sacrificing the pace of development. Stated differently, the environmental Kuznets does not imply that poor growing economies will necessarily pollute more, while wealthy growing economies will necessarily pollute less.

With these criticisms in mind, this study investigates the relation between air pollution and income in China from the perspective of the environmental Kuznets curve hypothesis. My study represents an improvement over previous Chinese studies in several dimensions. First, my data are more recent than past studies and spans 18 years from 1998 to 2015. For instance, the most widely cited paper that investigated the environmental Kuznets curve for China, Jalil and Mahmud (2009), exploit data from 1975 to 2005. Second, I consider several air pollutants, including sulfur dioxide, nitrogen oxides, and smoke & dust, the latter being a proxy for particulate matter. Third, my estimation strategy employs temporal and spatial heterogeneity in emissions and income across space and time by using province-level data. I estimate two-way fixed effects panel data models that: 1) pool across all provinces and assume a common relationship between air pollution and income and 2) disaggregate the province-level data into three regions where the relationship between air pollution and income is estimated separately. An advantage of the pooled model is its overall representativeness for China, while the separate regional models can potentially reveal important spatial heterogeneity across Chinese provinces. My regression results for all three air pollutants yield a negative quadratic term and a positive linear term, which supports the environmental Kuznets curve hypothesis regarding the air pollution in China. In addition, given the GDP per capita in China for 2015, the current income level locates at the downward portion of the environmental Kuznets curve for sulfur dioxide, but locates at the upward portion for nitrogen oxides and smoke & dust. Thus, based on the environmental Kuznets curve hypothesis, as GDP per capita continues to grow in China, sulfur dioxide is likely to decline, but nitrogen oxides and smoke & dust may continue to increase.

Furthermore, the direction of causality between income and emissions triggers another debate. Stern et al. (1996) address the simultaneity issue between economic growth and environmental changes. Meanwhile, Coondoo and Dinda (2002) question that economic growth unidirectionally causes changes in air pollution. Thus, Coondoo and Dinda (2002) study the causality between income and emissions by forming country groups and conclude that the causality turns out to be bi-directional for Asian countries. On the other hand, for a large, relatively low-income nation like China, higher consumption of market goods is demanded by the vast majority of its citizens, which implies continuously expanding production. Without substantial investments in pollution abating technologies, pollution in China is likely to grow. As Landrigan et al. (2017)

suggest, government policies can be adopted to deal with pollution, and thus environmental degradation in China is not inevitable.

This chapter proceeds as follows. The next section presents the Chinese data and econometric specifications used, including descriptive statistics. The third section reports my key empirical results, and the final section concludes with a summary and interpretation of my results.

4.2. Data and Econometric Model

4.2.1. Data

For this study, I compile data from the *China Statistical Yearbook*, published by the National Bureau of Statistics of the People's Republic of China, and the *China Statistical Yearbook on Environment*, published by the National Bureau of Statistics and the Ministry of Environmental Protection of the People's Republic of China. A balanced panel data set is constructed, which covers all 31 provinces in mainland China for 18 years from 1998 to 2015. To be more specific, the *China Statistical Yearbook* provides the data of Gross Domestic Product (GDP), the Consumer Price Index (CPI), population and a selected set of air pollution emissions at the province level, while the *China Statistical Yearbook on Environment* provides further information on air pollution emissions. Income in China is measured by real GDP per capita of each province in constant 2000 million Yuan, which is converted from nominal GDP using the CPI and province-level population. I use all three air pollutants that are available in the data set, which is the quantity of sulfur dioxide, nitrogen oxides and smoke & dust of each province in China over years.

As previously mentioned, in current studies, carbon dioxide (Cole et al., 1997; Bruyn et al., 1998; Jalil and Mahmud, 2009; etc.) and sulfur dioxide (Selden and Song, 1994; Cole et al., 1997; Panayotou, 1997; etc.) are commonly used measures of air pollution. However, carbon dioxide is not reported as an air pollutant in the data set I use. Besides, as pointed out by Gill et al. (2018), carbon dioxide is a global pollutant, and is therefore not necessarily detrimental to the country where it is generated. Thus, I did not exploit carbon dioxide in this study. In addition, nitrogen oxides (Selden and Song, 1994; Cole et al., 1997; Bruyn et al., 1998; etc.) and suspended particulate matter (Selden and Song, 1994; Cole et al., 1997; Harbaugh et al., 2002; etc.) are widely used measures of air pollution as well. Meanwhile, as reported by the Pan American Health Organization and the World Health Organization (2018), particulate matter, or PM, represents particles found in the air, including dust, dirt, soot, smoke, and liquid droplets. Thus, smoke & dust reported in the data set could serve as a good proxy of suspended particulate matter[18]. Therefore, in this study, air pollution is measured by sulfur dioxide, nitrogen oxides and smoke & dust for each province in China over years.

Data on the air pollution emissions in China are collected from both sources. For sulfur dioxide and smoke & dust, the *China Statistical Yearbook* provides both industry and consumption emissions from 1998 to 2010, while the same item is reported by the *China Statistical Yearbook on Environment* from 2011 to 2015. For nitrogen oxides, neither data source provides a complete report. The *China Statistical Yearbook on Environment* reports both industry and consumption emissions of nitrogen oxides from 2011 to 2015, while the same data from 2006 to 2010 are

[18] In both data source, the item name *smoke & dust* is used since 2011. Before 2011, the same item is reported separately by industrial soot, consumption soot and industrial dust. I continue to use the item name *smoke & dust*, and the data of total smoke & dust before 2011 are obtained by adding up industrial soot, consumption soot and industrial dust.

obtained from the Internet[19]. In addition, according to available data documentation, the emissions data are constructed from comprehensive surveys from major industrial companies, while the emissions data for smaller companies and households are estimated based on engineering studies that exploit information about existing technologies and economic activity. More detailed information is provided in the appendix.

Furthermore, for sulfur dioxide, according to a report from the U.S. Environmental Protection Agency (2018), the largest source in the atmosphere is the burning of fossil fuels by power plants and other industrial facilities, while other sources include industrial processes such as extracting metal from ore, natural sources such as volcanoes, and locomotives, ships, as well as other vehicles and heavy equipment that burn fuel with a high sulfur content. Meanwhile, for nitrogen oxides, as reported by the U.S. Environmental Protection Agency (2018), it primarily gets in the air from the burning of fuel, including emissions from cars, trucks and buses, power plants, and off-road equipment. In addition, according to the Pan American Health Organization and the World Health Organization (2018), large concentrations of particulate matter are typically emitted by sources such as diesel vehicles, waste and crop burning, and coal-fired power plants.

4.2.2. Econometric Model

To investigate the relationship between air pollution and income in China, I employ variations of the following econometric specification:

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[19] The data for nitrogen oxides from 2006 to 2010 are collected from a user on bbs.pinggu.org (a Chinese website for sharing economic data regarding China), whose name is not specified on the website. In the *China Statistical Yearbook on Environment*, the data for nitrogen oxides are available only from 2011 to 2015. For the years when the data are available in the *China Statistical Yearbook on Environment*, the data published by the user are exactly the same; for the years when the data are not available in the *China Statistical Yearbook on Environment*, the data published by the user are consistent with the rest and have already been verified by some other users. Thus, the data for nitrogen oxides used in this study are reliable.

$$\ln(\text{Air Pollution}_{it}) = \alpha_0 + \alpha_1 * \text{GDP}_{it}^2 + \alpha_2 * \text{GDP}_{it} + \text{Year}_t + \text{Province}_i + \varepsilon_{it}. \quad (1)$$

where province-level population weights that vary by year are employed in the estimation. Separate regressions are run for each of the three air pollutants. The dependent variable is the log of emissions, while the independent variables of interests are real GDP per capita in linear and quadratic form, year dummies, and province dummies. Year dummies control for common (economic) shocks across provinces that vary by year, while province dummies control for unobserved heterogeneity at the province level that is fixed over time. This specification follows the reduced-form model presented by Kijima et al. (2010), as well as, the panel data model with cross-section weights assuming cross-sectional heteroskedasticity developed by Akbostancı et al. (2009).

Two variations of equation (1) are estimated. First, I run a model with data pooled across all provinces in China. This model allows me to identify the average effects of per capita income on the air pollution emissions in China. One limitation with this specification is that because China is so large and diverse, the relationship between income and the air pollution may vary spatially, and averaging across all provinces might mask important heterogeneity. Therefore, my second specification groups Chinese provinces into one of four geographic regions: 1) the southern region, 2) the northern region, 3) the Qinghai-Tibet region and 4) the northwest region. Because of the limited number of provinces in the Qinghai-Tibet and the northwest regions, I aggregate the two regions into one, which I hereafter refer to as the western region. Operationally, these three regions consist of the following provinces:

- **Northern region**: Beijing, Hebei, Heilongjiang, Henan, Jilin, Liaoning, Ningxia, Shaanxi, Shandong, Shanxi, Tianjin.

- **Southern region**: Anhui, Chongqing, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Hubei, Hunan, Jiangsu, Jiangxi, Shanghai, Sichuan, Yunnan, Zhejiang.
- **Western region**: Gansu, Inner Mongolia, Qinghai, Tibet, Xinjiang.

Figure 4.7 presents a map of China and how provinces are grouped into regions.

Following Selden and Song (1994), a separate set of models are run with population density included as a control variable. Selden and Song (1994) point out that to credibly forecast any pollution-GDP relationship into the future, it is important to consider the distribution of income, the pattern of income growth rates, as well as, the pattern of population growth rates. Also, Selden and Song (1994) argue that GDP and population density are exogenous factors that affect emissions. In my study, population density is constructed by dividing the population of each province in China by its land area, which is measured in square kilometers. In addition, a third set of models is run where either industry or household pollution emissions are included separately as right-hand side variables. This follows the idea of production-based versus consumption-based approaches to examining the EKC hypothesis developed by Rothman (1998).

4.2.3. Descriptive Statistics

Figure 4.2 visually presents trends in my data. From 1998 to 2015, real GDP per capita grew continuously in China at an exceptional 10.5 percent, reaching 0.020 million Yuan per capita in 2015. The growth rate fell modestly in 2008 and 2009 due to the Great Recession. Per capita GDP grew continuously in all regions, except for the western region which experienced declines after 2014. For instance, the southern region was growing at an average annual rate of 10.6 percent with an average real GDP per capita of 0.020 million Yuan from 1998 to 2015, while for the northern region, the average annual growth rate was 10.4 percent, which led to an average real

GDP per capita of 0.020 million Yuan in the same time period. In the western region, average real GDP per capita was 0.016 million Yuan and the annual growth rate was 11.6 percent up from 1998 to 2015, but the growth rate declined from 3.2 percent to -3.1 percent between 2014 and 2015[20]. Summary statistics for these data are presented in Table 4.5.

Next, statistics for the three air pollution emissions are presented in Figure 4.3. From 1998 to 2015, Chinese per capita pollution emissions for sulfur dioxide and nitrogen oxides increased initially and then later decreased, with some fluctuations in sulfur dioxide emissions between 1998 and 2002. Per capita emissions for smoke & dust, by contrast, does not follow a clear trend. Across different regions in China, as displayed in Figures 4.4, 4.5 and 4.6, per capita air pollution emissions are highest in the western region and lowest in the southern region. The sharp rise of the air pollution emissions in the western region around 2001 is consistent with the Great Western Development Strategy pursued by the Chinese government. Several new projects and building initiatives in this region generated a major increase in the emission levels of air pollution. With only modest population growth, emissions per capita in western China rose significantly after 2001. Tables 4.3 and 4.4 present summary statistics for these data.

4.3. Results

Regression results in Table 4.6 report the coefficients for each model, heteroskedastic robust standard errors clustered by provinces, and the corresponding level of statistical significance. The pooled model for all three air pollutants yields a negative quadratic term and a positive linear term. This indicates that the relationship between emissions per capita and GDP per

[20] From 2014 to 2015, nominal GDP in the western region remained relatively constant, but the price level and population grew, which resulted in a decline in real GDP.

capita follows an inverse-U shape, which provides evidence supporting the environmental Kuznets curve hypothesis. In addition, for all three pollutants, the quadratic term is statistically significant, while the linear term is statistically significant only for nitrogen oxides. Furthermore, given the magnitude of the coefficients, the turning point of sulfur dioxide comes earliest, and the turning point of nitrogen oxides arises earlier than smoke & dust. To be more specific, for sulfur dioxide, the turning point occurs when GDP per capita reaches 0.023 million Yuan; for nitrogen oxides, the turning point arises when GDP per capita attains 0.041 million Yuan; for smoke & dust, the turning point appears when GDP per capita is equal to 0.044 million Yuan. On the other hand, according to Table 4.5, in 2015, the GDP per capita in China was 0.037 million Yuan. This income level locates at the downward portion of the environmental Kuznets curve for sulfur dioxide, but locates at the upward portion for nitrogen oxides and smoke & dust. In other words, based on the environmental Kuznets curve hypothesis, as GDP per capita continues to grow in China, sulfur dioxide is expected to decline, but nitrogen oxides and smoke & dust are predicted to rise in the future.

Next, the regression results for the grouped model are reported. As displayed in Table 4.7, for all three air pollutants, in all three regions, the quadratic term is negative, while the linear term is positive. The signs of the coefficients for the grouped model are consistent with the pooled model, which indicate the same inverse-U shaped pattern, and thus the environmental Kuznets curve hypothesis is supported. But the western region demonstrates statistical significance for sulfur dioxide and smoke & dust only, while the other two regions exhibit statistical significance for nitrogen oxides only. Since the grouped model fails to demonstrate much statistical significance, the difference in the grouped model from the combined model could reflect sampling noise. Inference is problematic for the grouped model in general.

Furthermore, regression results for robustness check are given in the tables as well. Multiple models have been attempted as robustness check, such as level-level and double-log models, but none of them demonstrates much statistical significance, and thus are not reported. The regression results of robustness check with population density added as an additional regressor following Selden and Song (1994) are reported in Tables 4.8, 4.9, 4.10 and 4.11. Compared with the main model, this robustness check model fails to demonstrate much statistical significance either. In this model, population density is correlated with GDP per capita ($\rho = 0.573$). In other words, population density and GDP per capita are interdependent, and thus a high correlation between explanatory variables would cause multicollinearity that results in imprecise inference. To be more specific, for overall China, the regression results are consistent with the environmental Kuznets curve hypothesis for the most part, except the industry emissions of smoke & dust. Yet, only the total emissions and the household emissions of nitrogen oxides have demonstrated statistical significance. For the southern region, only the regression results for nitrogen oxides are statistically significant and consistent with the environmental Kuznets curve hypothesis. For the northern region, only the regression results for the total emissions and the household emissions of sulfur dioxide are statistically significant, but it contradicts the environmental Kuznets curve hypothesis by revealing a U-shaped pattern. For the western region, the regression results for sulfur dioxide, as well as, the total emissions and the household emissions of nitrogen oxides are significant statistically, and also demonstrate consistency with the environmental Kuznets curve hypothesis. Overall, in general, adding in population density as an explanatory variable leads to broadly similar conclusions.

4.4. Conclusion

This study investigates the link between air pollution and income in China, a rapidly developing country that has experienced significant environmental problems in recent years. Per capita emissions of sulfur dioxide, nitrogen oxides and smoke & dust for each province in China are utilized to measure air pollution, and real GDP per capita for each province is used to measure income. A two-way, fixed effects panel data model is employed, and two specifications are considered: 1) a pooled model where the relationship between income and pollution is assumed stable across provinces, and 2) a disaggregated specification where the income-pollution relationship is allowed to vary across three geographic regions. The pooled model provides evidence supporting the environmental Kuznets curve hypothesis regarding the air pollution in China and demonstrates statistical significance. The grouped model also provides evidence supporting the environmental Kuznets curve hypothesis, although many key parameters are not statistically significant.

Even though the model provides evidence supporting the environmental Kuznets curve hypothesis regarding the air pollution in China based on sulfur dioxide, nitrogen oxides and smoke & dust, actions should still be taken to deal with pollution. Dasgupta et al. (2002) point out that there is no evidence in support of the view that it would be economically advantageous to experience rising pollution levels until per capita incomes rise significantly, and countries whose economic policies induce a rapid expansion of income and employment may experience severe environmental damage unless appropriate environmental regulations are enacted and enforced. As Landrigan et al. (2017) argue, actions should be taken to deal with pollution, instead of waiting for a "turning point" that alleviates the environmental problems automatically. In the meantime, more aggressive policies have been initiated in China to deal with severe air pollution. As reported by

Koleski (2017), according to the 13th Five-Year Plan, the government of China is attempting to clean up the serious environmental degradation left by its "growth at any cost" strategy and shift toward a more sustainable economic model, which is the most environmentally-focused plan to date. In this five-year plan, to control air pollution is a key target in the environment goal, and the government has set tight restrictions on the maximum amount of coal allowed to be used during the next five years. Also, the government of China has set higher emissions reduction targets for sulfur dioxide and nitrogen oxides, as well as, a tight control of $PM_{2.5}$, in addition to a requirement for Chinese oil refiners to produce higher quality gasoline.

CHAPTER 5

Conclusion

In this dissertation research, I address three main issues: 1) the effects of exports on the air pollution in China; 2) the effects of exports on wages in China; and 3) the link between air pollution and income in China.

For the first question, I use provincial-level panel data on the emissions of sulfur dioxide, nitrogen oxides, and smoke & dust to empirically assess if they increase with export intensity. The instrumental variable strategy I employ uses the temporal variation in export demand for Chinese manufacturing goods brought about by the Great Recession and geographic variation in provincial location (on the coast vs. inland) that affords coastal areas an exporter advantage to provide an estimate for the effects of exports on the air pollution. I find that a decrease in export intensity decreases the emissions of sulfur dioxide and nitrogen oxides, implying that greater export intensity leads to higher levels of air pollution in China.

For the second question, an instrumental variable strategy is employed to avoid endogeneity, which uses the temporal variation in export demand for Chinese manufacturing goods brought about by the Great Recession and geographic variation in provincial location, i.e., on the coast vs. inland. The results show that a reduction in trade (exports) lowers the average monthly wage of individuals with a college degree, which is the opposite of what Heckscher-Ohlin model predicts if China is a low-skill labor abundant country.

For the third question, a two-way, fixed effects panel data model is employed, and two specifications are considered: 1) a pooled model where the relationship between income and pollution is assumed stable across provinces, and 2) a disaggregated specification where the income-pollution relationship is allowed to vary across three geographic regions. The pooled model provides evidence supporting the environmental Kuznets curve hypothesis regarding the air pollution in China and demonstrates statistical significance. The grouped model also provides evidence supporting the environmental Kuznets curve hypothesis, but fails to find much statistical significance.

The conclusion from the first essay (Chapter II) is consistent with the pollution haven hypothesis, which indicates that western countries are exporting pollutions and importing personal goods, while China is becoming a "pollution haven." By exporting a large scale of personal goods, China generates considerable income and creates abundant jobs for its citizens, but it also results in severe pollutions. At this point, it is hard to determine whether the benefits exceed the costs of export driven growth. The welfare gains from trade, as well as, the social costs from pollution need to be quantified to resolve the real effects of trade. Future research might collect data from Chinese citizens about their willingness to pay for cleaning up the air pollution in a reliable survey.

The conclusion from the second essay (Chapter III) is consistent with the recent evidence in the literature (e.g. Verhoogen, 2008) showing that exports are complementary with high-skill (or college education). In China, there has been an intense debate whether people should invest in education. The results from this study indicate that exports in China increase the returns to higher education, even if China is exporting mass-produced, labor-intensive goods. Thus, the results from this study could inform this long standing and intense debate.

My final essay (Chapter IV) provides evidence supporting the environmental Kuznets curve hypothesis regarding the air pollution in China. These results hold for the three pollutants I consider – sulfur dioxide, nitrogen oxides and smoke & dust. Given its current income level, China is located on the downward portion of the environmental Kuznets curve for sulfur dioxide, but is located on the upward portion for nitrogen oxides and smoke & dust. In other words, based on the environmental Kuznets curve hypothesis, as GDP per capita continues to grow in China, sulfur dioxide is expected to decline, while nitrogen oxides and smoke & dust are predicted to rise in the future. But as Landrigan et al. (2017) argue, China must decide whether actions should be taken to deal with pollution, instead of assuming pollution will decline automatically.

Table 2.1: Definition of Variables

Variable	Definition
SO	Total sulfur dioxide, measured by million ton, log form is used in the regression, and the log form is measured by ton.
SO_Indus	Sulfur dioxide emitted by industry, measured by million ton, log form is used in the regression, and the log form is measured by ton.
NO	Total nitrogen oxides, measured by million ton, log form is used in the regression, and the log form is measured by ton.
NO_Indus	Nitrogen oxides emitted by industry, measured by million ton, log form is used in the regression, and the log form is measured by ton.
SD	Smoke & dust, measured by million ton, log form is used in the regression, and the log form is measured by ton.
Exp	Exports, measured in constant 2000 trillion Yuan, log form is used in the regression.
Imp	Imports, measured in constant 2000 trillion Yuan, log form is used in the regression.
GDP	GDP, measured in constant 2000 trillion Yuan, log form is used in the regression.
ExpInt	Export Intensity, equals *Exp* over *GDP*.
SOInt	Sulfur Dioxide Intensity, equals *SO* (measured by million ton) over *GDP* (measured in constant 2000 trillion Yuan).
NOInt	Nitrogen Oxides Intensity, equals *NO* (measured by million ton) over *GDP* (measured in constant 2000 trillion Yuan).
SDInt	Smoke & Dust Intensity, equals *SD* (measured by million ton) over *GDP* (measured in constant 2000 trillion Yuan).
Coas	Coastal, equals 1 if a province is coastal and equals 0 if a province is inland.
GreRec	Great Recession, equals 1 if it is 2009 and after, and equals 0 if it is 2008 and before.
GreRec_Coa	Equals *GreRec* times *Coas*.
ExpInt_Coa	Equals *ExpInt* times *Coas*.
TotCons	Total Consumption, equals *GDP* plus *Imp* minus *Exp*, measured in constant 2000 trillion Yuan.
Ex_Co_Ra	Exports Consumption Ratio, equals *Exp* over *TotCons*.
Im_Co_Ra	Imports Consumption Ratio, equals *Imp* over *TotCons*.
DomesConsum	Domestic Consumption, equals *GDP* minus *Exp*, measured in constant 2000 trillion Yuan.

Table 2.2: Descriptive Statistics

	Overall (2003-2015)		After Great Recession (2009-2015)		Before Great Recession (2003-2008)	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Total Sulfur Dioxide (Million Ton)	0.718	0.453	0.673	0.415	0.771	0.488
Sulfur Dioxide by Industry (Million Ton)	0.643	0.412	0.602	0.370	0.657	0.425
Total Nitrogen Oxides (Million Ton)	0.620	0.424	0.666	0.435	0.515	0.382
Nitrogen Oxides by Industry (Million Ton)	0.449	0.319	0.473	0.320	0.392	0.311
Smoke & Dust (Million Ton)	0.518	0.384	0.448	0.327	0.600	0.429
Exports (Real 2000 Trillion Yuan)	0.254	0.493	0.299	0.549	0.202	0.413
Imports (Real 2000 Trillion Yuan)	0.216	0.402	0.255	0.447	0.170	0.339
GDP (Real 2000 Trillion Yuan)	1.036	0.955	1.361	1.086	0.656	0.582
Export Intensity	0.168	0.193	0.149	0.161	0.189	0.222
Sulfur Dioxide Intensity	1.161	1.248	0.703	0.603	1.695	1.559
Nitrogen Oxides Intensity	0.682	0.476	0.641	0.446	0.778	0.529
Smoke & Dust Intensity	0.880	0.954	0.474	0.405	1.353	1.169
Domestic Consumption (Real 2000 Trillion Yuan)	0.781	0.657	1.062	0.730	0.454	0.341
Coastal	0.355	0.479	0.355	0.480	0.355	0.480

Table 2.3: Correlation Table

	Sulfur Dioxide	Sulfur Dioxide by Industry	Nitrogen Oxides	Nitrogen Oxides by Industry	Smoke & Dust
Sulfur Dioxide	1				
Sulfur Dioxide by Industry	0.9833	1			
Nitrogen Oxides	0.7788	0.8226	1		
Nitrogen Oxides by Industry	0.7985	0.8334	0.9837	1	
Smoke & Dust	0.7896	0.7859	0.5824	0.6163	1

Table 2.4: The Impact of the Great Recession on GDP, Exports, Imports and Domestic Consumption in Coastal Provinces

	ln (GDP) (Real 2000 trillion Yuan)	ln (Exports) (Real 2000 trillion Yuan)	ln (Imports) (Real 2000 trillion Yuan)	ln (DomesConsum) (Real 2000 trillion Yuan)	Exports/GDP	Exports/Total Consumption	Imports/Total Consumption
Great Recession* Coastal	-0.082** (0.040)	-0.252* (0.130)	-0.124 (0.124)	0.165* (0.088)	-0.100*** (0.030)	-0.124*** (0.034)	-0.084** (0.032)
	Robustness Check Using Trade Measured by the Initial Position or the Final Destination of the Traded Goods						
Great Recession* Coastal	-0.082** (0.040)	-0.077 (0.135)	0.037 (0.136)	0.142* (0.079)	-0.088*** (0.027)	-0.100*** (0.029)	-0.073** (0.030)
	Robustness Check with Weights by the Province Average Population over the Entire Sample						
Great Recession* Coastal	-0.096*** (0.033)	-0.322*** (0.117)	-0.291** (0.127)	0.180 (0.127)	-0.101*** (0.031)	-0.125*** (0.038)	-0.098** (0.043)
Province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	403	403	403	403	403	403	403

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 2.5: The Impact of the Great Recession on Sulfur Dioxide Emissions in Coastal Provinces (Log-level Model)

	ln (Sulfur Dioxide) (Ton) (Endogenous Regression)	ln (Sulfur Dioxide) (Ton) (IV Regression)	Exports/GDP (1st Stage of the IV)	ln (Sulfur Dioxide) (Ton) (Reduced Form)
Great Recession*Coastal			-0.100***	-0.200*
			(0.032)	(0.108)
Exports/GDP	0.898	2.004*		
	(0.563)	(1.065)		
Robustness Check Using Trade Measured by the Initial Position or the Final Destination of the Traded Goods				
Great Recession*Coastal			-0.088***	-0.200*
			(0.029)	(0.108)
Exports/GDP	0.829	2.278*		
	(0.609)	(1.222)		
Robustness Check with Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.101***	-0.137**
			(0.033)	(0.067)
Exports/GDP	0.521	1.365**		
	(0.343)	(0.647)		
Robustness Check with GDP Added as Regressor				
Great Recession*Coastal			-0.095**	-0.181
			(0.035)	(0.116)
Exports/GDP	0.816	1.909		
	(0.548)	(1.204)		
ln (GDP)	0.282	0.115	0.061	0.231
	(0.383)	(0.416)	(0.104)	(0.431)
Robustness Check with GDP Added as Regressor and Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.089***	-0.139*
			(0.029)	(0.071)
Exports/GDP	0.490	1.561*		
	(0.294)	(0.876)		
ln (GDP)	0.068	-0.205	0.122	-0.015
	(0.267)	(0.378)	(0.100)	(0.311)
Province FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Observations	403	403	403	403

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 2.6: The Impact of the Great Recession on Sulfur Dioxide Emissions in Coastal Provinces (Level-level Model)

	Sulfur Dioxide (Million Ton) (Endogenous Regression)	Sulfur Dioxide (Million Ton) (IV Regression)	Exports/GDP (1st Stage of the IV)	Sulfur Dioxide (Million Ton) (Reduced Form)
Great Recession*Coastal			-0.100***	-0.113**
			(0.032)	(0.051)
Exports/GDP	0.074	1.136*		
	(0.253)	(0.614)		
Robustness Check Using Trade Measured by the Initial Position or the Final Destination of the Traded Goods				
Great Recession*Coastal			-0.088***	-0.113**
			(0.029)	(0.051)
Exports/GDP	-0.012	1.292*		
	(0.238)	(0.721)		
Robustness Check with Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.101***	-0.120**
			(0.033)	(0.051)
Exports/GDP	0.265	1.192**		
	(0.330)	(0.513)		
Robustness Check with GDP Added as Regressor				
Great Recession*Coastal			-0.089**	-0.043
			(0.037)	(0.051)
Exports/GDP	-0.199	0.483		
	(0.175)	(0.624)		
GDP	-0.157***	-0.122***	-0.020	-0.131***
	(0.029)	(0.042)	(0.024)	(0.034)
Robustness Check with GDP Added as Regressor and Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.073***	-0.042
			(0.027)	(0.059)
Exports/GDP	-0.212	0.581		
	(0.220)	(0.861)		
GDP	-0.143***	-0.088	-0.040	-0.111**
	(0.034)	(0.072)	(0.025)	(0.043)
Province FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Observations	403	403	403	403

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 2.7: The Impact of the Great Recession on Nitrogen Oxides Emissions in Coastal Provinces (Log-level Model)

	ln (Nitrogen Oxides) (Ton) (Endogenous Regression)	ln (Nitrogen Oxides) (Ton) (IV Regression)	Exports/GDP (1^{st} Stage of the IV)	ln (Nitrogen Oxides) (Ton) (Reduced Form)
Great Recession*Coastal			-0.100***	-0.259**
			(0.032)	(0.102)
Exports/GDP	1.459***	2.443***		
	(0.534)	(0.920)		
Robustness Check Using Trade Measured by the Initial Position or the Final Destination of the Traded Goods				
Great Recession*Coastal			-0.088***	-0.259**
			(0.029)	(0.101)
Exports/GDP	1.558**	2.616***		
	(0.684)	(1.016)		
Robustness Check with Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.101***	-0.238***
			(0.033)	(0.075)
Exports/GDP	1.504***	2.138***		
	(0.271)	(0.481)		
Robustness Check with GDP Added as Regressor				
Great Recession*Coastal			-0.095**	-0.160*
			(0.035)	(0.082)
Exports/GDP	0.923**	1.764**		
	(0.373)	(0.883)		
ln (GDP)	1.246***	0.992***	0.061	1.358***
	(0.314)	(0.384)	(0.104)	(0.344)
Robustness Check with GDP Added as Regressor and Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.089***	-0.143**
			(0.029)	(0.062)
Exports/GDP	1.047***	1.565***		
	(0.224)	(0.526)		
ln (GDP)	0.892***	0.702**	0.122	1.048***
	(0.294)	(0.319)	(0.100)	(0.329)
Province FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Observations	306	306	403	306

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 2.8: The Impact of the Great Recession on Nitrogen Oxides Emissions in Coastal Provinces (Level-level Model)

	Nitrogen Oxides (Million Ton) (Endogenous Regression)	Nitrogen Oxides (Million Ton) (IV Regression)	Exports/GDP (1st Stage of the IV)	Nitrogen Oxides (Million Ton) (Reduced Form)
Great Recession*Coastal			-0.100***	-0.082
			(0.032)	(0.051)
Exports/GDP	0.457*	0.752*		
	(0.232)	(0.392)		
Robustness Check Using Trade Measured by the Initial Position or the Final Destination of the Traded Goods				
Great Recession*Coastal			-0.088***	-0.082
			(0.029)	(0.051)
Exports/GDP	0.478**	0.811*		
	(0.222)	(0.432)		
Robustness Check with Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.101***	-0.090
			(0.033)	(0.070)
Exports/GDP	0.796***	0.810*		
	(0.245)	(0.434)		
Robustness Check with GDP Added as Regressor				
Great Recession*Coastal			-0.089**	-0.082*
			(0.037)	(0.048)
Exports/GDP	0.467*	0.897**		
	(0.236)	(0.451)		
GDP	0.006	0.039	-0.020	0.001
	(0.055)	(0.053)	(0.024)	(0.059)
Robustness Check with GDP Added as Regressor and Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.073***	-0.060
			(0.027)	(0.059)
Exports/GDP	0.772***	0.769		
	(0.235)	(0.549)		
GDP	-0.008	-0.009	-0.040	-0.059
	(0.061)	(0.063)	(0.025)	(0.071)
Province FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Observations	310	310	403	310

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 2.9: The Impact of the Great Recession on Smoke & Dust Emissions in Coastal Provinces (Log-level Model)

	ln (Smoke & Dust) (Ton) (Endogenous Regression)	ln (Smoke & Dust) (Ton) (IV Regression)	Exports/GDP (1^{st} Stage of the IV)	ln (Smoke & Dust) (Ton) (Reduced Form)
Great Recession*Coastal			-0.100***	-0.053
			(0.032)	(0.123)
Exports/GDP	-0.173	0.528		
	(0.695)	(1.178)		
Robustness Check Using Trade Measured by the Initial Position or the Final Destination of the Traded Goods				
Great Recession*Coastal			-0.088***	-0.053
			(0.029)	(0.123)
Exports/GDP	-0.309	0.600		
	(0.759)	(1.345)		
Robustness Check with Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.101***	0.106
			(0.033)	(0.113)
Exports/GDP	-0.723	-1.056		
	(0.573)	(1.133)		
Robustness Check with GDP Added as Regressor				
Great Recession*Coastal			-0.095**	-0.094
			(0.035)	(0.130)
Exports/GDP	-0.058	0.988		
	(0.709)	(1.371)		
ln (GDP)	-0.398	-0.558	0.061	-0.498
	(0.333)	(0.402)	(0.104)	(0.348)
Robustness Check with GDP Added as Regressor and Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.089***	0.031
			(0.029)	(0.114)
Exports/GDP	-0.391	-0.346		
	(0.600)	(1.181)		
ln (GDP)	-0.731*	-0.742*	0.122	-0.785*
	(0.428)	(0.450)	(0.100)	(0.440)
Province FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Observations	403	403	403	403

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 2.10: The Impact of the Great Recession on Smoke & Dust Emissions in Coastal Provinces (Level-level Model)

	Smoke & Dust (Million Ton) (Endogenous Regression)	Smoke & Dust (Million Ton) (IV Regression)	Exports/GDP (1^{st} Stage of the IV)	Smoke & Dust (Million Ton) (Reduced Form)
Great Recession*Coastal			-0.100***	0.034
			(0.032)	(0.070)
Exports/GDP	-0.373	-0.343		
	(0.222)	(0.638)		
Robustness Check Using Trade Measured by the Initial Position or the Final Destination of the Traded Goods				
Great Recession*Coastal			-0.088***	0.034
			(0.029)	(0.070)
Exports/GDP	-0.443*	-0.390		
	(0.241)	(0.726)		
Robustness Check with Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.101***	0.114
			(0.033)	(0.084)
Exports/GDP	-0.580*	-1.127		
	(0.330)	(0.845)		
Robustness Check with GDP Added as Regressor				
Great Recession*Coastal			-0.089**	0.118
			(0.037)	(0.089)
Exports/GDP	-0.630***	-1.325		
	(0.223)	(0.853)		
GDP	-0.148**	-0.183***	-0.020	-0.157**
	(0.055)	(0.072)	(0.024)	(0.068)
Robustness Check with GDP Added as Regressor and Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.073***	0.199*
			(0.027)	(0.117)
Exports/GDP	-0.943**	-2.719**		
	(0.362)	(1.348)		
GDP	-0.109*	-0.230**	-0.040	-0.123
	(0.063)	(0.110)	(0.025)	(0.078)
Province FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Observations	403	403	403	403

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 2.11: The Impact of the Great Recession on Sulfur Dioxide Intensity in Coastal Provinces

	Sulfur Dioxide Intensity (Endogenous Regression)	Sulfur Dioxide Intensity (IV Regression)	Exports/GDP (1st Stage of the IV)	Sulfur Dioxide Intensity (Reduced Form)
Great Recession*Coastal			-0.100***	0.647**
			(0.032)	(0.294)
Exports/GDP	-2.055**	-6.483**		
	(0.944)	(2.996)		
Robustness Check Using Trade Measured by the Initial Position or the Final Destination of the Traded Goods				
Great Recession*Coastal			-0.088***	0.647**
			(0.029)	(0.294)
Exports/GDP	-1.587*	-7.371**		
	(0.892)	(3.584)		
Robustness Check with Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.101***	0.526**
			(0.033)	(0.254)
Exports/GDP	-2.644***	-5.222**		
	(0.695)	(2.342)		
Province FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Observations	403	403	403	403

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 2.12: The Impact of the Great Recession on Nitrogen Oxides Intensity in Coastal Provinces

	Nitrogen Oxides Intensity (Endogenous Regression)	Nitrogen Oxides Intensity (IV Regression)	Exports/GDP (1st Stage of the IV)	Nitrogen Oxides Intensity (Reduced Form)
Great Recession*Coastal			-0.100***	-0.029
			(0.032)	(0.066)
Exports/GDP	0.193	0.269		
	(0.393)	(0.560)		
Robustness Check Using Trade Measured by the Initial Position or the Final Destination of the Traded Goods				
Great Recession*Coastal			-0.088***	-0.029
			(0.029)	(0.066)
Exports/GDP	0.205	0.290		
	(0.431)	(0.605)		
Robustness Check with Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.101***	-0.005
			(0.033)	(0.049)
Exports/GDP	-0.021	0.040		
	(0.185)	(0.401)		
Province FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Observations	310	310	403	310

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 2.13: The Impact of the Great Recession on Smoke & Dust Intensity in Coastal Provinces

	Smoke & Dust Intensity (Endogenous Regression)	Smoke & Dust Intensity (IV Regression)	Exports/GDP (1st Stage of the IV)	Smoke & Dust Intensity (Reduced Form)
Great Recession*Coastal			-0.100***	0.625**
			(0.032)	(0.232)
Exports/GDP	-1.564*	-6.260***		
	(0.771)	(2.312)		
Robustness Check Using Trade Measured by the Initial Position or the Final Destination of the Traded Goods				
Great Recession*Coastal			-0.088***	0.625**
			(0.029)	(0.232)
Exports/GDP	-1.206	-7.117**		
	(0.891)	(2.824)		
Robustness Check with Weights by the Province Average Population over the Entire Sample				
Great Recession*Coastal			-0.101***	0.609***
			(0.033)	(0.201)
Exports/GDP	-2.491***	-6.046***		
	(0.505)	(1.929)		
Province FEs	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes
Observations	403	403	403	403

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 3.1: Definition of Variables

Variable	Definition
Monthly Wage	Monthly wage of an individual, measured in constant 2000 Yuan, log form is used in the regression.
Education	Education of an individual, includes none, elementary, elementary not complete, junior high school, junior high school not complete, senior high school, senior high school not complete, technical school, technical school not complete, college, college not complete, master and above.
College and Above	Equals 1 if an individual has earned a college degree or higher, and equals 0 if an individual does not have a college degree.
Manufacture	Equals 1 if an individual works for a manufacture sector, and equals 0 if an individual works for a service sector.
Coastal	Equals 1 if a province is coastal, and equals 0 if a province is inland.
Great Recession	Equals 1 if it is 2009 and after, and equals 0 if it is 2008 and before.

Table 3.2: Descriptive Statistics for Monthly Wage (Real 2000 Yuan)

	Mean	S.D.	Medium	Max	Min
2004	844.985	840.811	742.604	11424.680	47.603
2006	1052.082	1385.121	829.262	22113.640	46.070
2009	1470.984	2407.675	1086.891	76666.760	41.803
2011	1852.991	2050.018	1535.789	34555.250	33.787
Total	1406.385	1899.523	1003.284	76666.760	33.787

Table 3.3: Difference in Monthly Wage between Coastal and Inland Provinces (Real 2000 Yuan)

	Mean	S.D.	Medium	Max	Min
Coastal	1343.384	1898.596	952.057	76666.760	33.787
Inland	1474.113	1898.371	1086.891	34555.250	41.803
Total	1406.385	1899.523	1003.284	76666.760	33.787

Table 3.4: Difference in Average Monthly Wage between Coastal and Inland Provinces across Years (Real 2000 Yuan)

	2004	2006	2009	2011	Total
Coastal	854.609	1025.627	1380.346	1768.442	1343.384
Inland	834.233	1080.657	1575.836	1937.754	1474.113
Total	844.985	1052.082	1470.984	1852.991	1406.385

Table 3.5: Difference in Average Monthly Wage between Individuals with College Degree or Higher and Individuals without a College Degree before and after the Great Recession (Real 2000 Yuan)

	No College Degree	College Degree and above	Total
Before the Great Recession	875.861	1404.822	952.529
After the Great Recession	1494.373	2436.939	1702.818
Total	1236.079	2127.555	1406.385

Table 3.6: Category of Individuals by Year

	Total Sampling			Identical Sampling over Years[21]		
	All	Male	Female	All	Male	Female
2004	2590	1543	1044	1272	786	492
2006	2725	1609	1112	1272	786	492
2009	2899	1732	1166	1272	786	492
2011	4469	2596	1867	1272	786	492
Total	12683	7480	5189	5088	3144	1968

Table 3.7: Category of Individuals by Location

	Total Sampling			Identical Sampling over Years		
	All	Male	Female	All	Male	Female
Coastal	6554	3782	2772	2625	1574	1046
Inland	6115	3698	2417	2240	1365	866
Total	12669	7480	5189	4865	2939	1912

Table 3.8: Category of Individuals by Working Sectors

	Total Sampling			Identical Sampling over Years		
	All	Male	Female	All	Male	Female
Manufacturing Sector	6188	3879	2305	2462	1545	914
Service Sector	6495	3601	2884	2408	1394	998
Total	12683	7480	5189	4870	2939	1912

Table 3.9: Category of Individuals by Education

	Total Sampling			Identical Sampling over Years		
	All	Male	Female	All	Male	Female
College and Above	2110	1137	973	482	286	194
No College Degree	10559	6343	4216	4383	2653	1718
Total	12669	7480	5189	4865	2939	1912

[21] The number of observations used in the regression is lower than the number of the observations available in the data set, because some individuals miss certain covariants, and is thus dropped from the regression.

Table 3.10: The Impact of Trade on the Wage Rate in China among Skilled and Non-skilled Workers across Coastal and Inland Areas before and after the Great Recession between Manufacturing and Service Workers

	ln (Monthly Wage) All (Real 2000 Yuan)	ln (Monthly Wage) Male Only (Real 2000 Yuan)	ln (Monthly Wage) Female Only (Real 2000 Yuan)
Age	0.036***	0.049***	0.030***
	(0.004)	(0.004)	(0.007)
Age Squared	0.000***	-0.001***	0.000***
	(0.000)	(0.000)	(0.000)
Great Recession*Coastal	-0.147***	-0.219***	-0.086**
	(0.025)	(0.031)	(0.036)
College and Above*Coastal	-0.138	-0.184**	-0.077
	(0.080)	(0.066)	(0.124)
College and Above* Great Recession	0.058	0.049	0.030
	(0.072)	(0.076)	(0.106)
Great Recession*Manufacture	0.130***	0.043**	0.148***
	(0.017)	(0.019)	(0.042)
Coastal*Manufacture	-0.043	-0.102	0.008
	(0.054)	(0.065)	(0.022)
College and Above*Manufacture	0.035	0.067	0.011
	(0.048)	(0.053)	(0.092)
College and Above* Coastal*Great Recession	0.158	0.212**	0.107
	(0.094)	(0.092)	(0.136)
Great Recession* Coastal*Manufacture	0.058	0.185***	-0.052
	(0.043)	(0.047)	(0.059)
Great Recession* College and Above*Manufacture	-0.111	-0.095	-0.041
	(0.075)	(0.105)	(0.101)
College and Above* Coastal*Manufacture	0.349***	0.350***	0.342*
	(0.090)	(0.072)	(0.174)
College and Above*Coastal* Great Recession*Manufacture	-0.326**	-0.396***	-0.291
	(0.120)	(0.109)	(0.214)
Year FEs	Yes	Yes	Yes
Province FEs	Yes	Yes	Yes
Individual FEs	No	No	No
Observations	9566	5609	3957

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 3.11: Robustness Check with Individual Fixed Effects

	ln (Monthly Wage) All (Real 2000 Yuan)	ln (Monthly Wage) Male Only (Real 2000 Yuan)	ln (Monthly Wage) Female Only (Real 2000 Yuan)
Age	0.148***	0.167***	0.117***
	(0.016)	(0.026)	(0.017)
Age Squared	0.000**	-0.001**	0.000
	(0.000)	(0.000)	(0.000)
Great Recession*Coastal	-0.124*	-0.184**	-0.033
	(0.068)	(0.061)	(0.118)
College and Above*Coastal	-0.042	-0.121	0.090
	(0.046)	(0.074)	(0.071)
College and Above* Great Recession	0.043	-0.010	0.137
	(0.072)	(0.095)	(0.100)
Great Recession*Manufacture	0.037	0.031	0.044
	(0.040)	(0.069)	(0.048)
Coastal*Manufacture	-0.038	-0.091***	0.026
	(0.022)	(0.019)	(0.029)
College and Above*Manufacture	-0.020	0.028	-0.039
	(0.068)	(0.116)	(0.062)
College and Above* Coastal*Great Recession	0.052	0.105	-0.050
	(0.087)	(0.093)	(0.146)
Great Recession* Coastal*Manufacture	0.034	0.107	-0.080
	(0.060)	(0.078)	(0.112)
Great Recession* College and Above*Manufacture	0.040	-0.001	0.084
	(0.079)	(0.151)	(0.066)
College and Above* Coastal*Manufacture	0.093	0.060	0.042
	(0.091)	(0.127)	(0.145)
College and Above*Coastal* Great Recession*Manufacture	-0.184	-0.253	-0.047
	(0.124)	(0.167)	(0.226)
Year FEs	Yes	Yes	Yes
Province FEs	Yes	Yes	Yes
Individual FEs	Yes	Yes	Yes
Observations	9566	5609	3957

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 3.12: Robustness Check with Identical Sampling over Years

	ln (Monthly Wage) All (Real 2000 Yuan)	ln (Monthly Wage) Male Only (Real 2000 Yuan)	ln (Monthly Wage) Female Only (Real 2000 Yuan)
Age	0.038***	0.050***	0.037
	(0.010)	(0.010)	(0.021)
Age Squared	0.000***	-0.001***	0.000
	(0.000)	(0.000)	(0.000)
Great Recession*Coastal	-0.041	-0.107	0.038
	(0.058)	(0.059)	(0.104)
College and Above*Coastal	0.035	0.156	0.120
	(0.209)	(0.177)	(0.219)
College and Above* Great Recession	0.221	0.189	0.320**
	(0.130)	(0.236)	(0.108)
Great Recession*Manufacture	0.203***	0.167***	0.193***
	(0.039)	(0.035)	(0.051)
Coastal*Manufacture	0.009	-0.015	0.025
	(0.051)	(0.047)	(0.042)
College and Above*Manufacture	0.147	0.126	0.340*
	(0.101)	(0.077)	(0.178)
College and Above* Coastal*Great Recession	-0.014	-0.087	-0.127
	(0.169)	(0.242)	(0.127)
Great Recession* Coastal*Manufacture	-0.085	0.036	-0.213
	(0.078)	(0.059)	(0.122)
Great Recession* College and Above*Manufacture	-0.224	-0.189	-0.292*
	(0.173)	(0.288)	(0.142)
College and Above* Coastal*Manufacture	0.206	0.067	0.069
	(0.162)	(0.106)	(0.188)
College and Above*Coastal* Great Recession*Manufacture	-0.091	-0.076	0.088
	(0.214)	(0.292)	(0.196)
Year FEs	Yes	Yes	Yes
Province FEs	Yes	Yes	Yes
Individual FEs	No	No	No
Observations	3551	2143	1397

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 3.13: Robustness Check with Identical Sampling including Individual Fixed Effects

	ln (Monthly Wage) All (Real 2000 Yuan)	ln (Monthly Wage) Male Only (Real 2000 Yuan)	ln (Monthly Wage) Female Only (Real 2000 Yuan)
Age	0.143***	0.165***	0.120***
	(0.025)	(0.032)	(0.025)
Age Squared	0.000	-0.001*	0.000
	(0.000)	(0.000)	(0.000)
Great Recession*Coastal	-0.085	-0.169**	0.046
	(0.075)	(0.060)	(0.173)
College and Above*Coastal	0.001	-0.165	0.302**
	(0.116)	(0.156)	(0.128)
College and Above* Great Recession	0.047	-0.012	0.164**
	(0.144)	(0.199)	(0.054)
Great Recession*Manufacture	0.085	0.077	0.085*
	(0.053)	(0.067)	(0.039)
Coastal*Manufacture	-0.025	-0.054	0.013
	(0.036)	(0.042)	(0.062)
College and Above*Manufacture	-0.045	-0.093	0.087
	(0.123)	(0.222)	(0.114)
College and Above* Coastal*Great Recession	-0.005	0.067	-0.156
	(0.153)	(0.193)	(0.136)
Great Recession* Coastal*Manufacture	-0.036	0.022	-0.119
	(0.075)	(0.069)	(0.179)
Great Recession* College and Above*Manufacture	0.078	0.101	0.049
	(0.198)	(0.306)	(0.177)
College and Above* Coastal*Manufacture	-0.017	0.079	-0.176
	(0.179)	(0.280)	(0.167)
College and Above*Coastal* Great Recession*Manufacture	-0.108	-0.185	-0.025
	(0.213)	(0.296)	(0.276)
Year FEs	Yes	Yes	Yes
Province FEs	Yes	Yes	Yes
Individual FEs	Yes	Yes	Yes
Observations	3551	2143	1397

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 4.1: Past Studies of the Environmental Kuznets Curve

Author(s)	Country/Region	Level	Data Period	Pollutant Used	Methodology	EKC Hypothesis
Selden and Song (1994)	Cross-country	Country	1979-1984	Suspended particulate matter, sulfur dioxide, nitrogen oxides, carbon monoxide	Panel data	Supported for all four pollutants.
Panayotou (1997)	Cross-country	City	1982-1994	Sulfur dioxide	Panel data	Supported.
Cole et al. (1997)	Cross-country	Country	Varies by pollutants	Carbon dioxide, CFCs and halons, methane, nitrogen dioxide, sulfur dioxide, suspended particulate matter, carbon monoxide, nitrates, municipal waste, energy consumption and traffic volumes	Panel data	Supported for local air pollutants, rejected for global case.
Harbaugh et al. (2002)	Cross-country	City	Varies by pollutants	Sulfur dioxide, smoke, total suspended particulates	Panel data	Rejected.
Bruyn et al. (1998)	Four countries (Netherlands, UK, USA, Western Germany)	Country	Varies by countries	Carbon dioxide, nitrogen oxides, sulfur dioxide	Panel data	Rejected.
Stern and Common (2001)	Cross-country	Country	Varies by countries	Sulfur dioxide	Panel data	Rejected.
Jalil and Mahmud (2009)	China	Country	1975-2005	Carbon dioxide	Auto regressive distributed lag	Supported.
Galeotti et al. (2006)	Cross-country	Country	Varies by countries	Carbon dioxide	Reduced-form	Supported for OECD countries, rejected for non-OECD countries.
List and Gallet (1999)	United States	State	1929-1994	Sulfur dioxide, nitrogen oxides	Reduced-form	Supported.
Akbostancı et al. (2009)	Turkey	Country/ Province	1968-2003/ 1992-2001	Carbon dioxide/ PM_{10} and sulfur dioxide	Time series model/ Panel data model	Rejected: time series model, monotonically increase; panel data model, N-shape relationship.

Table 4.2: Definition of Variables

Variable	Definition
GDP	GDP, measured by million Yuan per capita in 2000 real term.
SO	Sulfur dioxide, measured by ton per capita.
NO	Nitrogen oxides, measured by ton per capita.
SD	Smoke & dust, measured by ton per capita.

Table 4.3: Population Weighted Descriptive Statistics for Overall China

	Mean	S.D.	Max	Min
GDP Per Capita	0.020	0.014	0.075	0.002
Sulfur Dioxide Per Capita	0.016	0.009	0.064	0.000
Nitrogen Oxides Per Capita	0.014	0.008	0.072	0.000
Smoke & Dust Per Capita	0.009	0.007	0.058	0.000

Table 4.4: Population Weighted Descriptive Statistics for Different Regions of China

	Southern Region				Northern Region				Western Region			
	Mean	S.D.	Max	Min	Mean	S.D.	Max	Min	Mean	S.D.	Max	Min
GDP Per Capita	0.020	0.015	0.073	0.002	0.021	0.014	0.075	0.004	0.017	0.013	0.051	0.003
Sulfur Dioxide Per Capita	0.014	0.007	0.053	0.003	0.019	0.008	0.064	0.003	0.030	0.016	0.064	0.000
Nitrogen Oxides Per Capita	0.011	0.004	0.025	0.004	0.018	0.007	0.072	0.006	0.028	0.016	0.057	0.000
Smoke & Dust Per Capita	0.006	0.003	0.021	0.001	0.012	0.008	0.058	0.002	0.017	0.010	0.041	0.000

Table 4.5: Population Weighted Average GDP Per Capita

	Overall		Southern Region		Northern Region		Western Region	
	Level	Growth Rate	Level	Growth Rate	Level	Growth Rate	Level	Growth Rate
1998	0.007	-	0.007	-	0.007	-	0.005	-
1999	0.007	0.00%	0.007	0.00%	0.007	0.00%	0.005	0.00%
2000	0.008	14.29%	0.008	14.29%	0.008	14.29%	0.005	0.00%
2001	0.008	0.00%	0.008	0.00%	0.009	12.50%	0.006	20.00%
2002	0.009	12.50%	0.009	12.50%	0.010	11.11%	0.007	16.67%
2003	0.011	22.22%	0.011	22.22%	0.011	10.00%	0.008	14.29%
2004	0.012	9.09%	0.012	9.09%	0.013	18.18%	0.009	12.50%
2005	0.014	16.67%	0.014	16.67%	0.015	15.38%	0.011	22.22%
2006	0.017	21.43%	0.016	14.29%	0.017	13.33%	0.013	18.18%
2007	0.019	11.76%	0.019	18.75%	0.020	17.65%	0.015	15.38%
2008	0.021	10.53%	0.021	10.53%	0.022	10.00%	0.018	20.00%
2009	0.023	9.52%	0.023	9.52%	0.024	9.09%	0.020	11.11%
2010	0.027	17.39%	0.026	13.04%	0.028	16.67%	0.023	15.00%
2011	0.030	11.11%	0.030	15.38%	0.031	10.71%	0.027	17.39%
2012	0.032	6.67%	0.032	6.67%	0.033	6.45%	0.029	7.41%
2013	0.034	6.25%	0.034	6.25%	0.035	6.06%	0.031	6.90%
2014	0.036	5.88%	0.036	5.88%	0.036	2.86%	0.032	3.23%
2015	0.037	2.78%	0.038	5.56%	0.037	2.78%	0.031	-3.13%
Average	0.020	10.48%	0.020	10.63%	0.020	10.42%	0.016	11.60%

Table 4.6: The Impact of Income on the Air Pollution in China

	ln (Sulfur Dioxide Per Capita)	ln (Nitrogen Oxides Per Capita)	ln (Smoke & Dust Per Capita)
GDP Per $Capita^2$	-367.478**	-628.136***	-219.636*
	(156.8)	(153.9)	(129.2)
GDP Per Capita	17.145	52.097***	19.147
	(15.90)	(17.38)	(12.55)
Province FEs	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes
Observations	558	306	558

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 4.7: The Impact of Income on the Air Pollution in Different Regions of China

	ln (Sulfur Dioxide Per Capita)			ln (Nitrogen Oxides Per Capita)			ln (Smoke & Dust Per Capita)		
	Southern	Northern	Western	Southern	Northern	Western	Southern	Northern	Western
GDP Per Capita^2	-319.573	-277.052	-728.959***	-748.752***	-524.263**	-588.956	-121.806	-233.602	-859.699***
	(228.8)	(234.9)	(124.0)	(222.1)	(218.1)	(302.5)	(226.0)	(141.0)	(143.5)
GDP Per Capita	16.261	0.157	47.640**	64.637**	51.258*	34.983	21.209	3.918	56.018**
	(21.28)	(25.44)	(13.59)	(29.80)	(24.68)	(26.42)	(21.21)	(13.77)	(15.48)
Province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	270	198	90	150	110	46	270	198	90

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 4.8: Robustness Check for Overall China Following Selden and Song (1994)

	Sulfur Dioxide Per Capita			Nitrogen Oxides Per Capita			Smoke & Dust Per Capita		
	Total	Household	Industry	Total	Household	Industry	Total	Household	Industry
GDP Per Capita^2	-2.375	-1.661	-0.713	-7.357**	-6.185**	-1.172	-1.228	-1.425	0.197
	(3.047)	(2.761)	(1.023)	(3.187)	(2.375)	(1.547)	(1.287)	(1.242)	(0.389)
GDP Per Capita	0.183	0.083	0.100	0.772*	0.704**	0.069	0.146	0.180	-0.034
	(0.376)	(0.339)	(0.143)	(0.405)	(0.310)	(0.183)	(0.147)	(0.146)	(0.045)
PD	0.000***	0.000***	0.000**	0.000	0.000	0.000*	0.000*	0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	558	558	558	310	310	310	558	558	558

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 4.9: Robustness Check for Southern China Following Selden and Song (1994)

	Sulfur Dioxide Per Capita			Nitrogen Oxides Per Capita			Smoke & Dust Per Capita		
	Total	Household	Industry	Total	Household	Industry	Total	Household	Industry
GDP Per Capita^2	-0.549	0.553	-1.102	-7.753**	-5.193*	-2.561**	0.297	0.153	0.144
	(2.187)	(1.616)	(1.552)	(3.274)	(2.482)	(1.169)	(0.982)	(1.059)	(0.536)
GDP Per Capita	0.020	-0.206	0.225	0.775*	0.548	0.226	0.100	0.070	0.030
	(0.268)	(0.139)	(0.226)	(0.418)	(0.331)	(0.141)	(0.125)	(0.118)	(0.053)
PD	0.000***	0.000***	0.000**	0.000	0.000	0.000	0.000***	0.000	0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	270	270	270	150	150	150	270	270	270

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 4.10: Robustness Check for Northern China Following Selden and Song (1994)

	Sulfur Dioxide Per Capita			Nitrogen Oxides Per Capita			Smoke & Dust Per Capita		
	Total	Household	Industry	Total	Household	Industry	Total	Household	Industry
GDP Per Capita²	9.559***	8.652***	0.907	-15.155	-14.922	-0.233	-3.162	-1.995	-1.167
	(3.009)	(2.264)	(2.071)	(9.129)	(9.159)	(2.421)	(4.442)	(4.286)	(1.458)
GDP Per Capita	-0.803**	-0.653**	-0.150	1.407	1.379	0.028	0.096	0.145	-0.049
	(0.300)	(0.248)	(0.122)	(0.783)	(0.834)	(0.215)	(0.268)	(0.223)	(0.113)
PD	0.000***	0.000***	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	198	198	198	110	110	110	198	198	198

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

Table 4.11: Robustness Check for Western China Following Selden and Song (1994)

	Sulfur Dioxide Per Capita			Nitrogen Oxides Per Capita			Smoke & Dust Per Capita		
	Total	Household	Industry	Total	Household	Industry	Total	Household	Industry
GDP Per Capita^2	-36.308***	-31.469***	-4.839**	-13.402	-17.054***	3.652	-6.175	-4.901	-1.274
	(3.889)	(2.894)	(1.447)	(6.508)	(1.924)	(4.885)	(8.550)	(7.515)	(1.347)
GDP Per Capita	2.869***	2.572***	0.297*	1.663**	1.912***	-0.249	0.576	0.548	0.028
	(0.234)	(0.160)	(0.114)	(0.485)	(0.164)	(0.365)	(0.531)	(0.451)	(0.092)
PD	0.003**	0.005***	-0.002***	0.005	0.007***	-0.002	0.003**	0.005**	-0.001**
	(0.001)	(0.001)	(0.000)	(0.005)	(0.001)	(0.004)	(0.001)	(0.001)	(0.000)
Province FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	90	90	90	50	50	50	90	90	90

Robust standard errors clustered by provinces are in parentheses.
*** = significant at 1 percent level, ** = significant at 5 percent level, * = significant at 10 percent level

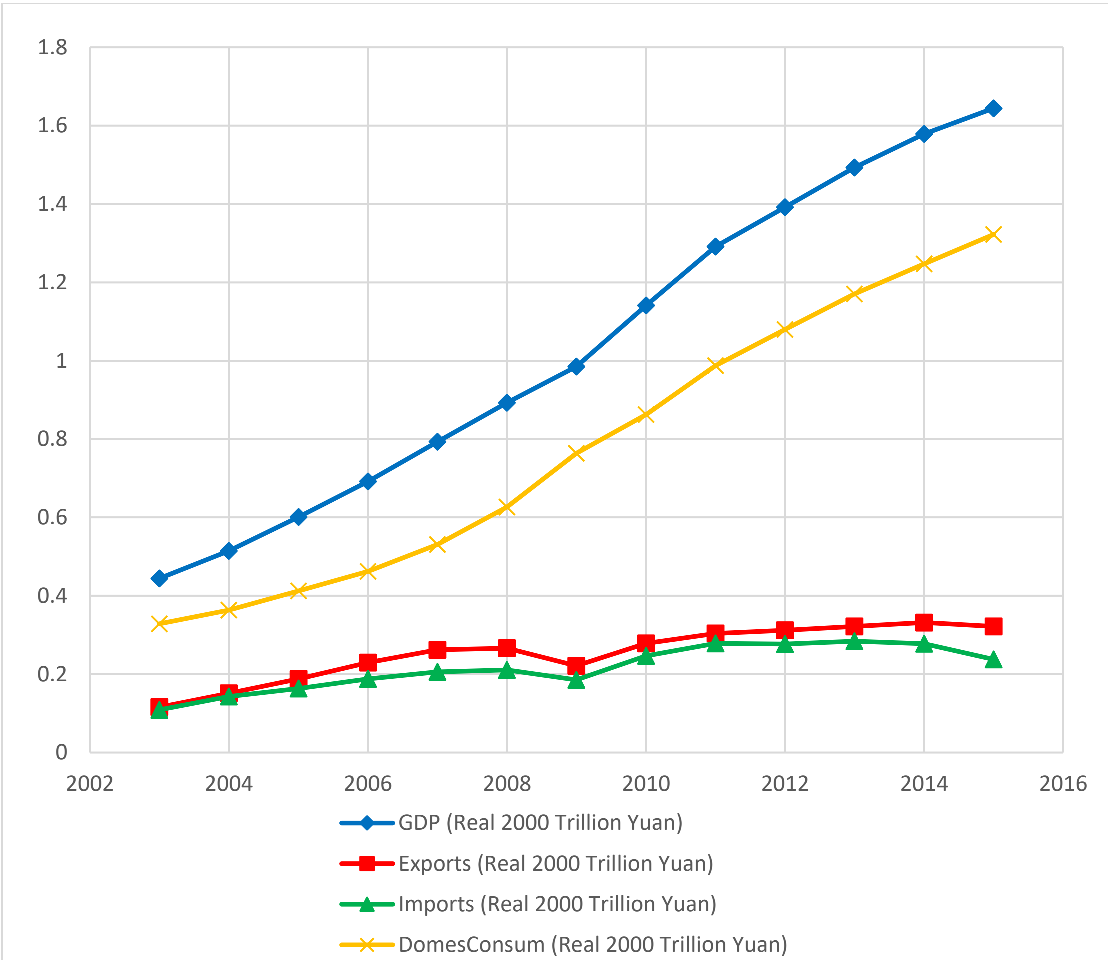

Figure 2.1: Trend of GDP, Exports, Imports and Domestic Consumption in China

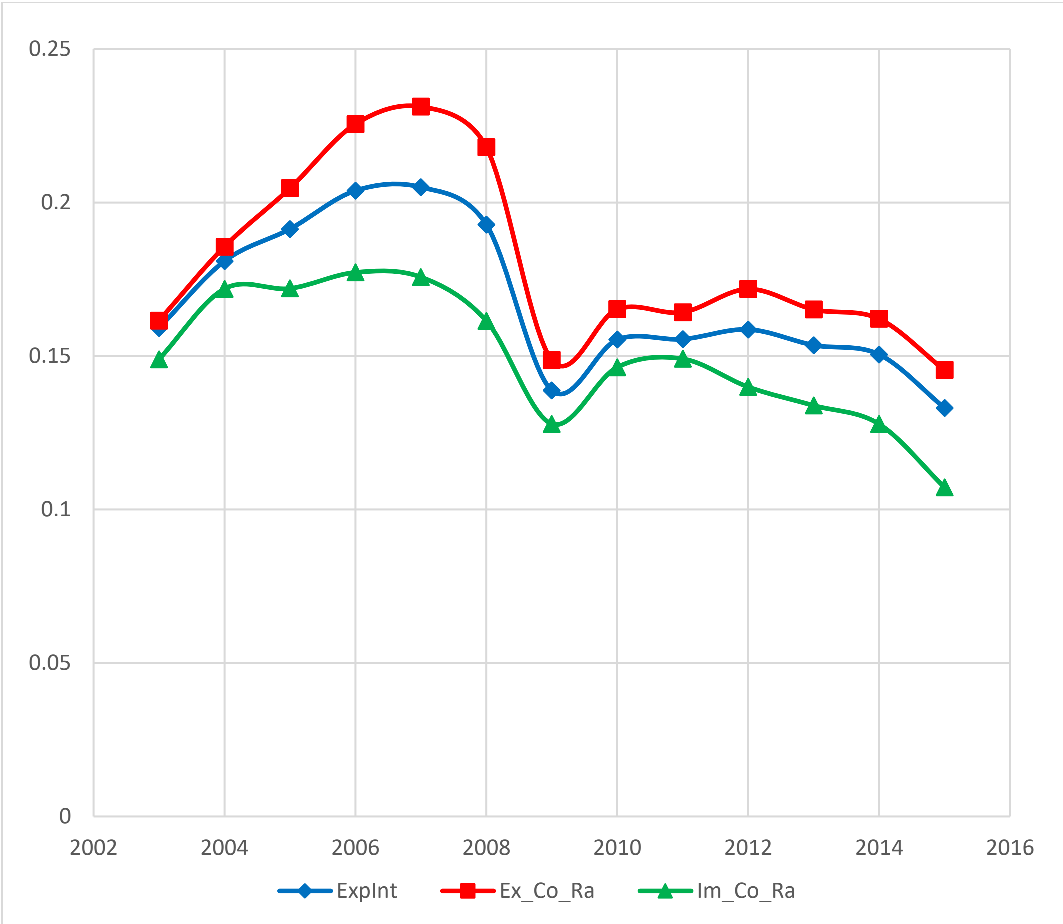

Figure 2.2: Trend of Exports over GDP, Exports over Total Consumption and Imports over Total Consumption in China

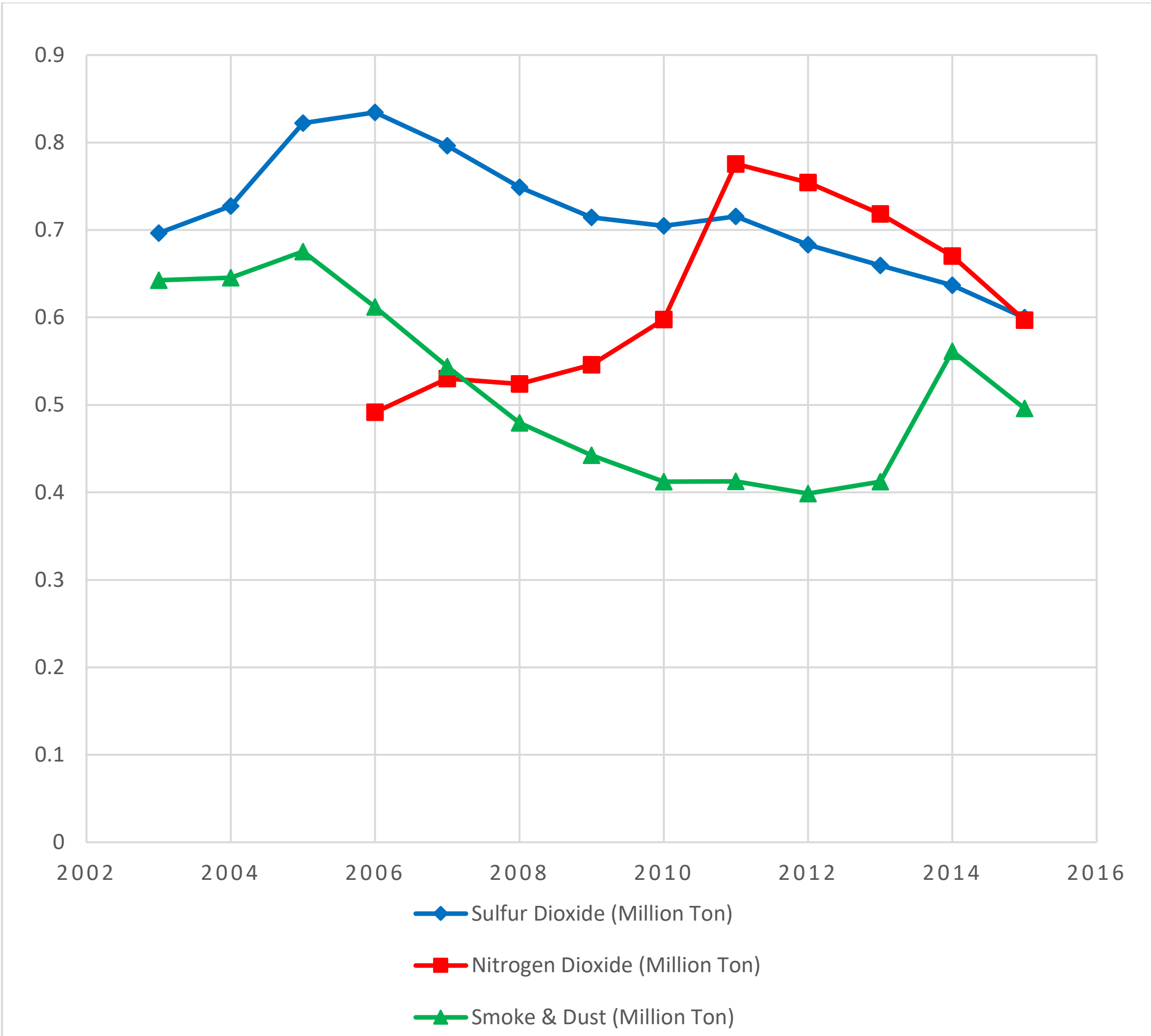

Figure 2.3: Trend of the Air Pollution in China

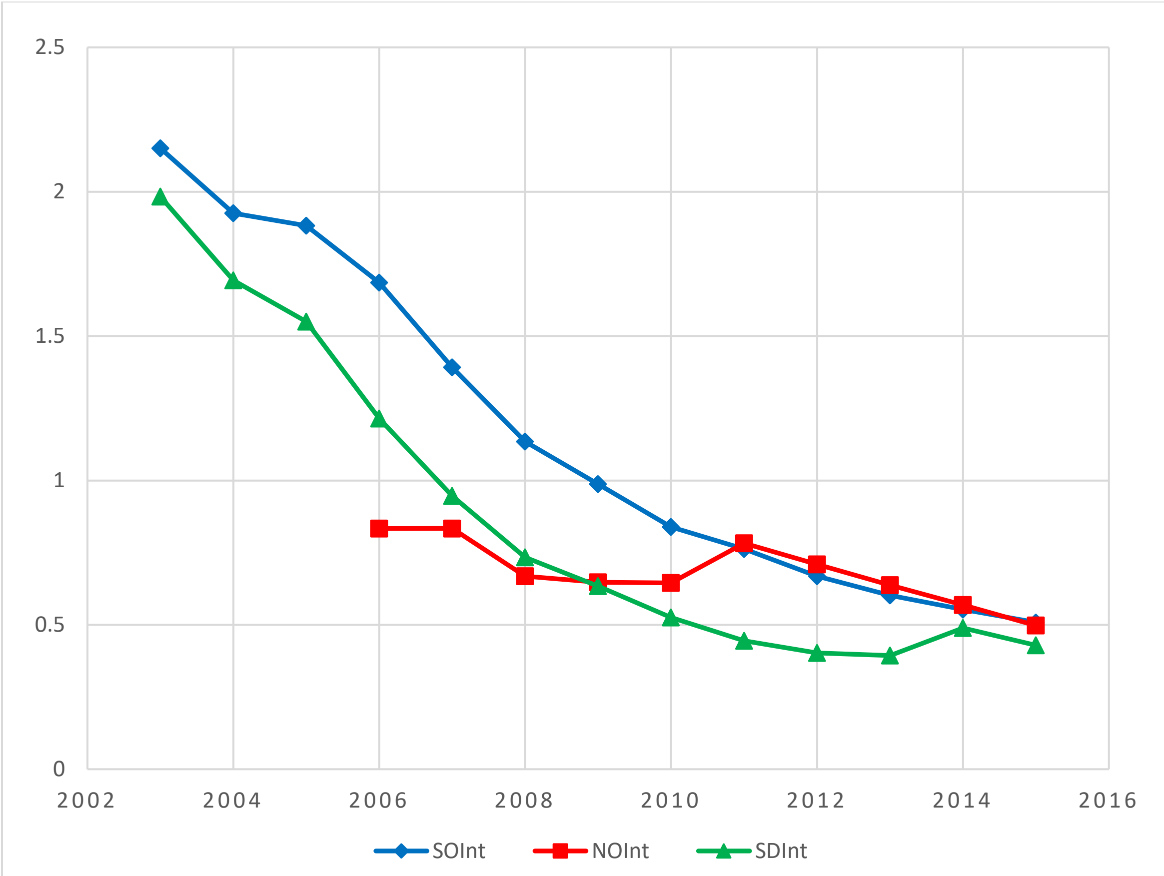

Figure 2.4: Trend of the Air Pollution Intensity in China

Figure 2.5: Map of China with Province Outlines

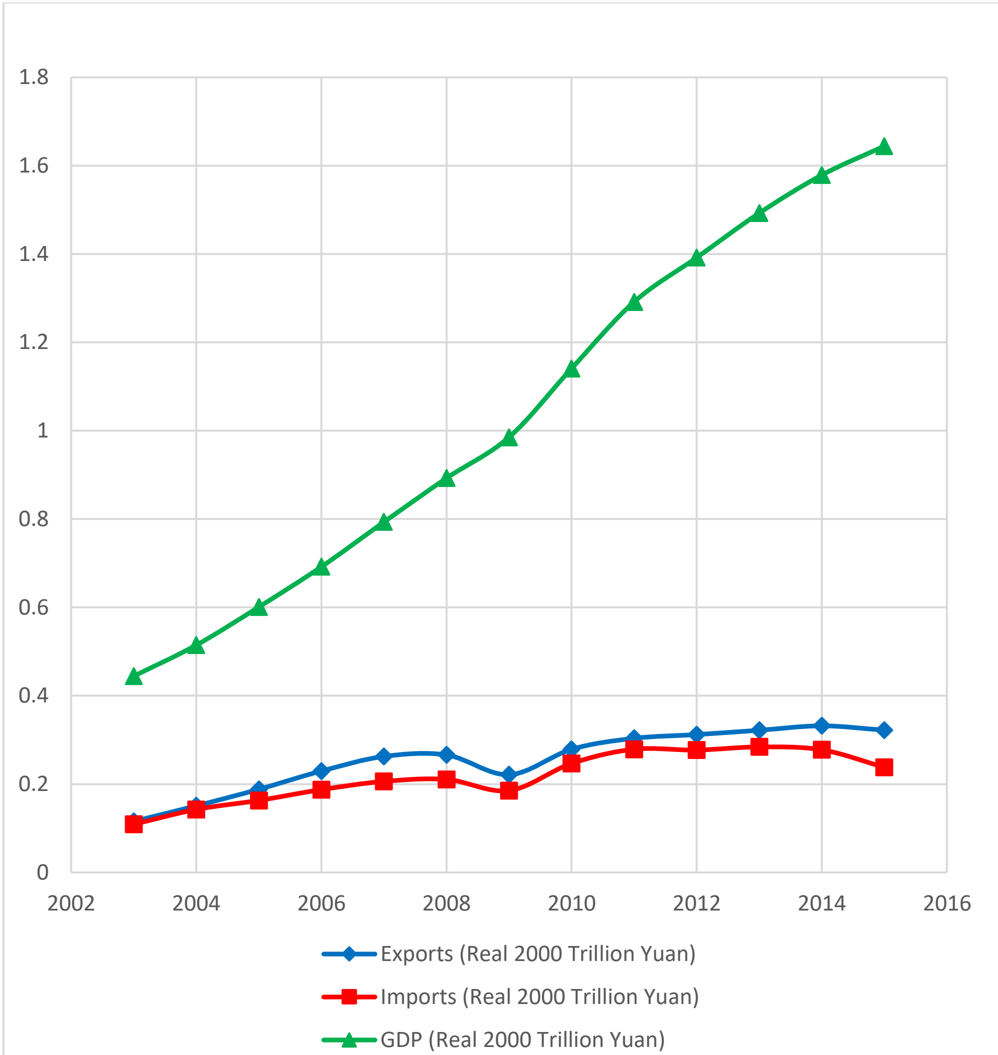

Figure 3.1: Trend of GDP, Exports and Imports for Overall China

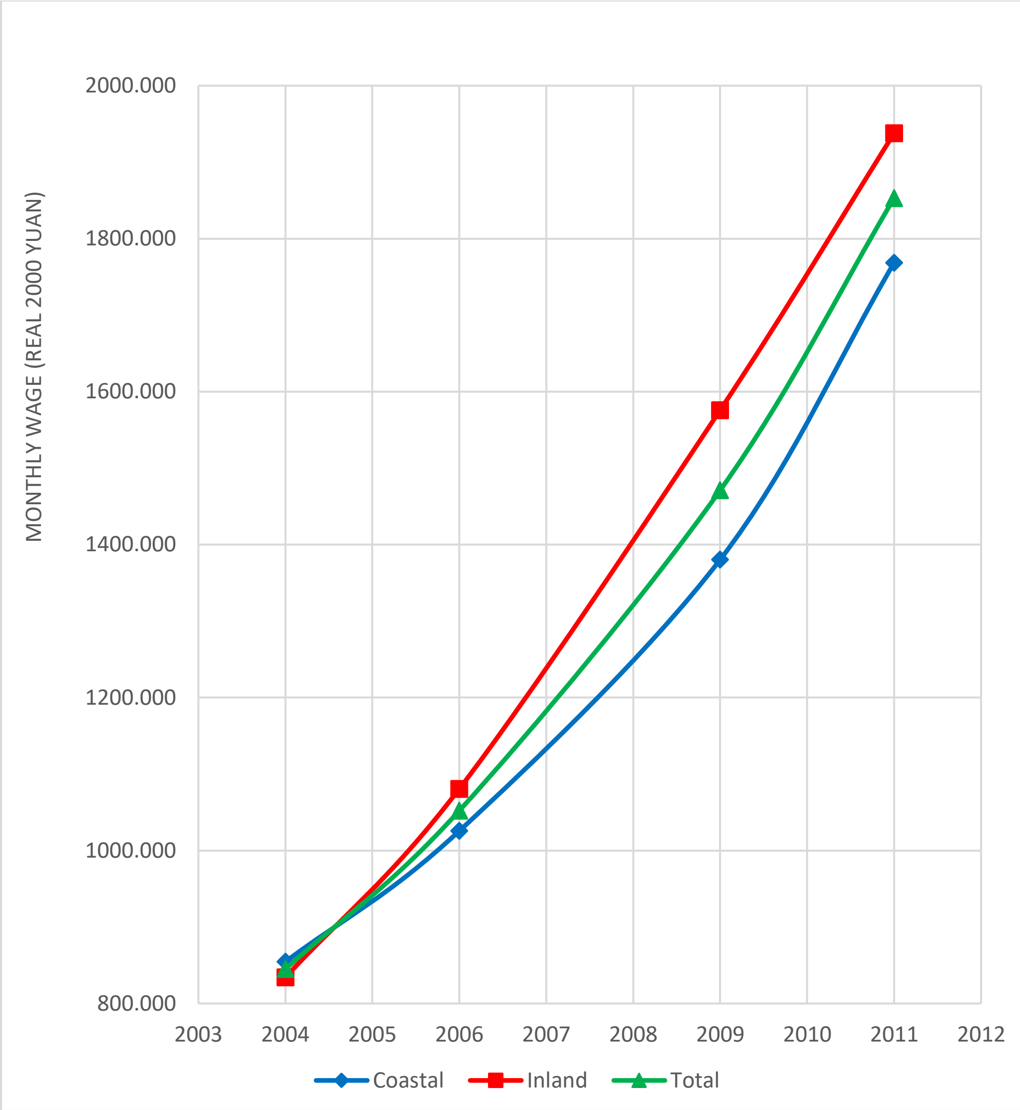

Figure 3.2: Trend of Average Monthly Wage for the Surveyed Area in China

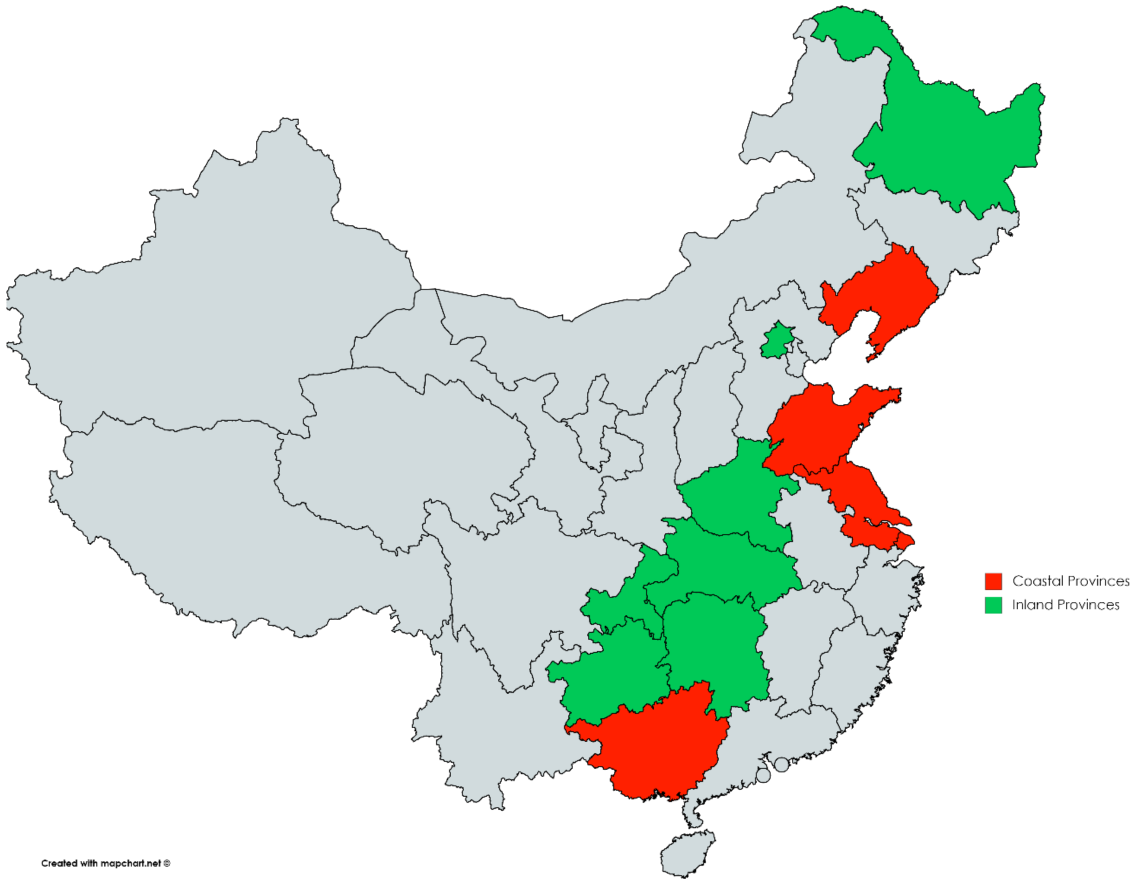

Figure 3.3: Map of China with Surveyed Provinces Colored

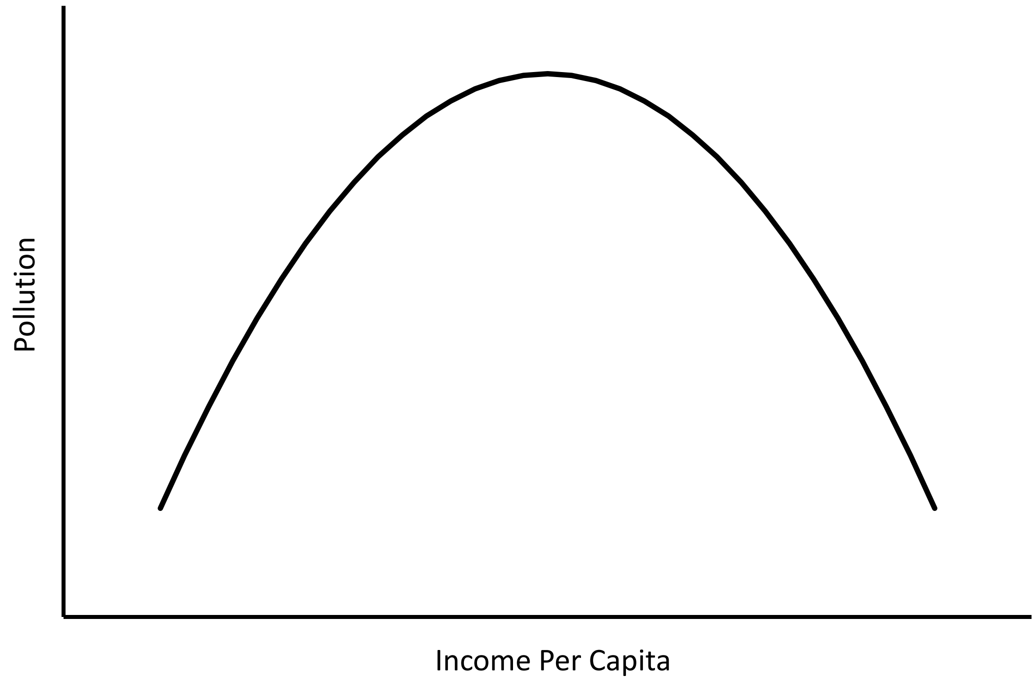

Figure 4.1: Environmental Kuznets Curve

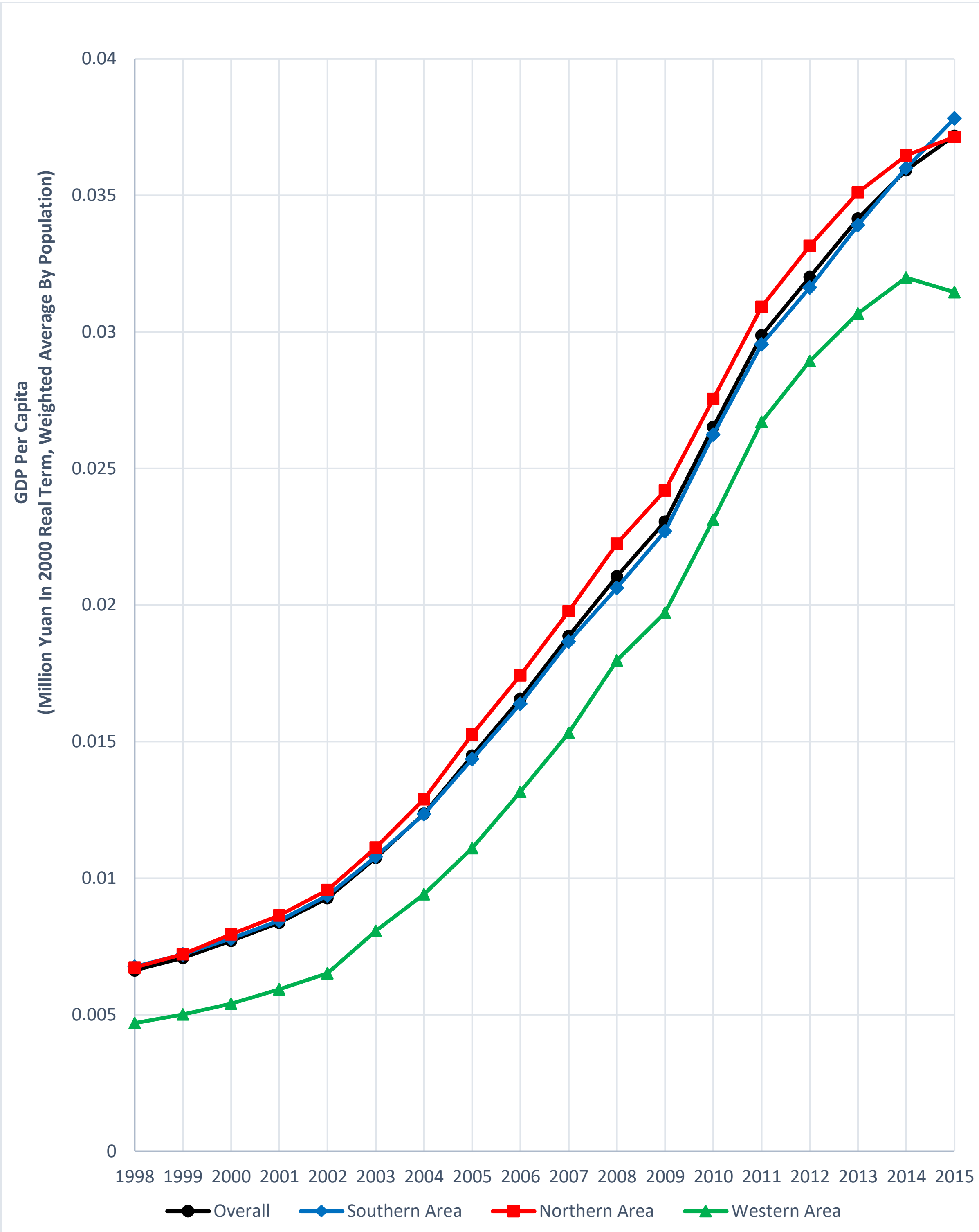

Figure 4.2: Trend of GDP Per Capita in China

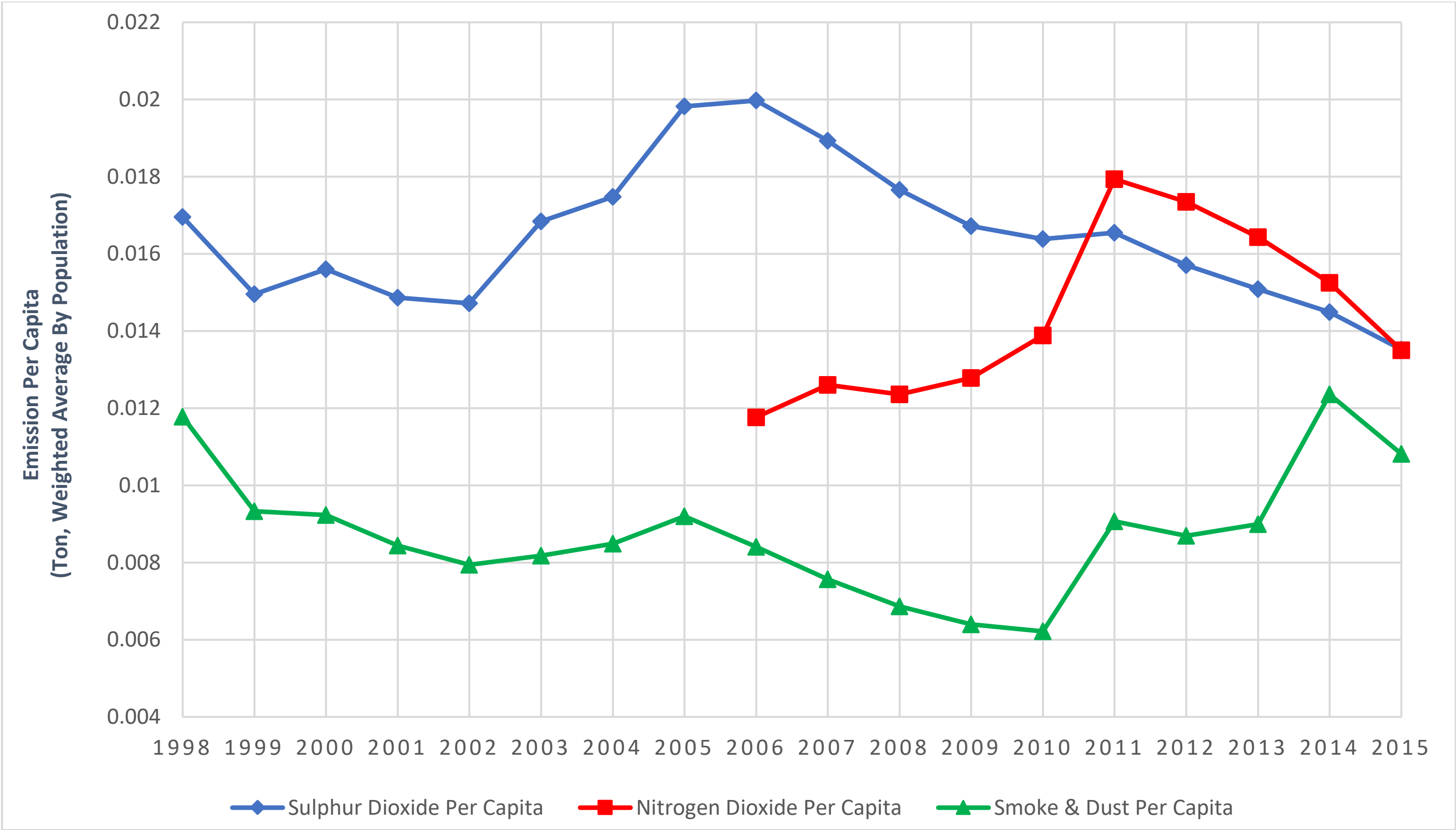

Figure 4.3: Trend of Air Pollution Per Capita in China

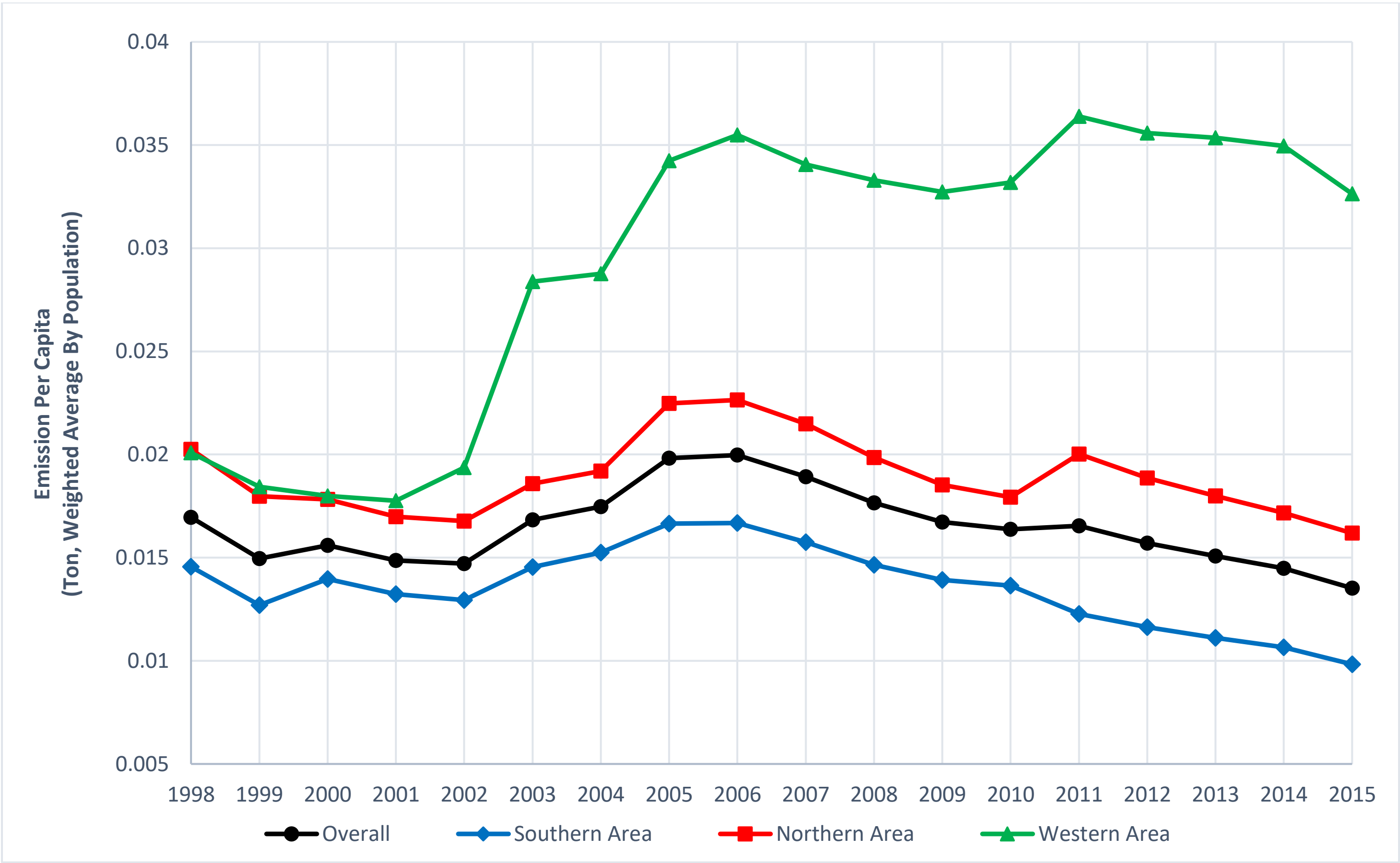

Figure 4.4: Trend of Sulfur Dioxide Per Capita in China

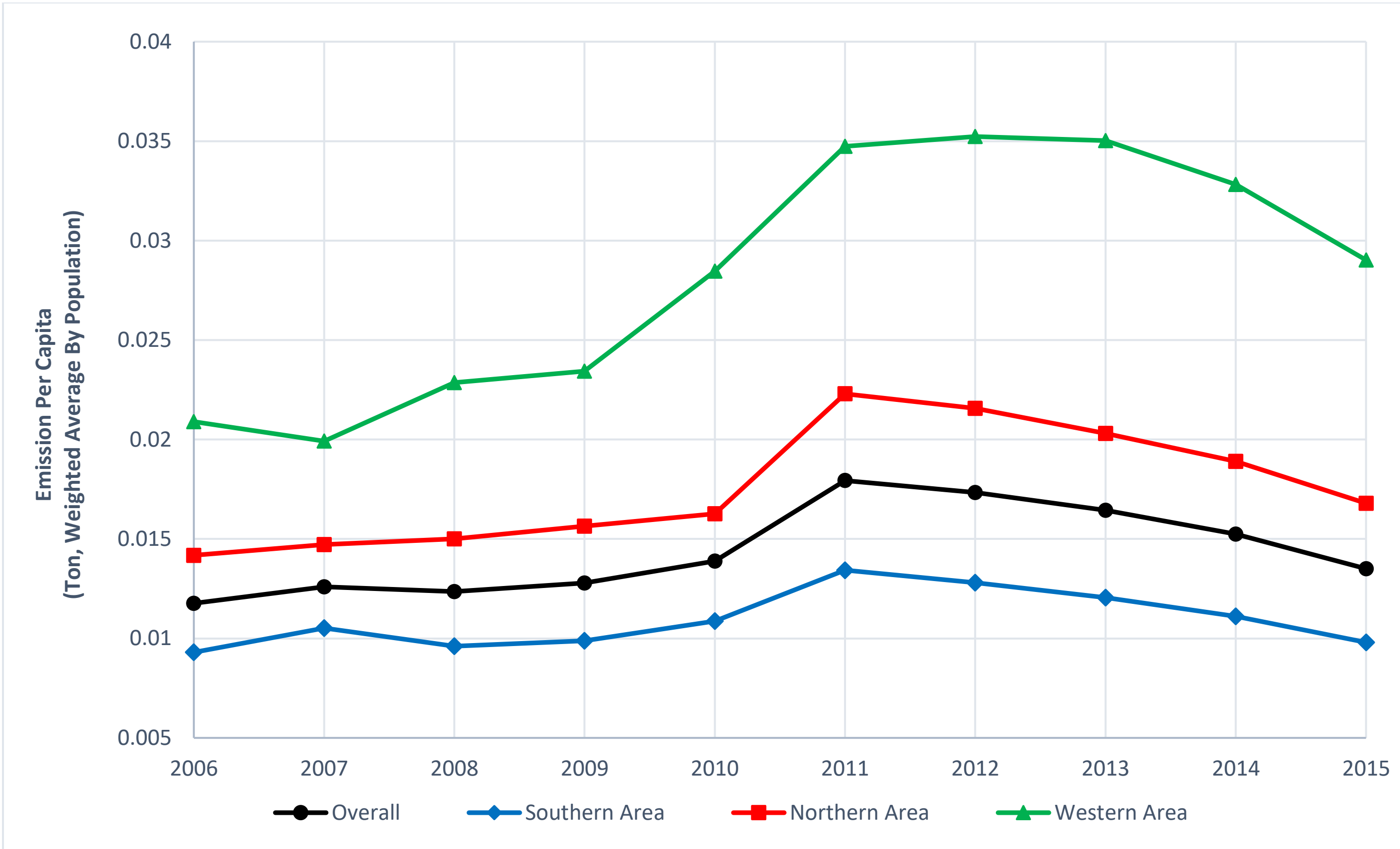

Figure 4.5: Trend of Nitrogen Oxides Per Capita in China

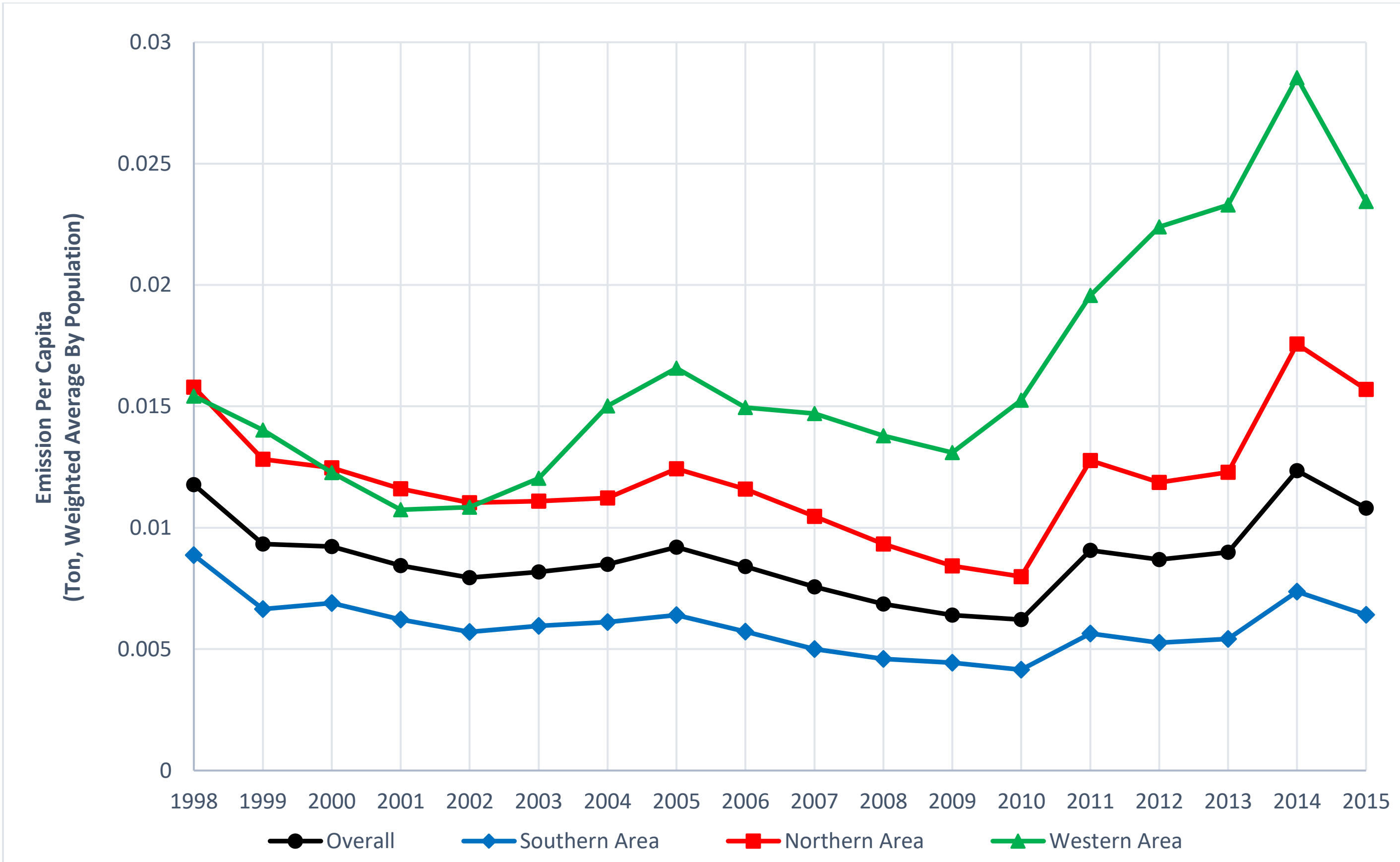

Figure 4.6: Trend of Smoke & Dust Per Capita in China

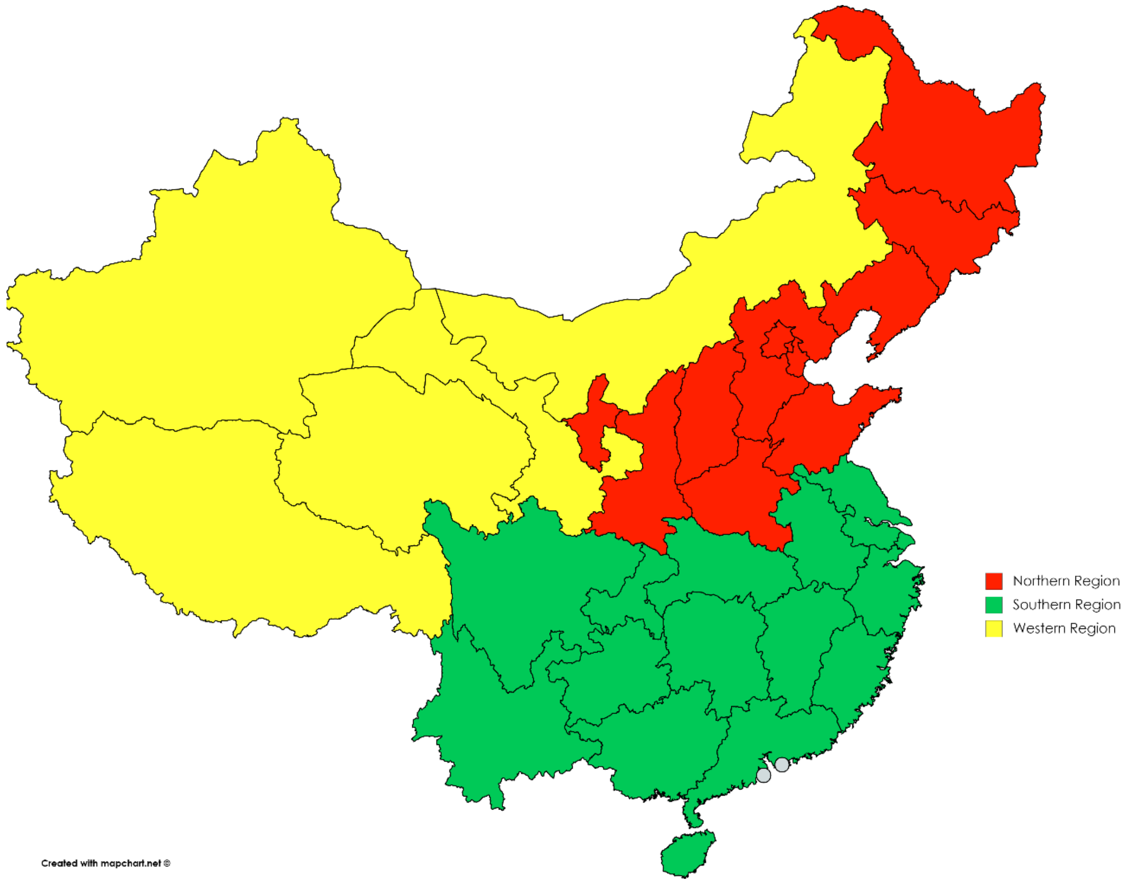

Figure 4.7: Map of China with Grouped Province Colored

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APPENDIX

Detailed Information about the Data Source of Each Air Pollutant

General: According to the data documentation from the *China Statistical Yearbook*, the data for pollutions are self-reported, collected by the Ministry of Environmental Protection of the People's Republic of China, including the emissions from industrial companies, as well as, the emissions from household daily use in urban areas. The data for major industrial companies are collected by comprehensive surveys, while the data for other companies are estimated, so the data for the total industrial emissions are obtained by adding up the two. The data for the emissions from household daily use are estimated based on relevant statistics and technical parameters.

Sulfur Dioxide: According to the data documentation from the *China Statistical Yearbook*, the industrial sulfur dioxide emissions are generated from the use of fuel, as well as other production procedures of industrial companies, while the volume of sulfur dioxide emitted from non-industrial activities is calculated based on the amount of coal used by households as well as other non-industrial activities, and the amount of sulfur contained in the coal. The formula is given by:

sulfur dioxide emitted from non-industrial activities = the amount of coal used by households and other non-industrial activities * sulfur content * 0.8 * 2

Nitrogen Oxides: The data for nitrogen oxides are incomplete in the *China Statistical Yearbook*, so the data are collected from a user on bbs.pinggu.org (a Chinese website for sharing economic data regarding China), whose name is not specified on the website. In the *China Statistical Yearbook*, the data for nitrogen oxides are available only from 2011 to 2015. For the years when the data are available in the *China Statistical Yearbook*, the data published by the user are exactly the same; for the years when the data are not available in the *China Statistical Yearbook*, the data published by the user are consistent with the rest and have already been verified by some other users. Thus, the data for nitrogen oxides used in this study are reliable.

Smoke & Dust: According to the data documentation from the *China Statistical Yearbook*, industrial soot is generated from the use of fuel by industrial companies. Non-industrial soot is emitted from the fuel use of all social and economic activities, as well as, public facility operations other than industrial production. It is calculated based on the amount of coal used by households and other non-industrial activities.

According to the data documentation from the *China Statistical Yearbook*, industrial dust is emitted from the industrial companies during their production and suspends in the air for a long period. It includes the dust from refractory materials of steel factories, coke-screening systems and sintering machines of coke plants, lime kilns and cement production for construction needs, but soot and dust emitted from power plants are not included.