2016

The Effects of Air Pollution on Education and Human Capital: Evidence from Chinese Cities

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May 2016

Acknowledgements

I am very thankful to everyone at Connecticut College for their support with my research over this past year. Most importantly, I would like to thank my advisor professor Wei Zhang for her help and guidance throughout this process. I also would like to thank the Economics department for their four years of tutelage and helping me love the study of economics. I would like to thank the Connecticut College Library staff for their assistance with finding the resources necessary for this research. I would also like to thank all of my friends and family, especially my parents for their unconditional support. And last, but certainly not least, I extend a huge “thank you” to Connor Trapp for helping me translate all of the Chinese I dealt with throughout my research.

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Abstract

This analysis investigates the impact of pollution on human capital stocks in Chinese cities. The Chinese economy, despite its high growth rates over the past few decades, has reached a point where it must seriously consider the costs of its severe pollution levels. Using panel data, from multiple data sources, of 283 Chinese cities for the years 2004-2013, we conduct an econometric analysis on the negative effects pollution has on the human capital stocks of these cities. Our findings show evidence that pollution has significant effects on the human capital stocks of these Chinese cities. These negative effects are mostly found on average wages and the number of college graduates in cities that are more heavily polluted.

I. Introduction

At the junction of the environment and the economy, conflicts often arise. Although our economy is dependent on our natural resources from the environment, often times these resources are often used inefficiently and can cause serious issues both to our environment and to our own health. Perhaps one of the most salient examples of economic production harming the environment is through pollution, most notably air and water pollution. We burn fossil fuels and generate vast amounts of chemical wastes in order to power our global economic endeavors. Waste, a consequence of the goods our system creates, is often dumped or released into the environment as a result, causing damaging effects, which degrade the environment and worsen the health of citizens.

Although all countries face this issue of balancing economic prosperity and environmental protection, developing countries are most exposed to these issues. Today, many developing countries face issues of dangerous levels of air pollution, which are not only degrading their environment but also harming the couple billion of citizens that live there. Perhaps no country is a better representation of a fast developing economy facing issues of air pollution than China is today. Since its "opening up" and capitalistic reforms starting in 1978, China has seen unprecedented economic growth. According to the World Bank, China's annualized average growth since 1990 is about 9.9% (World Bank 2012). When that figure is compared to the global annualized average growth rate of about 3.9% for the same time period, it shows how impressive China's economy has been in the past decades. Contextualized, these impressive growth rates have raised millions of Chinese citizens out of poverty and led to significantly better standards of living for the majority of its citizens.

However, this incredibly impressive economic track record of China has come at a cost: namely the degradation of its environment and the compromising of its citizens’ long-term health and well-being. Since 2008, when it overtook the United States, China has been deemed the world’s largest polluter. China has seen increasing levels of air and water pollution concentrations over the past decades, and the issues resulting from said pollution are becoming a growing concern. According to Pan Yue, the Vice Minister of State Environmental Protection Administration “The [economic] miracle will end soon because the environment can no longer keep pace” (Economy 2007). Recently, in December of 2015, the city of Beijing came to a “standstill” as schools, businesses and roadways were shut down due to the poisonous levels of air pollution (Wong 2015). A very salient and controversial debate today, both in China and in countries across the globe, there have been increasing pressures from societies and governments to curb economic goals in order to protect the environment and public health.

The World Bank (2012) report discusses many issues with the current scope of the Chinese economy, such as inefficient financial systems and rising labor costs, but it also discusses the need for China to become more environmentally conscious. World Bank (2012) acutely echoes the inspiration for this research paper in their analysis, claiming the importance of human capital promotion as well as environmental protection for the Chinese economy. According to the report “increasing the quality of human capital will not only increase labor productivity and maintain China's competitiveness; it will also allow manufacturing and services to move up the value chain" (World Bank 2012). And in regard to environmental protection and economic prosperity, the report claims "instead of considering environmental protection and climate change mitigation as burdens that hurt competitiveness and slow growth, this report stresses that green development could potentially become a significant new growth opportunity (World Bank 2012).

It is clear that the interaction between the environment and the economy of China is an intriguing and vital one to study. The degree to which the economy is impacted by these negative environmental effects, however, is still unknown. Is this path of economic growth, fueled by these massive pollution emissions, sustainable? Conversely, could the negative effects of pollution on citizens actually lead to a decrease or stagnation in economic growth? The World Bank estimates that the "costs" of air pollution approach 6.5% of GDP and 2.1% for water pollution (World Bank 2012). How the environmental degradation, such as toxic concentrations of air and water pollution, affects the Chinese economy is fundamental in determining what is the best pathway to economic prosperity and security for China and its 1.3 billion citizens.

Our economic systems often overlook and do not factor in externalities, such as pollution, and thus it is important to study the costs to society that they bring us in order to correct them. Although there is a multitude of ways environmental degradation is impacting the Chinese economy, this study focuses on how the levels of air and water pollution impact the economy of Chinese cities through its effects on the human capital of its citizens. Using panel data, from multiple data sources, of

283 Chinese cities for the years 2004-2013, we conduct an econometric analysis on the negative effects pollution has on the human capital stocks of its cities. The major findings of our analysis show evidence that pollution has some negative effects on the human capital stock in Chinese cities. These negative effects are mostly found on wages and the numbers of college graduates in cities that are more heavily polluted.

The structure of this analysis will be as follows. Section II will review the existing literature and analysis regarding human capital's importance to economic growth as well as the effects of pollution on human capital. It will also discuss briefly how this analysis can contribute to the existing literature. Section III will outline the theoretical framework of our econometric analysis. Section IV will enumerate the data sources and variables selected for this analysis, as well as define and report summary statistics of these variables. Section V will hold the key results of our econometric analysis. Section VI will report the conclusions from our results, while Section VII will discuss the importance of this analysis as well as future studies and policy implications.

II. Literature Review

Human capital plays an instrumental role economy, especially in the long-term growth of an economy. Governments, as a result, often try to emphasize policies to promote the health and education of its population for economic reasons. Education accumulation and worker productivity can be influenced by many different factors, such as the environmental quality in which individuals grow up and live in. Negative environmental factors, such as air pollution, can hinder the human capital accumulation of a society, and consequently hindering the potential of its economy.

Human Capital's Role in Economic Growth:

Innumerable works of economic research, both theoretical and empirical have emphasized the importance of human capital for economic growth. The understanding of the importance of human capital to economies dates back to Adam, who claimed the "improved dexterity of a workman may be considered in the same light as a machine or instrument of trade which facilitates and abridges labour, and which, though it costs a certain expense, repays that expense with a profit" (Smith 1776). Although Smith does not use the term "human capital," he understands that the investment in one's ability to perform labor is important economic endeavors.

The term human capital began to become more widely accepted and studied as the fields of developmental and growth economics matured during the 20th century. Although some growth theory models originally did not incorporate human capital, such as the Solow-Swan model, developed independently by Robert Solow (1956) and Trevor Swan (1956), most mainstream models have included human capital. Not only is human capital now deemed a necessary part in economic growth models, but some estimates show that it is an increasingly promising prospect for the Chinese economy. One study finds that the estimated total returns to investments in human capital by Chinese citizens, when accounting for both private and social returns, were around 30% or even 40%, significantly higher than most OECD countries (Fleisher and Wang, 2014). Most mainstream economic growth models, with both endogenous and exogenous frameworks, agree that increases in human capital stock will spur economic growth significantly.

Human capital is a more difficult term to define than physical capital due to its less tangible nature. Human capital can crudely be defined as the value of a person or population's ability to perform labor. This "ability" can be measured through characteristics such as personality and creativity as well education, health and experience. It is, perhaps rather obviously, difficult to quantify these elements of human capital and thus it is difficult to select a single perfect measure of human capital. The literature to this point has not come to a clear consensus on the best indicator to measure human capital, and thus different studies of human capital use different variables to act as a proxy for human capital. Different studies assume different variables, such as years of schooling, enrollment, worker productivity and wages, as measurements for human capital. Because different variables can produce different results, it is important to look at the assumptions these studies make for measuring human capital.

One such study that looks at the different ways of measuring human capital is Mulligan and Sala-i-Martin (2014). According to this paper, it is impossible to find a perfect measure for human capital, but economists should still strive to find the best proxy statistic for its measurement in studies. One of the most standard ways, used by economist R.J. Barro (1991), to measure human capital is through average years of schooling. The authors of this article spell out a few major problems with using average years of schooling as a proxy for human capital, revolving around the poor assumption that all schooling is equally productive or useful.

Mulligan and Sala-i-Martin (2014) introduces a different proxy, which they call "labor-income-based" measure, which attempts to measure human capital based on individuals' wages. Theoretically a worker would receive a higher wage depending on how useful his/her education, and thus their wage rate divided by the wage rate of a "zero-skill" worker would measure their level of human capital. This measure also has issues as they had to assume that the "zero-skill" worker was a perfect substitute for other workers, and thus created some bias in the study. Furthermore, this assumes that perfect competition exists, and that no issues of biases or misinformation affect hiring decisions. Despite these issues with imperfect quantifiable indicators for human capital, economists can still use these as variables as useful estimators.

Pollution and Human Capital:

In a similar manner to human capital, there are many different ways to measure air quality and air pollution levels. The criteria pollutants (ozone, particulate matter, lead, carbon monoxide, Nitrogen Dioxides and Sulfur Dioxide) measured by air monitoring stations, are the major way air quality is measured. Occasionally, economists use air quality index (AQI), which aggregates the levels of these 6 pollutants to measure air quality. A major issue with AQI and locally monitored pollution levels is the validity of the reported statistics due to the potential of officials "gaming" statistics, especially in developing countries. Ghanem and Zhang (2014) found significant evidence of fixed environmental data (specifically AQI figures) by Chinese city governments. Thus, due to this potential issue of falsified data, scientists and economists have had to figure out alternative ways to measure air pollution. A different way to measure air quality that environmental economists have used is aerosol optical depth (AOD). AOD, measured by satellites, measures the liquid and solid particles in the atmosphere that affect electromagnetic radiation. However, due to natural sources of aerosol (e.g. sea salt, dust storms and forest fires), AOD is only useful in relative rather than absolute analysis, as regional differences distort figures. Another indication of air pollution is visibility, which is shown as a good predictor of air pollutant concentrations (Zhang, Zhang, and Chen, 2015).

The current literature in the environmental economics field provides strong evidence that air quality has various impacts on the human capital levels of individuals and communities. Economists have shown that air pollution has various negative impacts on the human capital of individuals and communities, such as increased school absences (Currie et al., 2009), lower academic performance (Stafford, 2015), lower worker productivity (Zivin and Neidell, 2012), and the emigration of the highly educated workers (Cameron and McConnaha, 2006; Banzhaf and Walsh, 2008).

Currie et. al (2009) found that carbon dioxide concentration levels deemed by the EPA as "safe" still led to increased school absences in Texas. This fact shows that adverse effects on education can occur even at seemingly low levels of pollution. In a similar study, also conducted in school districts in Texas, Stafford showed that after renovations to improve indoor air quality led to markedly higher standardized test scores. Zivin and Neidell (2012) found that reductions in ozone concentrations improved the productivity of agricultural workers. Cameron and McConnaha (2006) find that increased emigration and lower housing prices are associated with communities that face "environmental emergencies." In a similar study, Banzhaf and Walsh (2008) find evidence that people "vote with their feet" by emigrating from communities with worse air quality to communities with better air quality.

Another strand of studies focuses on the effects of pollution on early childhood development and its consequences on future human capital accumulation. Almond and Currie (2011), among others, have found evidence that air pollution, including pre-natal exposures, can have severe and lasting impacts on the human capital accumulation of children under 5 years old. Most of the studies on the effects of pollution on human capital have been conducted in developed countries like the United States. Developed countries face pollution issues, but the nature of pollution in developing countries is different, as they tend to experience both more severe and frequent pollution shocks. Moreover, people in developing countries have limited resources for pollution mitigation. Thus, studies on the effects of pollution on human capital in developing countries contribute to the literature in significant ways (Currie and Vogl, 2013). This study will look to further delve into this underrepresented aspect in the literature.

III. Framework:

Theoretical Framework of Human Capital

As has been discussed in the literature review, human capital is difficult to define. It can be roughly described as the value of a person or population's ability to perform labor. Such value can be derived from one's health, education, experience, personality and a myriad of different factors. Thus theoretically, the human capital stock of an individual would be the sum of his/her inputs of such different factors. However, even assuming that levels of human capital can be aggregated or summed from quantifiable factors is a huge assumption, as workers are not homogenous even if all quantifiable factors are the same due to simple human differences. Thus the issue with measuring human capital, in comparison to something more easily quantifiable like physical capital, is trying to find the most accurate or representative estimate to the true immeasurable level, whether it is for an individual or population.

The Impact of Human Capital on Economic Growth

Human capital is a vital part of economic growth. For better or for worse, a main barometer of economic success is the growth rate of countries, in terms of Gross Domestic Product. However, as economies and markets are incredibly complex and multifaceted, it is impossible to perfectly explain why some countries grow faster than others. Nonetheless, economists have developed many models that are actually relatively good at predicting ranges of economic growth for countries. One major theoretical way to look at how and why economic growth occurs is through the Solow Swan model, an exogenous economic growth model developed independently by Robert Solow (1956) and Trevor Swan (1956), and the various contributions other economists have added to the model over the past decades.

Originally the model looked at how capital accumulation, population growth and productivity increased economic growth. The formula of the basic Solow-Swan model is as follows:

$$(1)\ Y_t = A * K_t^{\alpha} * L_t^{1-\alpha}$$

Where:

$Y_t = Income\ at\ time\ period\ t$
$A = Productivity$
$K_t = Capital\ stock$
$L_t = Labor\ Force$
$\alpha = Capital's\ share\ of\ income$ (<1)

For a while, these were seen as the main drivers of economic growth. In this model, the only reasons for economic growth (an increase in Y) were from positive exogenous changes to the labor force, capital stock or productivity (increases in L, K or A respectively). However, this model soon became outdated and flawed, due to its less than effective ability to predict economic growth. As a result economists, such as Mankiw, Romer and Weil (1992) added human capital into the framework of the model. This makes conceptual sense, as workers with higher human capital would be able to use physical capital in a more productive manner, leading to greater output per worker. With the addition of human capital, the Solow-Swan model is as follows:

$$(2)\ Y_t = h^{1-\alpha} * A * K_t^{\alpha} * L_t^{1-\alpha}$$

Where:

$h = Human\ Capital\ Level$

Thus, with human capital added into the model, economic growth can now be spurred by increases in human capital. Although the model is not perfect, and many economists prefer using endogenous economic growth models rather than the Solow-Swan exogenous model, it still provides us with a basic framework that shows the importance of human capital on economic growth.

The Effects of Pollution on Human Capital

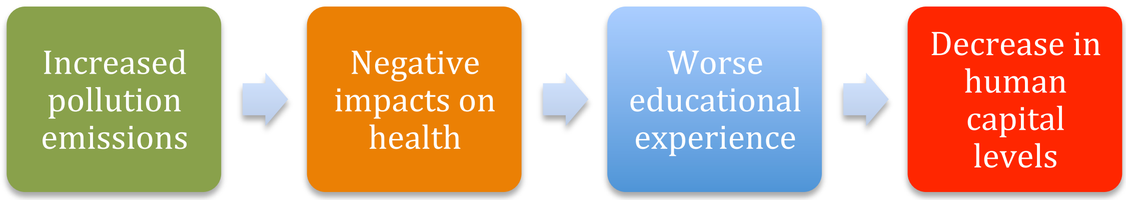
Now that we see a clear theoretical link between human capital and economic growth, the next step would be to examine the interaction between pollution and human capital. Again, human capital can be roughly defined as the value of a person or population's ability to perform labor. Such value can be derived from one's health, education, experience, personality and a myriad of different factors. Determining how pollution effects these quantifiable factors is a difficult and not always obvious.

In this analysis we will mainly look at how the education of individuals, which is just a single factor (although a major factor) of human capital, is impacted by pollution levels. In this case, there is no significant direct impact of pollution on education. The impact, however, does come through the health. As has been shown in the literature review, the impact of pollution on health is abundantly clear. Pollution, as has been shown by many studies, can lead to many distinct medical issues, which in turn can affect one's educational experience. It is important to note, as a point of clarification, that educational experiences do not immediately impact the human capital stock of an economy, as the students have yet to enter the labor market. Instead, this impact on education would have a delayed effect on the long-term human capital stock of an economy. This delayed effect can be rather short, when looking at higher education, or much longer if the analysis revolves around pre-school or primary school factors. Formulaically, we assume that Human capital is a function of education, amongst other variables, and education is a function of health, amongst other variables, and that health is a function of health, amongst other variables.

$$Human\ Capital = F(\boldsymbol{Education}, Experience, Personality \ldots)$$
$$Education = F(\boldsymbol{Health}, Income, Residence \ldots)$$
$$Health = F(\boldsymbol{Pollution}, Genetics, Diet \ldots)$$

Thus, we would assume, theoretically that increases in pollution would lead to a deterioration of health, and thus a worse educational experience.

Figure 1: Process of the indirect effect of pollution on human capital



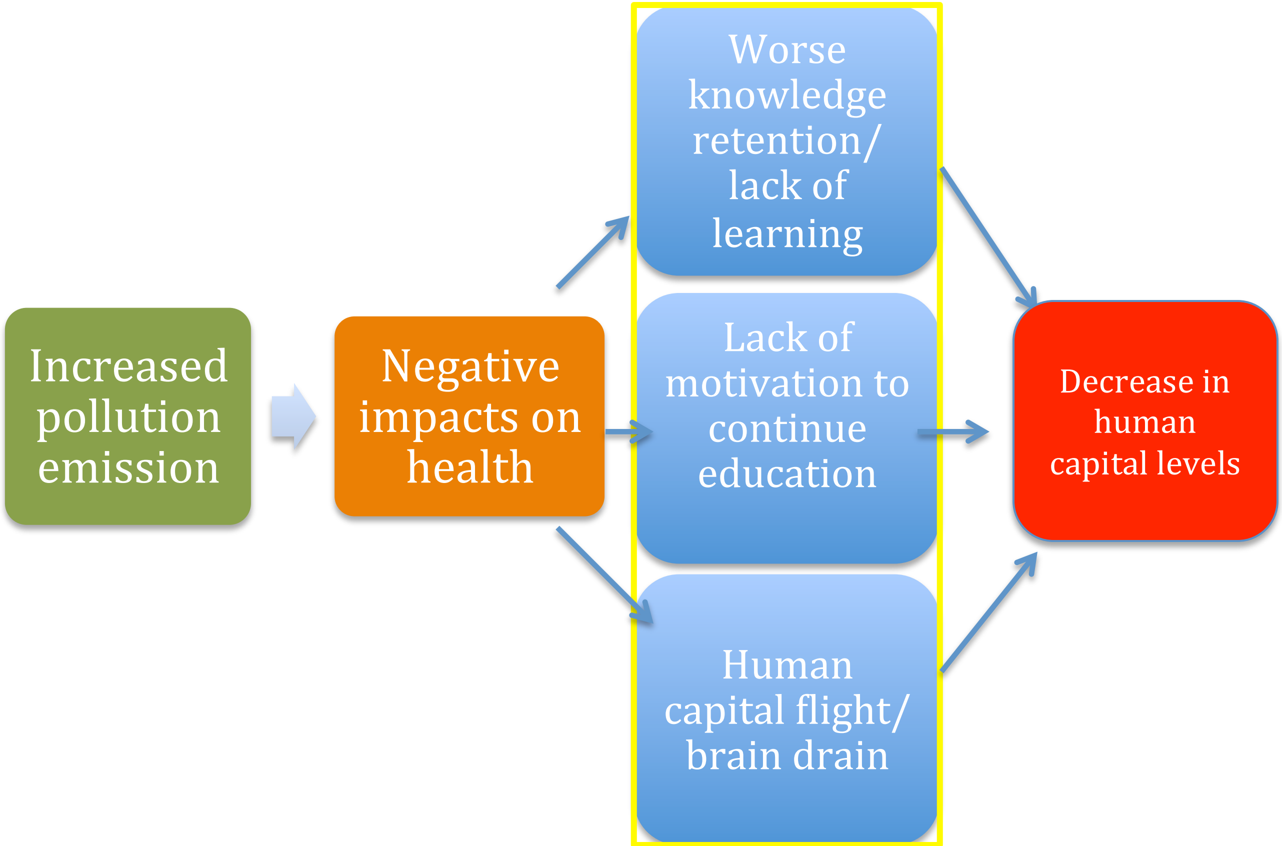
However, defining "worse educational experience" is important, as it is a rather subjective term. One way it could be interpreted is through a fundamental lack of learning, or worse knowledge retention by students. Thus, through school absences due to sickness or other means, pollution could indirectly lead to students learning less in schools. Although not a perfect way to measure knowledge retention or amount learned, test scores or other quantifiable grades would be a valid way to measure this effect. As we see with Stafford (2015), indoor pollution did affect test scores, and thus it would be reasonable to think outdoor pollution may have a similar impact.

However test scores and grades are not the only way to measure the educational experience, as we can also look at how far individuals continue with their educations. For instance, although grades and test scores may be high in one city, if most students leave school early or do not attend college, the human capital levels will be lower. Although likely connected (students with lower grades are less likely to be accepted into higher education institutions), students may be less motivated to continue their education if they are constantly sick due to high levels of pollution.

One further impact pollution can have on human capital is through "human capital flight." Similar to capital flight, where capital leaves a country or city, human capital flight, sometimes referred to as "brain drain," is when highly educated individuals leave a country or city in search for better jobs, educational opportunities, or general lifestyles. In this case, human capital flight could be a preemptive reaction to the negative health impacts of pollution, either through leaving or simply avoiding the city or country. This effect would be noticed through such variables as college attendance/graduation figures, demographic educational breakdowns and emigration rates. There is precedent for this "brain drain" as pointed out by Banzhaf and Walsh (2008). This brain drain could potentially be driven by the individual himself/herself (i.e. choosing to not go to college in a certain city) or by the individual's parents/guardians (i.e. moving in order to secure a better educational experience for their children).

Therefore we can see that the negative health impacts of pollution, of which there are several, can theoretically have many different impacts on the educational experience of individuals, and thus the human capital levels of the city or country.

Figure 2: Different ways pollution can negatively impact human capital



Now that we have looked at a few factors of how pollution impact human capital, by way of worse health, it is important to identify which factors can be studied and quantified in the case of Chinese cities. As is the case with many studies, data are not available or relevant for some countries. Thus, for this analysis we will have to focus on the latter two educational factors, human capital flight and lack of motivation to continue education. Due to lack of data for cities and years for China, this analysis will unfortunately have to ignore the pathway of worse knowledge retention on human capital.

For our analysis we will use educational variables as our dependent variable and pollution (for which we have several different metrics) as our dependent variable along with other control variables. Thus the basic function of our analysis will be as follows:

$$HumanCapital_t = F(Pollution_t, X_t, \dots)$$

Where X represents all of the other socioeconomic control variables that affect education. The basic econometric model of our analysis is:

$$(3)\ HumanCapital_t = \beta_0 + \beta_1 pollution_{it} + \beta_2 X_{it} + \cdots + \ e_{it}$$

Where A represents the coefficient for pollution, and B and C represent the coefficients for our socioeconomic control variables. Using this linear regression, through the OLS framework, we will attempt to isolate the effect of pollution on education. More specifically, we will run these six main regressions for each of our human capital variables, using average wage as an example:

$(\mathbf{4})\ AverageWage_{it} =$

$\beta_0 + (\beta_1 SO2_{it}) + (\beta_2 Population_{it}) + (\beta_3 GDPperCapita_{it}) +$

$(\beta_4 PassengerTraffic_{it}) + (\beta_5 FreightTraffic_{it})$

$(\mathbf{5})\ AverageWage_{it} =$

$\beta_0 + (\beta_1 SO2_{it}) + (\beta_2 Population_{it}) + (\beta_3 GDPperCapita_{it}) +$

$(\beta_4 PassengerTraffic_{it}) + (\beta_5 FreightTraffic_{it}) + (\beta_6 Region1_{it}) +$

$(\beta_7 Region2_{it}) + \cdots (\beta_{36} Region31_{it})$

$(\mathbf{6})\ AverageWage_{it} =$

$\beta_0 + (\beta_1 SO2_{it}) + (\beta_2 Population_{it}) + (\beta_3 GDPperCapita_{it}) +$

$(\beta_4 PassengerTraffic_{it}) + (\beta_5 FreightTraffic_{it}) + (\beta_6 Region1_{it}) +$

$(\beta_6 Region2_{it}) + \cdots (\beta_{36} Region31_{it}) + (\beta_{37} Region1T_{it}) + (\beta_{38} Region2T_{it}) +$

$\cdots (\beta_n Region31T_{it})$

$(\mathbf{7})\ AverageWage_{it} =$

$\beta_0 + (\beta_1 SO2_{it}) + (\beta_2 Population_{it}) + (\beta_3 GDPperCapita_{it}) +$

$(\beta_4 PassengerTraffic_{it}) + (\beta_5 FreightTraffic_{it}) + (\beta_6 City1_{it}) + (\beta_7 City2_{it}) +$

$\cdots (\beta_{288} City283_{it})$

$(\mathbf{8})\ AverageWage_{it} =$

$\beta_0 + (\beta_1 SO2_{it}) + (\beta_2 Population_{it}) + (\beta_3 GDPperCapita_{it}) +$

$(\beta_4 PassengerTraffic_{it}) + (\beta_5 FreightTraffic_{it}) + (\beta_6 City1_{it}) + (\beta_7 City2_{it}) +$

$\cdots (\beta_{288} City283_{it}) + (\beta_{289} Region1T_{it}) + (\beta_{290} Region2T_{it}) + \cdots (\beta_n Region31T_{it})$

$(\mathbf{9})\ AverageWage_{it} =$

$\beta_0 + (\beta_1 SO2_{it}) + (\beta_2 Population_{it}) + (\beta_3 GDPperCapita_{it}) +$

$(\beta_4 PassengerTraffic_{it}) + (\beta_5 FreightTraffic_{it}) + (\beta_6 City1_{it}) + (\beta_7 City2_{it}) +$

$\cdots (\beta_{288} City283_{it}) + (\beta_{289} City1T_{it}) + (\beta_{290} City2T_{it}) + \cdots (\beta_n City283T_{it})$

$\boldsymbol{Where}$:

$\boldsymbol{RegionX} = Region\ x$
$\boldsymbol{CityX} = City\ x$
$\boldsymbol{T} = Time\ period\ (starting\ with\ 2004)$

In words, equation 1, the most basic model, will simply try to capture the effects of pollution on our dependent human capital variable by controlling only for our socio-economic variables. Equation 2 will build upon equation 1, but adding further fixed effects controls for unfound regional differences (regional fixed effects). Equation 3 will add time-specific regional control to this model. Equation 4 will control for city specific fixed effects. Equation 5 will control for both city specific fixed effects and regional specific time trends. Lastly, Equation 6, will control for city fixed effects as well as city specific time trends.

IV. Data

In order to conduct our analysis, we have to compile data on variables that measure human capital stocks as well as variables that measure emissions of pollution in Chinese cities. Furthermore, we need to collect data on variables, such as socio-economic factors and weather, which also affect human capital.

For this analysis we use data in the "China Statistical Yearbooks" from 2003-2013 for 31 cities, the "China City Statistical Yearbooks" from 2004-2013 for 283 cities and the "China Data Center," a database that compiles data from multiple different sources, mostly from similar statistical yearbooks, from 1995-2013 for 274 cities[1]. The weather data are taken from the National Oceanic and Atmospheric Association (NOAA) database.

Human Capital:

As stated in the literature review, it is difficult to measure human capital accurately. There are many potential variables for human capital, but some are more suitable or appropriate for different research goals. Furthermore, whereas some measurements might be useful in certain states or countries, they might be obsolete or unavailable to use in others. For instance, primary school enrollment rates may seem like a useful indicator to gauge the human capital investment in young children; however, in the case of China, primary school enrollment is required by law so looking at enrollment rates would make little sense as all cities would be very close to 100%. It would be great to use more detailed measurement,

[1] The China Data Center is a database maintained by the University of Michigan. They compile data from multiple data sources, such as statistical yearbooks.

such as, standardized test scores or school absences, but unfortunately, these data are not easily accessible.

For this study, we measure human capital using multiple variables, namely school enrollments, graduates and wages. The first two categories of which revolve around the fact that schooling is the key contributor to education, and thus human capital development. If a higher percentage of citizens were enrolled or graduating from schools in a particular city, it would be safe to assume that the human capital levels of that city are higher, or will be higher in the future. We will look at all levels of education, from pre-school enrollments to college graduations as each variable can tell a different story. For instance, changes in the number of college graduates in a city can show a rather immediate change in human capital that will immediately affect the local economy, as most college graduates enter the workforce after graduation. On the other hand, a change in pre-school enrollments can show that there may be an increasing trend in the human capital levels in the city, as preschoolers will not have a direct impact on the local economy, at least not due to their human capital accumulation, for many years. Each school level variable can tell us different things about the sensitivity of that group to pollution in regards to their accumulation of human capital.

We must also look at how our variables fit in, in terms of our framework of human capital, or the three pathways in which pollution can affect human capital through its effects on education. Our value for college graduates will be a good indicator to look at how pollution affects the willingness or motivation to continue one's education, as college is not a compulsory educational step and is often attended by individuals who truly want to continue educating themselves. College graduate figures can also indicate the level of brain drain or human capital flight in a city in response to high pollution levels, as individuals are able to choose (to some extent) where they want to go to college.

We will also look at new enrollment for junior secondary and primary school figures to examine human capital flight, as they will be a measure of how families with children move in response to pollution levels. Pre-school enrollment can also be used for similar reasons of human capital flight as new enrollment figures. In fact, pre-school enrollment may be more useful as the literature shows how younger age groups are more greatly impacted, in terms of their human capital accumulation, by pollution.

We will also use average wages as a measure of human capital levels, as wages are theoretically associated with an individual's stock of human capital. Those who have greater human capital to offer potential employers can demand higher salaries than workers with lower stocks of human capital. Thus, cities with higher average wages are likely to have higher stocks of human capital than cities where average wages are lower. This theory relies on the efficiency and fairness of the labor markets as it assumes that workers are accurately compensated for their experience and education levels. In the case of China, as well as anywhere else in the world, this assumption of "perfect competition" is strong, but it can still be useful for our purposes.

Pollution:

This study will use both direct and proxy measurements of pollution. Pollution is an overarching problem that not only intersects with the economic sphere but also many other aspects of society. Furthermore, there are many different types of pollution ranging from noise pollution to air pollution. For this study, it is important to identify which sources of pollution have direct or indirect impacts on economic variables, specifically human capital stock variables. We emphasize on air pollution for two reasons: there is more evidence that it seriously negatively impacts people’s health and productivity and that it is a very serious and salient problem facing China today and in the future. However, wastewater emissions will also be examined, as water pollution can also lead to illnesses and other physical effects, and it also is becoming an increasingly important problem in China.

Air pollution is a very general term and encompasses many different types of pollutants, each of which has its own separate effects on humans and the environment. While there is an aggregate air pollution index (Air Quality Index or AQI) that summarizes the emissions of the major air pollutants, there is evidence that it is unreliable, as Chinese government officials likely “fix” the data in order to make themselves and their cities look better to the central government (Ghanem and Zhang, 2014). Thus, although AQI would theoretically give a great all-encompassing measure of a city’s air pollution level, this study will focus on other variables. Emissions data of individual pollutants are less likely to be manipulated, given that they are not directly linked to the evaluation of government officials, and thus using these data will be preferred to AQI figures. Pollution variables used in this study are emissions of individual pollutants including sulfur dioxide and particulate matters, in this case crudely called "soot and dust emissions." Many studies have looked at the effects of particulate matters, as they greatly affect individuals' respiratory systems, and thus likely have a huge direct impact on human capital stocks. On the other hand, sulfur dioxide is likely to have less of an impact on human capital, as its long-term effects on humans are less than particulate matters. However, because most sulfur dioxide is emitted from the burning of coal, which also releases other pollutants and CO2 into the atmosphere, sulfur dioxide emissions can serve as a measure of the general air quality. . We will also examine NO_2 and PM 10, as they also can have serious effects on the health of individuals.

We will also use visibility as a proxy for air pollution. Visibility can be roughly defined as "the greatest horizontal distance that can be seen in half or more of the horizon circle." Although not a direct measurement of air pollution, there has been evidence that there is a close correlation between visibility and air quality (Zhang, Zhang and Chen 2015). Moreover our visibility data, which comes a from different data source (NOAA), provides a robustness check against any faulty or "gamed" pollution data from China.

Socio-economic Variables:

The goal of our analysis is to isolate the effects of air pollution on human capital. Socio-economic factors, such as city populations and GDP per capita, affect the accumulation of human capital in a city through many channels. For example, because larger cities can be "hubs" for greater inspiration and innovation, we might expect them to have higher school enrollments and college graduates. Furthermore, richer cities likely have higher enrollments/graduations for non-compulsory pre-school and college admissions, as they often are relatively expensive. Larger and richer cities also likely have higher pollution emissions, due to the higher energy demands by their citizens. Including socio-economic factors in our model helps us to identify the impact of pollution on human capital in both Shanghai (estimated 14.3 million people in 2013) and Shihezi (estimated 355,000 people in 2013) in a meaningful way.

Transportation variables, such as passenger and freight traffic, are also included in the econometric model, because many of our pollution variables only take industrial emissions into account. While industrial emissions have been, and still are, a large proportion of air pollution in Chinese cities, mobile sources of air pollution from transportation have become increasingly relevant over the past years (Viard and Fu 2015).

Weather Data:

Lastly, we include weather variables, temperature, precipitation, and heating/cooling degree-days in different models. As stated before, we want to study the effects of pollution concentrations, and not just the emissions, as concentrations are the actual amount of pollutants in the atmosphere that affect human health. Air pollution concentrations are often impacted by weather conditions and thus we must control for these weather variables in order to better estimate the effect of air pollution on human capital.

Table 1: Definitions of Variables

Variable	Definition	Years	Data Source
Pollution Variables			
Industrial wastewater emissions (ten thousand tons)	Refers to total volume of wastewater discharged by all the drainage outlets in industrial factories area to outside of the above factories. These water includes discharged waste water from production, sewage from daily-life use in plant area, discharged directly cooled water, poisonous and harmful mineral and underground water exceeding the discharge standard of mine district, and exclude discharged indirectly cooled water. The directly cooled water and indirectly cooled water in some enterprises those are not discriminated easily can be calculated together.	2004-2013	China City Statistical Yearbook
Industrial sulfur dioxide emissions (tons)	Refers to the total volume of discharged sulfur dioxide into atmosphere from production and fuel-burning procedures of industrial factories.	2004-2013	China City Statistical Yearbook
Industrial Soot Emissions	Refers to the volume of solid soot in the smoke discharged in the process of fuel burning in the area of the factory.	2004-2013	China City Statistical Yearbook

Ceiling Visibility(feet)	Definitions: Ceiling is defined here as the height above ground of the base of the lowest layer of clouds that when combined with any layers below it, accounts for more than half of the sky above the point of observation. Visibility is defined as the greatest horizontal distance that can be seen in half or more of the horizon circle. Purpose: This summary shows the percent frequency of occurrence that weather station visibilities are greater than or equal to any of 16 selected visibility thresholds (given in miles) while ceilings are at or below any of 31 selected ceiling threshold values (given in feet). Ceiling values range from 0 to 20,000 feet and visibilities range from 0 to 7 miles.	2004-2013	NOAA
PM 10 (mg/m^3)	Average Annual Concentration of Particulate matters measured at 10 micrometers	2004-2013	China Statistical Yearbook
NO2 (mg/m^3)	Average Annual Concentration of Nitrogen Dioxide	2004-2013	China Statistical Yearbook
Days Above Air Quality II	The number of days that meet a certain criteria of good air quality (based off of SO_2, TSP, PM10, NO_x, NO_2, CO, O_3 concentrations)	2004-2013	China Statistical Yearbook
Human Capital Variables			
College Graduates(persons)	Refers to number of graduates from higher education institutions	2004-2013	China Data Center
New Enrollment Junior Secondary (persons)	Refers to the number of newly registered students in schools.	2004-2013	China Data Center
New Enrollment Primary (persons)	Refers to the number of newly registered students in schools.	2004-2013	China Data Center
Pre-School Enrollment(persons)	Refers to the number of registered students in pre-primary educational institutions.	2004-2013	China Data Center
*Average Wage(*Yuan/Year*)*	Refers to the average wage in money terms per person during a certain period of time	2004-2013	China Data

	for staff and workers in enterprises, institutions, and government agencies, which reflects the general level of wage income during a certain period of time and is calculated as follows: Average Wage of Staff and Workers = Total Wages of Staff and Workers in Reference Period/Average Number of Staff and Workers in Reference Period.		Center
Socio-Economic Variables			
Population (persons)	Urban Population/ Rural Population are classified according to the Regulation of Statistics Classification on Urban and Rural Population (Draft), formulated by the National Bureau of Statistics in 1999.	2004-2013	China Data Center
Passenger Traffic (persons)	Refers to the volume of passenger transported with various means. Passenger traffic is calculated in the number of persons. Despite the travelling distance and ticket price, the passenger traffic is calculated by the principle that one person can be counted only once in one travel. The passengers who travel with a half price ticket or a child ticket is also calculated as one person. The passenger traffic provides a quantitative measure to show how the transport industry serves the national economy and people, and is also an important indicator for planning the transport industry and for studying the development scale and speed of the transport industry.	2004-2013	China Data Center
Freight Traffic (tons)	Refers to the volume of freight transported with various means. Freight transport is calculated in tons. Despite the type of freight and travelling distance, the freight transport is calculated in the actual weight of the goods. The freight traffic provides a quantitative measure to show how the transport industry serves the national economy and people, and is also an	2004-2013	China Data Center

	important indicator for planning the transport industry and for studying the development scale and speed of the transport industry.		
GDP Per Capita	Refers to the final products of all resident units in a country (or a region) during a certain period of time. Gross domestic product is expressed in three different forms, i.e. value, income, and products respectively. The form of value refers to the total value of all products and services produced by all resident units during a certain period of time minus total value of intimidate input of materials and services of the nature of non-fixed assets or the summation of the value-added of all resident units; the form of income includes all the income created by all resident units and distributed primarily to all resident and non-resident units; the form of products refers to the value of all final goods and services for final use by all resident units plus the value of net exports of goods and services during a given period of time. In the practice of national accounting, gross domestic product is calculated with three approaches, i.e. production approach, income approach, and expenditure approach, which reflect gross domestic product and its composition from different aspects.	2004-2013	China Data Center
Weather Data			
Heating/Cooling Degree Days	A mean daily temperature (average of the daily maximum and minimum temperatures) of 65°F is the base for both heating and cooling degree-day computations. Heating degree-days are summations of negative differences between the mean daily temperature and the 65°F base; cooling degree days are summations of positive differences from the same base.	2004-2013	NOAA

Precipitation (inches)	Total precipitation amount in inches	2004-2013	NOAA
Mean Temperature (Fahrenheit)	Mean daily temperature in degrees Fahrenheit	2004-2013	NOAA

Table 2: Summary Statistics of Data

Variable	Obs	Mean	Std. Dev.	Min	Max
Human Capital Variables					
AverageWage (Yuan/Year)	2,172	27971.4	14337.86	6207.11	320626.3
College Graduates (Persons)	2,063	17885.02	32758.53	200	240800
PreSchool Enrollment (Persons)	2,160	89473.47	70064.4	4000	501000
Primary New Enrollment (Persons)	2,165	59273.72	69564.94	2200	1485400
Junior Secondary New Enrollment (Persons)	1,957	84527.75	52365.67	3000	313900
Pollution Variables					
SO_2 (1000 tons)	2,936	102.2613	402.8927	0.003	19814.95
Soot (1000 tons)	2,769	122.9794	3274.66	0.047	171224.3
Wastewater (1000 tons)	2,023	12.05744	55.36569	0.017	2278.003
NO_2 Concentration (mg/m^{3})	361	41.38	12.92	73	12
PM 10 Concentration (mg/m^{3})	361	102.478	31.18	30	305
Days above Air Quality Grade II	361	301.17	50.79	49	366
Socio-Economic Variables					
Population (1000 persons)	2,189	4208.948	2564.563	16.76	14323.4
PassengerTraffic (10,000 persons)	2,167	9491.371	14280.41	3300	286597
FreightTraffic (tons)	2,166	9786.129	15794.1	2900	554458
GDPPerCapita (Yuan)	2,139	29567.52	27374.75	6207.11	467749

Cooling Degree Days	512	1954.08	1102.92	42	5208
Heating Degree Days	512	3865.66	2778.006	44	10654
Precipitation (inches)	520	38.43212	22.15004	2.4	119.7
Temperature (F°)	515	53.104	11.403	30.425	80.24

V. Results

China City Statistical Yearbook Results

In the first part of this econometric analysis, we use pollution data from the China City Statistical Yearbooks. For the most part, we examine how sulfur dioxide emissions affect our human capital variables. In Appendix A, we explore whether soot emissions and wastewater emissions affect human capital. These results are also useful and interesting to note, and pollution variables are not jointly significant in most specifications.

Table 3 contains our estimation results with the number of college graduates as our dependent variable and sulfur dioxide emissions as the independent pollution variable. The first column is the OLS estimation of equation (4)[2], while the second and third columns use regional fixed effects (equations 5 and 6), with the third column using region-specific time trends as an additional control variable. The fourth and fifth column (equations 7 and 8) use city fixed effects, with the fifth column using region-specific time trends as a further control. The final column includes city fixed effects and city-specific time trends (equation 9). Our results show that sulfur dioxide emissions have an estimated negative effect on college graduate figures when city fixed effects are included with and without region-specific time trends. We can interpret these significant coefficients in columns four and five as a 1000-ton increase in sulfur dioxide emissions reduces the number of college graduates by about seven. In context, the mean SO_2 emissions for Chinese

[2] Equations can be found on pages 22 and 23 in the "Framework" section

cities, according to our data, is 100,000 tons while the mean for college graduates is estimated to be 17,885. When we include city-specific time trends in the model, the negative effect of sulfur dioxide emissions is not statistically significant. As there are a lot more estimated coefficients when using city-specific time trends, we would expect the standard errors to increase and our estimates to be less precise.

Table 3: The Effect of SO_2 Emissions on Number of College Graduates

	1	2	3	4	5	6
SO2	13.87	11.48	13.71	-7.836**	-7.455**	-2.164
	(1.80)	(1.43)	-(1.51)	-(3.17)	(-3.14)	(-1.77)
Population	48.26***	57.51***	60.09***	128.4***	119.4***	120.0***
	(10.99)	(11.64)	-(11.35)	(8.51)	-(7.44)	-(5.10)
GDP per capita	0.335***	0.397***	0.460***	0.179***	0.102	-0.00237
	(5.44)	(5.34)	-(4.60)	(3.72)	-(1.53)	(-0.14)
F Traffic	0.164	0.135	0.169	0.0148	-0.00681	-0.0529
	(1.00)	(0.89)	-(1.07)	(0.35)	(-0.22)	(-1.82)
P Traffic	0.168	0.141	0.0982	0.0613	0.0814	0.128*
	(1.36)	(1.04)	-(0.76)	(0.97)	-(1.74)	-(2.14)
Constant	-17732.6***	-17292.0***	-23344.3***	-16670.2***	-88165.6***	-71477.3***
	(-8.07)	(-5.46)	(-8.29)	(-9.22)	(-7.43)	(-5.09)
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	1959	1887	1814	1951	1814	1951
adj. R-sq	0.308	0.43	0.438	0.907	0.921	0.971

* p <.05; ** p < .01; *** p < .001

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons.

Table 4 reports results using new enrollment in junior secondary schools as the dependent variable. Unlike with our model using the number of college graduates as the dependent variable, sulfur dioxide emissions are not found to significantly negatively affect new enrollment in junior secondary schools.

Table 4: The Effect of SO_2 Emissions on Junior Secondary School New Enrollment

	1	2	3	4	5	6
SO2	-3.08	0.614	-9.167	3.4	0.846	2.44
	-(0.65)	(0.14)	(-1.93)	(1.01)	-(0.32)	-(1.13)
Population	187.5***	191.2***	195.8***	88.86***	117.4***	135.0***
	(55.29)	(55.01)	-(59.50)	(5.68)	-(11.13)	-(12.50)
GDP per capita	-0.291***	-0.270***	-0.0444	-0.412***	0.197***	0.0161
	-(10.62)	-(9.28)	(-1.64)	-(12.79)	-(3.89)	-(0.33)
F Traffic	-0.298***	-0.219***	-0.120***	-0.182**	-0.0644**	-0.0187
	-(4.13)	-(3.65)	(-3.49)	-(3.18)	(-3.07)	(-0.75)
P Traffic	0.443***	0.294***	0.185***	0.224***	0.0820**	0.0348
	(6.02)	(5.08)	-(3.54)	(4.52)	-(2.77)	-(0.73)
Constant	13492.5***	13037.4***	28603.1***	101741.8***	86692.9***	90495.4***
	-11.16	-6.15	-7.22	-8.35	-11.21	-8.6
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	1856	1786	1723	1849	1723	1849
adj. R-sq	0.814	0.863	0.889	0.935	0.958	0.975

* $p < .05$; ** $p < .01$; *** $p < .001$

“Population” is measured by 1,000 persons, GDP per capita is measured in Yuan, “F Traffic” refers to Freight traffic, measured in tons, and “P Traffic” refers to passenger traffic, measured by 10,000 persons.

Table 5: The Effect of SO_2 Emissions on Primary School New Enrollment

	1	2	3	4	5	6
SO2	-6.837	-12.25	-17.87	4.279	2.994	4.676
	-(0.52)	-(0.91)	(-1.20)	(0.82)	(0.60)	(1.03)
Population	158.8***	149.9***	152.5***	66.23***	97.96***	120.7***
	(12.29)	(12.17)	-(11.51)	(3.36)	-(5.77)	-(4.81)
GDP per capita	-0.102**	-0.0136	0.0535	-0.00615	0.116***	0.0225
	-(2.68)	-(0.46)	-(1.53)	-(0.25)	-(3.42)	-(1.29)
F Traffic	-0.321**	-0.262**	-0.233**	-0.125*	-0.0856*	-0.044
	-(2.88)	-(2.88)	(-2.87)	-(2.02)	(-1.98)	(-0.89)
P Traffic	0.368***	0.325***	0.340***	0.0907	0.103	-0.0245
	(3.33)	(3.49)	-(3.49)	(1.26)	-(1.32)	(-0.25)
Constant	-(4333.20)	-10153.1**	-17666.1***	(443.90)	62235.3***	(1144.40)
	(-1.33)	(-2.86)	(-3.68)	-0.18	-4.7	-0.07
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	2059	1984	1911	2051	1911	2051
adj. R-sq	0.307	0.406	0.406	0.426	0.42	0.37

* $p < .05$; ** $p < .01$; *** $p < .001$

“Population” is measured by 1,000 persons, GDP per capita is measured in Yuan, “F Traffic” refers to Freight traffic, measured in tons, and “P Traffic” refers to passenger traffic, measured by 10,000 persons.

Similarly, as shown in Table 5, we find no significant effects for sulfur dioxide emissions when new enrollment in primary schools is used as the dependent variable. As has discussed in the previous section, since primary and junior secondary enrollment are mandated by law, it perhaps is unsurprising that their respective enrollment figures are not affected by air pollution. Furthermore, the effects of pollution accumulate throughout a student’s development, and thus may not appear until later (i.e. in secondary school or college) despite there still being unseen negative effects. Another potential reason for the lack of significant coefficients when new enrollment in primary schools is used as the independent variable is the relatively low adjusted r^2 values. This suggests that there may be confounding variables that are not accounted for in our models.

Table 6 contains the results for our models in which pre-school enrollment numbers are used as the dependent variable. Similarly to our models using new enrollment in primary and junior secondary schools, do not find any significant results. This is perhaps slightly more surprising as pre-school is obviously not required as primary and junior secondary school. These results show that there is no evidence that pollution influences the decision of parents to enroll their children into pre-school programs in these Chinese cities.

Table 7 holds the results from our last set of models, which use average wage as our dependent variable. Unlike the other models that used educational variables as proxies for human capital, average wages is a way to gauge the human capital stock of the existing labor force. In the case of these models, we do find significant results that provide evidence that higher SO_2 emissions have a negative impact on wages in Chinese cities. Specifically we find negative effects when we include regional fixed effects (column 2), city fixed effects with region-specific time trends (column 5) and city fixed effects with city-specific time trends (column 6). For example, results in column 5 indicate that that a 1000-ton increase in sulfur dioxide emissions decreases average annual wages by four Yuan. Although this seems like a rather small decrease in annual wages, it is statistically significant when you

Table 6: The Effect of SO_2 Emissions on Pre-School Enrollment

	1	2	3	4	5	6
SO2	1.288	20.71*	26.11**	8.709	2.778	5.139
	(0.11)	(2.27)	(2.88)	(0.63)	-(0.21)	(0.37)
Population	160.4***	167.6***	155.7***	168.0***	100.9**	110.7*
	(24.64)	(23.73)	-(23.51)	(5.55)	-(3.17)	-(2.52)
GDP per capita	0.368***	0.457***	0.165	0.548**	-0.139	-0.297*
	(4.07)	(4.51)	-(1.47)	(3.11)	(-0.87)	(-2.07)
F Traffic	-0.297	-0.0618	-0.3	0.126	-0.214	-0.614**
	-(1.29)	-(0.25)	(-1.55)	(0.46)	(-1.42)	(-2.81)
P Traffic	1.058***	0.643**	0.924***	0.13	0.474**	0.881**
	(5.53)	(2.94)	-(5.41)	(0.46)	-(3.11)	-(3.29)
Constant	(3300.30)	-14068.9**	(13971.40)	-17884.3***	(32737.00)	-(31564.70)
	-1	(-2.76)	-1.8	(-4.96)	-1.15	(-1.08)
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	2055	1982	1910	2047	1910	2047
adj. R-sq	0.455	0.546	0.571	0.597	0.633	0.682

* p <.05; ** p < .01; *** p < .001
“Population” is measured by 1,000 persons, GDP per capita is measured in Yuan, “F Traffic” refers to Freight traffic, measured in tons, and “P Traffic” refers to passenger traffic, measured by 10,000 persons.

consider the standard deviation in our dataset for SO_2 emissions is 4,020 thousand tons (or 4,020,000 tons). In the case of this model, an increase of 4,020 thousand tons of sulfur dioxide in a city would estimate a decrease of 16,080 Yuan in its’ average annual wages. The negative and statistically impact of SO_2 on average wages supports the hypothesis that high-earning potential workers (who theoretically would have higher human capital stocks) are more likely to work in cities with less pollution

Table 7: The Effect of SO_2 Emissions on Average Wage

	1	2	3	4	5	6
SO2	-4.19	-4.757*	2.188	-1.139	-1.719**	-2.035**
	-(1.73)	-(2.14)	-(1.24)	-(0.79)	(-3.06)	(-3.30)
Population	2.05	6.279***	0.986	53.42**	10.29*	12.06
	(1.50)	(4.60)	-(1.11)	(2.97)	-(2.45)	-(1.49)
GDP per capita	0.313***	0.348***	0.149***	0.446***	0.0647**	0.0504*
	(13.44)	(12.08)	-(8.89)	(6.47)	-(3.19)	-(2.25)
F Traffic	0.111*	0.113*	0.0029	0.135*	0.00441	0.0207
	(2.06)	(2.33)	-(0.14)	(2.28)	-(0.45)	-(0.61)
P Traffic	-0.0511	-0.1	0.0259	-0.157	-0.013	-0.0451
	-(1.14)	-(1.78)	-(1.27)	-(1.74)	(-0.54)	(-0.58)
Constant	17113.8***	18783.6***	6020.8***	-(3863.50)	(1411.30)	-(1266.60)
	-23.59	-14.37	-8.94	(-1.85)	-0.46	(-0.27)
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	2066	1991	1919	2058	1919	2058
adj. R-sq	0.387	0.429	0.704	0.502	0.748	0.753

* $p < .05$; ** $p < .01$; *** $p < .001$

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons.

Visibility Data

This analysis also uses visibility as a proxy of air pollution, in order to provide robustness checks against potential pollution data manipulation. For most of our models, when using visibility as our main independent variable and the same five human capital indicators as our dependent variables, we find no significant effects of visibility. Although at first glance this may seem to conflict with our prior results using SO_2, it is more likely an issue of insufficient data. In comparison to our models using sulfur dioxide, the number of observations we have for visibility is significantly less.

Nonetheless, there were still a few significant results from our analysis using visibility as a proxy for air pollution, as can be seen in table 8, which uses average wage as the dependent variable. We can see that when we use models with no fixed effects (column 1) and only regional fixed effects (column 2), that our models predict negative coefficients for visibility. We can interpret these results as a 1% increase in the annual days with visibility over 6.9 miles, predicts a 9.128/4.006 decrease in average annual wages in Yuan for column 1 and 2 respectively. Although this shows further support that high-earning workers are likely to work in less polluted Chinese cities, it is important to note that when other fixed effects and controls are added to these models that the effects become insignificant.

Table 8: The Effect of Visibility on Average Wages

	1	2	3	4	5	6
Visibility	0.0529	4.211*	-7.289*	1.577*	-0.492	0.117
	(0.01)	(2.28)	-(2.25)	(2.25)	-(0.79)	-(0.36)
Population	41.39***	64.29***	63.52***	152.3***	171.1**	95.79
	(5.07)	(9.14)	(10.58)	(3.99)	(2.80)	-(1.91)
GDP per capita	0.223**	0.367***	0.850***	0.0953*	0.0294	-0.0407*
	(3.19)	(3.82)	(4.43)	(1.97)	(0.65)	(-2.17)
F Traffic	-0.268	-0.466*	0.131	-0.107	-0.169*	-0.098
	-(1.54)	-(2.52)	(0.69)	-(1.03)	-(2.07)	(-0.80)
P Traffic	0.954***	1.095***	1.042***	0.629***	0.257**	0.226*
	-(5.87)	-(7.48)	-(8.54)	-(5.94)	(3.09)	-(2.40)
Temperature	-84.45	-150.6	-170.4	344.2**	309.9***	144.3*
	-(0.91)	-(1.37)	-(1.63)	(2.93)	(4.03)	-(2.11)
Precipitation	-151.2***	-85.81*	-43.77	53.94*	28.56	-4.475
	-(4.80)	-(2.47)	-(1.23)	(2.44)	(1.64)	(-0.38)
Constant	-4309.1	-20842.9**	-20240.9*	-104926.5***	-112669.4**	-61903.4*
	(-0.69)	(-2.96)	(-2.27)	(-4.04)	(-2.95)	(-2.03)
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	317	317	317	317	317	317
adj. R2	0.452	0.738	0.789	0.959	0.969	0.987

* $p < .05$; ** $p < .01$; *** $p < .001$

“Population” is measured by 1,000 persons, GDP per capita is measured in Yuan, “F Traffic” refers to Freight traffic, measured in tons, and “P Traffic” refers to passenger traffic, measured by 10,000 persons, “Temperature” refers to average annual temperature, measured in degrees and “Precipitation” refers to total amount of annual precipitation, measured in inches.

China Statistical Yearbook

Our final regressions use data from the China Statistical Yearbooks, which only report pollution information for the major cities of China. However, along with SO_2 emissions, they also record concentrations for PM 10 and NO_2, as well as the number of days above air quality "Grade II." When we examine how these new pollution variables affect our five human capital indicators, we find some negative significant effects. Similarly to our results using other data sources, we find negative significant effects on average wages and the number of college graduates. Results from the models using the number of college graduates as the dependent variable are available in Table 7. It is interesting to note that we in fact find significant negative effects when PM 10 is the only air pollution variable (columns 1-3) and when PM 10, NO_2 and SO_2 are all include in the models (columns 10-12). Results from these models indicate that as these pollutants increase, the number of college graduates decreases. For example, when looking at the model described in column 12, it estimates that a 1-gram/m^3 increase in PM10 concentrations would lead to a decrease in college graduates by about 255.

It is also important to note the significant positive coefficients on the independent variable "Days of Grade II Air Quality" and determine what these results mean. Unlike our variables that measure emissions or concentrations, where higher numbers relate to worse air quality, this variable is a measure of good air quality. This variable measures the number of days when air quality is better than a predetermined standard within a city. Thus our positive results estimate that as the number of "good" air quality days improves, college graduates should increase. These results, as a whole from the China Statistical Yearbook data, provide support to our results found using our other data sources.

Table 9: The Effects of pollution emissions on the number of College Graduates

	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15
PM__10	300.4**	-354.1***	-228.1**							246.9*	-312.6***	-255.1**			
	-3.35	(-4.41)	(-2.90)							-2.54	(-3.57)	(-3.08)			
NO__2				101.2	-284.3	43.4				-196.8	-90.02	223.1			
				-0.39	(-1.07)	-0.25				(-0.72)	(-0.36)	-1.07			
SO__2							329.0*	-337.6**	-16.06	235.9	-134.8	-5.967			
							-2.6	(-2.66)	(-0.11)	-1.81	(-1.09)	(-0.04)			
DaysIIAQ													-143.1*	218.9***	131.3***
													(-2.30)	-5.64	-4.12
Population	89.03***	69.51	66.95	89.09***	86.16	72.83	90.40***	121.2	73.44	94.67***	91.02	68.22	91.59***	105.8	97.52
	-11.92	-1.04	-1.06	-7.86	-1.26	-1.09	-11.86	-1.7	-1.08	-8.18	-1.38	-1.06	-12.09	-1.57	-1.56
GDP per Capita	0.518*	0.516***	-0.777**	0.535*	0.623***	-0.977***	0.559*	0.577***	-0.975***	0.554*	0.529***	-0.750*	0.489*	0.705***	-0.495
	-2.25	-3.39	(-2.75)	-2.13	-3.9	(-3.50)	-2.29	-3.55	(-3.46)	-2.39	-3.66	(-2.53)	-2.02	-5.55	(-1.85)
F Traffic	1.642***	1.318***	-0.634	1.778***	1.049**	-0.628	1.745***	0.696	-0.631	1.661***	1.109**	-0.668	1.674***	1.119***	-0.703
	-3.56	-4.19	(-1.56)	-3.85	-3.12	(-1.45)	-3.76	-1.7	(-1.44)	-3.57	-2.84	(-1.57)	-3.59	-3.58	(-1.75)
P Traffic	-0.0136	0.485	-0.516	-0.169	0.652*	-0.346	-0.143	0.599*	-0.36	-0.0312	0.464	-0.508	-0.0267	0.354	-0.531
	(-0.04)	-1.8	(-1.64)	(-0.45)	-2.39	(-1.15)	(-0.39)	-2.14	(-1.08)	(-0.08)	-1.75	(-1.54)	(-0.07)	-1.35	(-1.82)
Temperature	233.7	440.5**	240.1	88.88	406.3*	250.5	160.4	482.8**	249.3	254.5	441.9**	254.6	201	474.0**	256.4
	-1.07	-2.72	-1.58	-0.42	-2.27	-1.52	-0.75	-2.8	-1.52	-1.15	-2.75	-1.58	-0.9	-3.28	-1.78
Precipitation	310.1*	-50.37	-158.3	136.4	-54.02	-157.1	215.4	-69.58	-157.1	334.3*	-53.04	-162.7	206.4	-35.16	-137.2
	-2.03	(-0.36)	(-1.28)	-0.91	(-0.38)	(-1.24)	-1.42	(-0.49)	(-1.25)	-2.27	(-0.38)	(-1.31)	-1.42	(-0.27)	(-1.12)
Fixed Effects	No	City	City	No	City	City	No	City	City	No	City	City	No	City	City
Time Trend	No	No	City	No	No	City	No	No	City	No	No	City	No	No	City
Constant	-67837.2***	12630.9	27707.6	-29068.1*	-25997.2	523.6	-47684.6**	-59496.4	2004.5	-71914.3***	-412.2	21591.8	11530	-130669.5	-65798.8
	(-3.93)	-0.2	-0.63	(-2.29)	(-0.38)	-0.01	(-3.30)	(-0.89)	-0.04	(-4.07)	(-0.01)	-0.48	-0.58	(-1.83)	(-1.29)
N	171	171	171	171	171	171	171	171	171	171	171	171	171	171	171
adj. R-sq	0.695	0.932	0.968	0.681	0.926	0.967	0.693	0.928	0.967	0.696	0.932	0.968	0.689	0.938	0.97

* p <.05; ** p < .01; *** p < .001

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons, "Temperature" refers to average annual temperature, measured in degrees and "Precipitation" refers to total amount of annual precipitation, measured in inches.

VI. Conclusion

Our estimated results, from all of our data sources, show that there are negative effects of air pollution on some of our human capital variables. Furthermore, the fact that our models use multiple data sources and pollution variables (including visibility figures) validates the robustness of our results. Specifically, we find that there are significant effects of air pollution on annual average wages and the number of college graduates. Our results using junior secondary, primary and pre-school enrollment numbers as our dependent variables found few significant results. Overall, however, our results do appear to provide evidence that worse air pollution in Chinese cities can lead to lower human capital stocks.

It is interesting to note that our significant results come from variables encompassing the number of college graduates and average wages, as these indicators of human capital likely have more immediate impacts on the economy. Average wages are a good indicator of the human capital stock of the labor force within a city at the current time period. The fact that our models predict a negative effect from pollution on wages indicates that it is likely highly skilled workers react negatively to air pollution concentrations when making career and residency choices. Human capital flight, or "brain drain," from highly polluted Chinese cities may be a serious issue according to our results.

Similarly, the number of college graduates can give us indication of the education level of the city, as they often join the labor force soon after graduation. Our models found evidence that cities with worse pollution are likely to have a lower number of college graduates. This negative effect could be from two pathways: individuals consciously choosing to go to college in a less-polluted city or that the pollution is having negative effects to the cognitive ability or motivation of students to continue on to higher education in highly polluted cities.

It is also interesting to find that our results do not indicate a negative effect of pollution on pre-school, primary and junior secondary enrollments. These variables would be better indicators for future human capital stock rather than the current stock, as these students will not enter the workforce soon. It is perhaps reasonable to expect little variation in primary and junior secondary new enrollment figures due to the requirement for children to attend. However, as pre-school is not mandatory, it is surprising that the impact of pollution on enrollment is not strong in our results. As has been stated, there is strong evidence that pollution negatively impacts the human capital accumulation of children under the age of five more so than any other age group. Despite the fact that this is a crucial age for human capital accumulation, there does not appear to be any evidence of parents moving their children out of polluted cities, to avoid these issues. Likewise, the effects on health of preschoolers does not appear to impact their enrollment status either.

VII. Discussion

Our econometric analysis has shown some evidence for the negative impact of air pollution on human capital stocks in Chinese cities. Specifically we find that there is more evidence that air pollution has negative effects on the number of college graduates and average wages, whereas few significant effects were found on new enrollments in junior secondary and primary and pre-schools. This study adds to the existing evidence that air pollution has negative effects on human capital stocks. Furthermore, this study of Chinese cities provides analysis in a developing economy, which is often underrepresented in the literature.

This study has found evidence that there is a negative impact of air pollution on the human capital stocks of Chinese cities, but the further implications of this must be recognized. Perhaps the most obvious question that stems from this study is what policies would be effective and viable to combat these negative effects of pollution in these Chinese cities. Pollution control policies such as command and control or, preferably, incentive based policies, such as cap-and-trade, could prove instrumental in improving the health and human capital of its citizens. Although a greater issue, especially in the case of China, is not the creation of effective policies but rather increased pressure on compliance of policies at the local level. The central government of China, due to both internal pressure from its citizens and external pressure from other countries, has been taking the issue of pollution very seriously. The central government has enacted many different policies, and is currently looking to integrate efficient new market-oriented policies, such as emission cap-and-trade systems. However, although the federal government has made pollution reduction a priority, local officials often prefer to prioritize economic goals rather than environmental ones (Economy 2007).

This study does not look to quantify the cost of the negative impact on human capital in these cities, which would be important to look at when deciding on policies. If, the economic impact (either in terms of growth or a different economic metric) of this hindrance on human capital from pollution is low, perhaps the Chinese government would be better off allocating time and resources to other issues within the Chinese economy and society. However, there is significant evidence, both from theoretical growth models and from empirical analyses by the World Bank (2012) report and Fleisher and Wang (2014) that investments in human capital stocks should be a priority of the Chinese government, and thus so should pollution control.

The results of this study could also lead to a noteworthy amount of further studies and questions. Assuming the availability of the data, other variables could be used as proxies for human capital, such as school absences and test scores in Chinese schools. Emigration and immigration data could also be used to further study the prominence of human capital flight in response to air pollution. As human capital is a very difficult concept to quantify, using multiple indicators in different models would create a more robust analysis, which would be useful for enacting the best possible policy decisions.

Another possible route of further study would be to look at different countries, specifically other developing economies facing major issues of pollution. Although Chinese cities are often viewed as the "dirtiest" or most polluted cities in the world, there are many cities that face similar and even worse situations. Countries such as India, Indonesia, Brazil and Turkey are developing economies that are facing similar situations of poisonous air pollution concentrations in their cities. It would be interesting to compare how the human capital stocks of different developing countries are affected by air pollution.

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XI. Appendix

Visibility model results

Table 10: The Effects of Visibility on Junior Secondary School New Enrollment

	1	2	3	4	5	6
Visibility	0.712	-4.399*	-0.195	-0.904	-2.191	-0.487
	(0.24)	-(1.98)	-(0.08)	-(0.83)	-(1.58)	(-0.99)
Population	198.2***	200.9***	201.9***	-230	-397.4	-102.6
	(20.22)	(21.82)	(20.96)	-(1.34)	-(1.65)	(-0.34)
GDP per capita	-0.166**	-0.387***	-0.450*	-0.141	0.469*	0.0922
	-(3.04)	-(4.45)	-(2.08)	-(1.93)	-(2.03)	-(0.98)
F Traffic	-0.998***	-1.354***	-1.427***	-0.743*	-0.109	0.232
	-(3.84)	-(3.52)	-(3.37)	-(2.21)	-(0.25)	-(0.39)
P Traffic	-0.618**	-0.634*	-0.772**	-0.544	-0.611	-0.164
	(-2.93)	(-2.49)	(-2.74)	(-1.76)	-(1.88)	(-0.87)
Temperature	-282.2*	-256.9*	-208.4	-357.3**	-67.82	6.681
	-(2.42)	-(2.13)	-(1.72)	-(2.66)	-(0.45)	-(0.05)
Precipitation	94.24*	207.6**	164.7*	31.35	-64.63	-30.06
	(2.02)	(2.90)	(2.15)	(0.43)	-(0.90)	(-0.49)
Constant	28295.9***	38672.4***	39789.7***	309170.4**	414023.8**	238015.6
	-(3.83)	-(5.00)	-(4.52)	-(2.97)	-(2.92)	-(1.30)
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	299	299	299	299	299	299
adj. R2	0.839	0.902	0.915	0.939	0.96	0.973

* p <.05; ** p < .01; *** p < .001

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons, "Temperature" refers to average annual temperature, measured in degrees and "Precipitation" refers to total amount of annual precipitation, measured in inches.

Table 11: The Effects of Visibility on Primary School New Enrollment

	1	2	3	4	5	6
Visibility	0.0313	-0.188	4.237	0.846	0.273	1.201
	(0.01)	-(0.12)	(1.91)	(0.77)	(0.15)	-(0.59)
Population	152.5***	129.1***	129.0***	119.7	817	1455.2
	(5.93)	(8.28)	(7.66)	(0.38)	(1.46)	-(1.01)
GDP per capita	-0.086	-0.103	-0.338**	-0.0119	0.0225	-0.0471
	-(1.25)	-(1.68)	-(2.85)	-(0.14)	(0.15)	(-0.34)
F Traffic	-0.703	-0.672	-0.932	-0.632	-0.773	-2.034
	-(1.09)	-(0.82)	-(0.97)	-(0.68)	-(0.42)	(-0.94)
P Traffic	-0.789**	0.0599	0.109	0.0671	0.00983	0.322
	(-2.94)	-(0.23)	-(0.41)	-(0.15)	(0.02)	-(0.47)
Temperature	-374.2	232.5	299.1	204.1	410.6	559.5
	-(1.23)	(1.23)	(1.12)	(0.67)	(0.76)	-(0.79)
Precipitation	168.4	220.6	219.3	344.5	471.5	464
	(1.68)	(0.67)	(0.66)	(0.87)	(1.00)	-(0.95)
Constant	19799.5	-16922	-20674.6	-23587.6	-454593.9	-847506.7
	-(1.33)	(-0.77)	(-0.61)	(-0.13)	(-1.26)	(-0.93)
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	325	325	325	325	325	325
adj. R2	0.348	0.443	0.417	0.436	0.411	0.38

* p <.05; ** p < .01; *** p < .001

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons, "Temperature" refers to average annual temperature, measured in degrees and "Precipitation" refers to total amount of annual precipitation, measured in inches.

Table 12: The Effects of Visibility on Pre-School Enrollment

	1	2	3	4	5	6
Visibility	-5.753	-1.143	3.339	2.282	-4.818	-3.67
	-(1.48)	-(0.31)	(0.65)	(0.67)	-(1.32)	(-1.26)
Population	162.4***	163.9***	161.2***	1205.4**	358.5	1046.1
	(13.04)	(8.85)	(9.12)	(3.22)	(0.44)	-(1.04)
GDP per capita	0.286**	0.312	-0.324	0.500*	0.740*	0.828**
	(2.95)	(1.54)	-(0.74)	(2.43)	(2.14)	-(3.05)
F Traffic	1.193	2.900**	2.311	0.137	1.984	0.166
	(1.77)	(3.07)	(1.89)	(0.14)	(1.44)	-(0.10)
P Traffic	-0.214	-0.302	0.0678	0.286	1.937	3.807*
	(-0.49)	(-0.59)	-(0.13)	-(0.33)	(1.68)	-(2.34)
Temperature	521.8*	392.1	249.7	227	95.18	-132.5
	(2.03)	(1.21)	(0.91)	(0.45)	(0.22)	(-0.24)
Precipitation	461.6***	95.65	-33.57	254.5	156.1	133.8
	(3.94)	(0.54)	-(0.20)	(1.37)	(0.71)	-(0.60)
Constant	- 45796.2**	- 77769.5***	- 44282.4*	-707560.9**	-185915.2	- 609584.6
	(-2.70)	(-3.98)	(-2.35)	(-3.07)	(-0.38)	(-1.00)
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	322	322	322	322	322	322
adj. R2	0.518	0.649	0.697	0.694	0.724	0.749

* $p < .05$; ** $p < .01$; *** $p < .001$

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons, "Temperature" refers to average annual temperature, measured in degrees and "Precipitation" refers to total amount of annual

Table 13: The Effects of Visibility on Number of College Graduates

	1	2	3	4	5	6
Visibility	0.0529	4.211*	-7.289*	1.577*	-0.492	0.117
	(0.01)	(2.28)	-(2.25)	(2.25)	-(0.79)	-(0.36)
Population	41.39***	64.29***	63.52***	152.3***	171.1**	95.79
	(5.07)	(9.14)	(10.58)	(3.99)	(2.80)	-(1.91)
GDP per capita	0.223**	0.367***	0.850***	0.0953*	0.0294	-0.0407*
	(3.19)	(3.82)	(4.43)	(1.97)	(0.65)	(-2.17)
F Traffic	-0.268	-0.466*	0.131	-0.107	-0.169*	-0.098
	-(1.54)	-(2.52)	(0.69)	-(1.03)	-(2.07)	(-0.80)
P Traffic	0.954***	1.095***	1.042***	0.629***	0.257**	0.226*
	-(5.87)	-(7.48)	-(8.54)	-(5.94)	(3.09)	-(2.40)
Temperature	-84.45	-150.6	-170.4	344.2**	309.9***	144.3*
	-(0.91)	-(1.37)	-(1.63)	(2.93)	(4.03)	-(2.11)
Precipitation	- 151.2***	-85.81*	-43.77	53.94*	28.56	-4.475
	-(4.80)	-(2.47)	-(1.23)	(2.44)	(1.64)	(-0.38)
Constant	-4309.1	- 20842.9**	- 20240.9*	- 104926.5***	-112669.4**	- 61903.4*
	(-0.69)	(-2.96)	(-2.27)	(-4.04)	(-2.95)	(-2.03)
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	317	317	317	317	317	317
adj. R2	0.452	0.738	0.789	0.959	0.969	0.987

* p <.05; ** p < .01; *** p < .001

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons, "Temperature" refers to average annual temperature, measured in degrees and "Precipitation" refers to total amount of annual precipitation, measured in inches.

China Statistical Yearbook model results

Table 14: Pollution effects on Average Wage

	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15
PM__10	-68.31**	-27.36	29.93							-31.56	-13.04	35.11*			
	(-2.68)	(-0.81)	-1.96							(-1.20)	(-0.40)	-2.23			
NO__2				-159.4**	-57.49	-7.724				-99.13	-36.92	-11.38			
				(-3.03)	(-0.79)	(-0.25)				(-1.95)	(-0.49)	(-0.34)			
SO__2							-101.7***	-55.53	-30.23	-77.36**	-43.82	-37.48			
							(-4.00)	(-1.14)	(-1.24)	(-3.13)	(-0.86)	(-1.36)			
DaysIIAQ													21	20.74	-9.513
													-1.24	-1.08	(-1.54)
Population	-4.003	51.36***	-1.186	0.495	53.83***	-2.097	-4.038	59.31***	-0.43	-0.62	58.68***	0.91	-4.624	54.60***	-3.97
	(-1.60)	-3.55	(-0.17)	-0.15	-3.53	(-0.27)	(-1.63)	-3.79	(-0.05)	(-0.19)	-3.87	-0.13	(-1.82)	-3.68	(-0.51)
GDP per Capita	0.425***	0.581***	0.152***	0.435***	0.593***	0.179***	0.413***	0.585***	0.184***	0.428***	0.586***	0.153***	0.427***	0.597***	0.145**
	-5.75	-10.23	-3.38	-6.76	-11.12	-4.29	-5.87	-10.8	-4.49	-6.14	-10.62	-3.41	-5.87	-12.42	-3.15
F Traffic	0.0489	0.1	0.287***	0.038	0.0728	0.290***	0.0321	0.0142	0.274**	0.0574	0.0288	0.269**	0.0319	0.086	0.297***
	-0.47	-0.98	-3.7	-0.36	-0.72	-3.51	-0.33	-0.12	-3.22	-0.59	-0.23	-3.33	-0.3	-0.85	-3.71
P Traffic	0.0703	-0.0703	0.0851	0.0954	-0.0623	0.0632	0.0938	-0.0684	0.0504	0.0736	-0.0771	0.0699	0.0852	-0.0863	0.0775
	-0.78	(-0.81)	-1.28	-1.15	(-0.70)	-0.98	-1.15	(-0.82)	-0.84	-0.87	(-0.91)	-1.17	-0.92	(-1.02)	-1.18
Temperature	40.71	-11.19	-32.27	68.95*	-18.18	-32.62	51.02	-7.59	-28.83	37.72	-13.99	-29.3	57.43	-7.069	-32.09
	-1.16	(-0.21)	(-1.12)	-2.05	(-0.33)	(-1.12)	-1.53	(-0.15)	(-0.99)	-1.11	(-0.26)	(-1.01)	-1.55	(-0.14)	(-1.10)
Precipitation	-91.70***	35	-6.648	-52.69*	35.13	-6.76	-74.72**	33.17	-8.319	-88.70**	34.59	-8.212	-62.20*	36.53	-8.212
	(-3.48)	-1.22		(-2.02)	-1.23		(-2.85)	-1.12		(-3.35)	-1.16		(-2.33)	-1.26	
Fixed Effects	No	City	City	No	City	City	No	City	City	No	City	City	No	City	City
Time Trend	No	No	City	No	No	City	No	No	City	No	No	City	No	No	City
Constant	23277.9***	- 40884.9***	-4140.5	16774.5***	- 41692.5***	-499.7	20300.8***	- 42421.0***	-1255.8	24766.4***	- 40124.3***	-4804.5	8330.7	- 52550.4***	4148.9
	-5.73	(-4.27)	(-0.76)	-6.11	(-4.71)	(-0.08)	-6.81	(-5.30)	(-0.21)	-5.94	(-4.00)	(-0.88)	-1.56	(-6.05)	-0.61
N	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175
adj. R-sq	0.759	0.9	0.985	0.758	0.9	0.984	0.768	0.901	0.985	0.775	0.9	0.985	0.748	0.901	0.985

* $p < .05$; ** $p < .01$; *** $p < .001$

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons, "Temperature" refers to average annual temperature, measured in degrees and "Precipitation" refers to total amount of annual precipitation, measured in inches.

Table 15: Pollution effects on Pre-School New Enrollment

	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15
PM__10	-378.9**	-147.6	16.48							-344.0*	75.75	35.68			
	(-3.04)	(-1.36)	-0.16							(-2.53)	-0.61	-0.29			
NO__2				-36.34	- 1512.6***	-48.55				341.9	- 1387.9**	90.63			
				(-0.08)	(-3.62)	(-0.16)				-0.82	(-3.28)	-0.23			
SO__2							-354.5*	-585.8**	-262.1	-241.3	-482.4*	-298.8			
							(-2.28)	(-3.07)	(-1.37)	(-1.66)	(-2.28)	(-1.33)			
DaysIIAQ													244.5***	89.77*	-23.29
													-3.5	-2.12	(-0.37)
Population	101.2***	83.32	292.8*	98.06***	136.1	292.0*	98.84***	163	306.2*	90.76***	196.6	309.8*	98.53***	98.34	287.7
	-9.61	-0.93	-2.07	-5.55	-1.44	-2.06	-9.98	-1.74	-2.12	-5.14	-1.9	-2.14	-10	-1.07	-1.95
GDP per Capita	0.473**	0.462*	0.657	0.437*	0.663***	0.671	0.412*	0.462*	0.712	0.417*	0.639***	0.688	0.542**	0.540**	0.588
	-2.64	-2.36	-1.44	-2.44	-4.1	-1.56	-2.5	-2.54	-1.6	-2.23	-3.96	-1.47	-2.88	-2.96	-1.03
F Traffic	2.511***	3.124***	-0.0088	2.334***	2.716***	-0.00303	2.395***	2.304***	-0.141	2.498***	2.093***	-0.171	2.507***	3.043***	0.0109
	-5.39	-5.56	(-0.01)	-5.01	-5.59	(-0.00)	-5.37	-3.88	(-0.15)	-5.41	-3.49	(-0.17)	-5.28	-5.48	-0.01
P Traffic	0.0674	0.999*	0.44	0.265	0.908*	0.422	0.222	0.95	0.312	0.0741	0.857	0.332	0.0282	0.943	0.461
	-0.21	-2.06	-0.96	-0.82	-2.07	-0.91	-0.71	-1.94	-0.73	-0.23	-1.95	-0.77	-0.09	-1.96	-0.97
Temperature	658.6***	222.3	336.2	843.7***	10.59	332.5	766.8***	264	364.2	636.4**	60.85	375	645.1***	238.7	336.2
	-3.43	-0.8	-1.05	-4.38	-0.04	-1.02	-4.24	-0.96	-1.14	-3.34	-0.25	-1.14	-3.38	-0.85	-1.05
Precipitation	141.4	-235.7	-363.7	363.1*	-208.9	-363	280.3	-248.3	-375.5	108.6	-220	-378.5	237.4	-230.8	-367.1
	-0.81	(-1.05)	(-1.63)	-2.22	(-1.01)	(-1.62)	-1.69	(-1.13)	(-1.66)	-0.65	(-1.05)	(-1.66)	-1.46	(-1.03)	(-1.64)
Fixed Effects	No	City	City	No	City	City	No	City	City	No	City	City	No	City	City
Time Trend	No	No	City	No	No	City	No	No	City	No	No	City	No	No	City
Constant	3820.3	-5371.6	- 131705.5	- 46381.3**	17484.7	- 127880.2	-24955.8	-67413.6	- 133615.5	8282.1	-30971.4	- 141836.3	- 113816.8***	-64690.7	- 117768.1
	-0.19	(-0.06)	(-1.30)	(-3.35)	-0.2	(-1.27)	(-1.76)	(-0.80)	(-1.30)	-0.4	(-0.31)	(-1.39)	(-4.76)	(-0.74)	(-0.97)
N	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173
adj. R-sq	0.73	0.904	0.955	0.716	0.914	0.955	0.725	0.908	0.956	0.731	0.916	0.955	0.731	0.904	0.955

* p <.05; ** p < .01; *** p < .001

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons, "Temperature" refers to average annual temperature, measured in degrees and "Precipitation" refers to total amount of annual precipitation, measured in inches.

Table 16: Pollution effects on Junior Secondary School New Enrollment

	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15
PM__10	-19.32	-121.8	-71.6							-70.13	-68.67	-82.68			
	(-0.37)	(-0.84)	(-0.52)							(-1.01)	(-0.49)	(-0.55)			
NO__2				254.2	513.4**	134.8				287	595.1**	139.7			
				-1.68	-2.69	-0.69				-1.88	-3.28	-0.58			
SO__2							40.92	-306.7*	74.83	38.56	-328.6**	39.56			
							-0.5	(-2.30)	-0.7	-0.43	(-2.94)	-0.37			
DaysIIAQ													45.21	121.8	18.24
													-1.14	-1.21	-0.15
Population	125.5***	111.4	212.4**	116.8***	110.5	224.9**	125.2***	148.2*	218.7*	116.2***	138.1	214.2**	125.2***	115.9	218.3**
	-21.56	-1.49	-2.72	-15.32	-1.6	-2.66	-21.58	-2.42	-2.58	-15.18	-1.9	-2.74	-21.85	-1.65	-2.83
GDP per Capita	-0.656***	-0.294	0.17	-0.681***	-0.244*	0.195	-0.655***	-0.279*	0.177	-0.673***	-0.375*	0.207	-0.661***	-0.318*	0.165
	(-6.44)	(-1.77)	-0.77	(-6.59)	(-2.13)	-0.89	(-6.47)	(-2.30)	-0.84	(-6.51)	(-2.47)	-0.9	(-6.51)	(-2.05)	-0.77
F Traffic	1.320***	-0.21	-0.209	1.264***	-0.21	-0.25	1.296***	-0.628*	-0.201	1.284***	-0.471	-0.196	1.357***	-0.245	-0.239
	-5.02	(-0.63)	(-0.46)	-5.16	(-0.73)	(-0.57)	-5.09	(-2.07)	(-0.49)	-5.08	(-1.25)	(-0.45)	-5.14	(-0.84)	(-0.55)
P Traffic	0.0227	-0.0933	-0.0489	0.0501	-0.0636	-0.032	0.0422	-0.115	-0.0268	0.0172	-0.0789	-0.04	-0.00168	-0.0875	-0.0332
	-0.12	(-0.48)	(-0.23)	-0.26	(-0.35)	(-0.16)	-0.22	(-0.63)	(-0.13)	-0.09	(-0.46)	(-0.18)	(-0.01)	(-0.44)	(-0.16)
Temperature	387.1**	-49.1	29.97	404.8***	40.21	42.21	404.0***	-13.96	20.82	380.2**	72.79	34.86	363.8**	-41.12	31.44
	-3.14	(-0.32)	-0.24	-3.55	-0.28	-0.34	-3.44	(-0.10)	-0.16	-3.06	-0.53	-0.28	-2.98	(-0.27)	-0.25
Precipitation	222.5*	26.46	37.13	235.8**	14.61	38.01	242.3**	18.19	42.63	206.4*	8.818	37.33	212.0*	34.95	40.68
	-2.55	-0.3	-0.54	-2.95	-0.18	-0.54	-2.87	-0.21	-0.62	-2.4	-0.11	-0.56	-2.58	-0.4	-0.54
Fixed Effects	No	City	City	No	City	City	No	City	City	No	City	City	No	City	City
Time Trend	No	No	City	No	No	City	No	No	City	No	No	City	No	No	City
Constant	11340.7	60095.7	7364.8	4509.3	15150.9	-14059.1	6267.8	26757.1	-6569.3	10906.3	9653.7	1114.8	-3294.1	5981.1	-10641.9
	-1.13	-0.67	-0.13	-0.68	-0.21	(-0.22)	-0.73	-0.41	(-0.10)	-1.08	-0.11	-0.02	(-0.29)	-0.12	(-0.13)
N	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164
adj. R-sq	0.784	0.909	0.942	0.787	0.911	0.942	0.784	0.911	0.942	0.786	0.915	0.941	0.785	0.91	0.942

* $p < .05$; ** $p < .01$; *** $p < .001$

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons, "Temperature" refers to average annual temperature, measured in degrees and "Precipitation" refers to total amount of annual precipitation, measured in inches.

Table 17: Pollution effects on Primary School New Enrollment

	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15
PM__10	-19.32	-121.8	-71.6							-70.13	-68.67	-82.68			
	(-0.37)	(-0.84)	(-0.52)							(-1.01)	(-0.49)	(-0.55)			
NO__2				254.2	513.4**	134.8				287	595.1**	139.7			
				-1.68	-2.69	-0.69				-1.88	-3.28	-0.58			
SO__2							40.92	-306.7*	74.83	38.56	- 328.6**	39.56			
							-0.5	(-2.30)	-0.7	-0.43	(-2.94)	-0.37			
DaysIIAQ													45.21	121.8	18.24
													-1.14	-1.21	-0.15
Population	125.5***	111.4	212.4**	116.8***	110.5	224.9**	125.2***	148.2*	218.7*	116.2***	138.1	214.2**	125.2***	115.9	218.3**
	-21.56	-1.49	-2.72	-15.32	-1.6	-2.66	-21.58	-2.42	-2.58	-15.18	-1.9	-2.74	-21.85	-1.65	-2.83
GDP per Capita	-0.656***	-0.294	0.17	- 0.681***	-0.244*	0.195	- 0.655***	-0.279*	0.177	-0.673***	-0.375*	0.207	- 0.661***	-0.318*	0.165
	(-6.44)	(-1.77)	-0.77	(-6.59)	(-2.13)	-0.89	(-6.47)	(-2.30)	-0.84	(-6.51)	(-2.47)	-0.9	(-6.51)	(-2.05)	-0.77
F Traffic	1.320***	-0.21	-0.209	1.264***	-0.21	-0.25	1.296***	-0.628*	-0.201	1.284***	-0.471	-0.196	1.357***	-0.245	-0.239
	-5.02	(-0.63)	(-0.46)	-5.16	(-0.73)	(-0.57)	-5.09	(-2.07)	(-0.49)	-5.08	(-1.25)	(-0.45)	-5.14	(-0.84)	(-0.55)
P Traffic	0.0227	-0.0933	-0.0489	0.0501	-0.0636	-0.032	0.0422	-0.115	-0.0268	0.0172	-0.0789	-0.04	-0.00168	-0.0875	-0.0332
	-0.12	(-0.48)	(-0.23)	-0.26	(-0.35)	(-0.16)	-0.22	(-0.63)	(-0.13)	-0.09	(-0.46)	(-0.18)	(-0.01)	(-0.44)	(-0.16)
Temperature	387.1**	-49.1	29.97	404.8***	40.21	42.21	404.0***	-13.96	20.82	380.2**	72.79	34.86	363.8**	-41.12	31.44
	-3.14	(-0.32)	-0.24	-3.55	-0.28	-0.34	-3.44	(-0.10)	-0.16	-3.06	-0.53	-0.28	-2.98	(-0.27)	-0.25
Precipitation	222.5*	26.46	37.13	235.8**	14.61	38.01	242.3**	18.19	42.63	206.4*	8.818	37.33	212.0*	34.95	40.68
	-2.55	-0.3	-0.54	-2.95	-0.18	-0.54	-2.87	-0.21	-0.62	-2.4	-0.11	-0.56	-2.58	-0.4	-0.54
Fixed Effects	No	City	City	No	City	City	No	City	City	No	City	City	No	City	City
Time Trend	No	No	City	No	No	City	No	No	City	No	No	City	No	No	City
Constant	11340.7	60095.7	7364.8	4509.3	15150.9	- 14059.1	6267.8	26757.1	-6569.3	10906.3	9653.7	1114.8	-3294.1	5981.1	- 10641.9
	-1.13	-0.67	-0.13	-0.68	-0.21	(-0.22)	-0.73	-0.41	(-0.10)	-1.08	-0.11	-0.02	(-0.29)	-0.12	(-0.13)
N	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164
adj. R-sq	0.784	0.909	0.942	0.787	0.911	0.942	0.784	0.911	0.942	0.786	0.915	0.941	0.785	0.91	0.942

* p <.05; ** p < .01; *** p < .001

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons, "Temperature" refers to average annual temperature, measured in degrees and "Precipitation" refers to total amount of annual precipitation, measured in inches.

China City Statistical Yearbook Model Results

Table 18: The effects of SO_2, Soot and Wastewater emissions on number of College Graduates

	1	2	3	4	5	6
SO2	-24.21**	-17.47	-17.77	2.779	1.396	-1.734
	-(2.64)	-(1.75)	(-1.76)	(0.35)	-(0.17)	(-0.48)
Soot	60.73*	51.7	81.55*	-50.4	-50.06	-2.017
	(2.27)	(1.69)	-(2.46)	-(1.56)	(-1.49)	(-0.17)
Wastewater	217.5**	117.1	111.8	16.85	32.16	8.941
	(2.66)	(1.61)	-(1.58)	(0.22)	-(0.41)	-(0.53)
Population	33.68***	42.42***	44.56***	67.12	55.03	-128.4***
	(6.09)	(6.19)	-(5.91)	(1.22)	-(0.87)	(-3.81)
GDP per capita	0.371***	0.591***	0.663***	0.592***	0.772***	0.0601
	(3.79)	(5.19)	-(5.37)	(6.70)	-(4.80)	-(1.15)
F Traffic	10.67**	10.09*	10.94*	1.44	1.7	0.559
	(2.65)	(2.29)	-(2.30)	(0.94)	-(1.08)	-(1.18)
P Traffic	0.0519	-0.0369	-0.124	0.0511	-0.00698	-0.0747
	(0.35)	-(0.24)	(-0.88)	(0.54)	(-0.08)	(-1.15)
Constant	-17377.9***	-16666.9***	-27805.0***	-(79137.40)	-(42316.40)	79529.2***
	(-7.68)	(-5.61)	(-6.47)	(-1.58)	(-0.93)	-3.92
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	1139	1093	1042	1132	1042	1132
adj. R-sq	0.406	0.524	0.542	0.901	0.913	0.982

* $p < .05$; ** $p < .01$; *** $p < .001$

“Population” is measured by 1,000 persons, GDP per capita is measured in Yuan, “F Traffic” refers to Freight traffic, measured in tons, and “P Traffic” refers to passenger traffic, measured by 10,000 persons.

Table 19: The effects of SO_2, Soot and Wastewater emissions on Junior Secondary School New Enrollment

	1	2	3	4	5	6
SO2	-9.019	-14.54*	-15.02	-13.72**	-10.46*	-11.37***
	-(0.88)	-(2.16)	(-1.79)	-(3.01)	(-2.13)	(-3.32)
Soot	9.075	84.14**	42.28	63.69**	12.95	21.18
	(0.32)	(3.24)	-(1.61)	(2.58)	-(0.54)	-(1.17)
Wastewater	-135.2*	-156.8**	-142.6**	13.7	86.12	32.82
	-(2.08)	-(2.77)	(-2.70)	(0.21)	-(1.55)	-(0.69)
Population	203.6***	204.7***	207.3***	89.11***	124.0***	122.9***
	(44.09)	(43.54)	-(43.74)	(4.63)	-(6.87)	-(5.33)
GDP per capita	-0.129**	-0.201***	-0.0951*	-0.358***	0.0466	-0.119
	-(2.62)	-(4.40)	(-2.02)	-(5.48)	-(0.47)	(-0.68)
F Traffic	-0.555***	-0.345***	-0.141	-0.549**	-0.115*	-0.00395
	-(4.01)	-(3.42)	(-1.55)	-(2.79)	(-2.30)	(-0.06)
P Traffic	0.475***	0.306***	0.183**	0.258***	0.0329	-0.0388
	(6.00)	(4.66)	-(2.61)	(4.25)	-(0.93)	(-0.90)
Constant	9667.3***	12977.0***	28452.2***	12765.6***	84050.1***	86321.7***
	-5.83	-4.83	-5.59	-5.42	-6.47	-5.94
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	1240	1192	1141	1233	1141	1233
adj. R-sq	0.829	0.88	0.892	0.949	0.964	0.972

* $p < .05$; ** $p < .01$; *** $p < .001$

“Population” is measured by 1,000 persons, GDP per capita is measured in Yuan, “F Traffic” refers to Freight traffic, measured in tons, and “P Traffic” refers to passenger traffic, measured by 10,000 persons.

Table 20: The effects of SO_2, Soot and Wastewater emissions on Primary School New Enrollment

	1	2	3	4	5	6
SO2	20.25	17.36	12.48	12	3.015	-18.13
	(0.76)	(0.71)	-(0.54)	(0.51)	-(0.14)	(-1.04)
Soot	19.77	-152	-133.8	-81.65	-43.66	58.25
	(0.30)	-(1.43)	(-1.22)	-(0.69)	(-0.34)	-(0.46)
Wastewater	-543.9**	-147.5	-136	123	134.9	61.25
	-(2.87)	-(0.88)	(-0.81)	(0.85)	-(0.82)	-(0.27)
Population	189.4***	176.5***	172.4***	407.9*	146.9	125.7
	(7.50)	(7.17)	-(6.95)	(1.98)	-(0.97)	-(0.66)
GDP per capita	0.0873	0.179	0.132	-0.0182	-0.0332	0.226
	(0.77)	(1.69)	-(1.23)	-(0.13)	(-0.16)	-(0.71)
F Traffic	-1.341**	-0.844*	-0.966*	-0.0215	-0.185	-0.21
	-(2.89)	-(2.46)	(-2.55)	-(0.14)	(-1.14)	(-0.82)
P Traffic	0.438*	0.335*	0.453**	-0.0497	0.189	0.165
	(2.49)	(2.34)	-(3.04)	-(0.48)	-(1.86)	-(0.83)
Constant	-(8954.20)	-14038.2*	-21275.4*	(89666.40)	(34641.20)	-(11978.50)
	(-1.39)	(-2.15)	(-2.40)	-0.29	-0.32	(-0.10)
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	1225	1177	1126	1218	1126	1218
adj. R-sq	0.25	0.387	0.42	0.372	0.406	0.317

* $p < .05$; ** $p < .01$; *** $p < .001$

"Population" is measured by 1,000 persons. GDP per capita is measured in Yuan. "F Traffic" refers to Freight traffic

Table 21: The effects of SO_2, Soot and Wastewater emissions on Pre-School Enrollment

	1	2	3	4	5	6
SO2	-13.51	15.27	4.73	26.57	14.95	22.79
	-(0.86)	(1.04)	-(0.32)	(0.93)	-(0.60)	-(1.18)
Soot	-93.58*	-26.78	-4.93	-44.55	-6.426	-6.579
	-(2.36)	-(0.64)	(-0.12)	-(0.80)	(-0.13)	(-0.13)
Wastewater	710.7***	322.1***	333.5***	-140.7	-158.4	-205.2*
	(7.50)	(3.90)	-(4.03)	-(0.92)	(-1.11)	(-2.02)
Population	141.3***	146.8***	140.7***	39.96	1.702	-33.23
	(22.59)	(22.36)	-(20.84)	(1.03)	-(0.05)	(-1.19)
GDP per capita	0.324**	0.352***	0.339**	0.535***	0.253	0.101
	(3.08)	(3.37)	-(3.00)	(3.61)	-(0.92)	-(0.37)
F Traffic	-0.151	0.135	0.0704	0.304	0.135	-0.132
	-(0.41)	(0.36)	-(0.18)	(0.78)	-(0.40)	(-1.30)
P Traffic	1.432***	1.002***	1.065***	0.408***	0.445***	0.231*
	(9.40)	(8.76)	-(8.32)	(3.79)	-(3.77)	-(2.00)
Constant	-(1585.60)	-18062.1***	14556.4**	(44214.90)	126799.4***	75650.6***
	(-0.59)	(-5.87)	-2.82	-1.24	-5.43	-4.07
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	1228	1182	1132	1221	1132	1221
adj. R-sq	0.658	0.766	0.773	0.868	0.881	0.936

* $p < .05$; ** $p < .01$; *** $p < .001$

"Population" is measured by 1,000 persons, GDP per capita is measured in Yuan, "F Traffic" refers to Freight traffic, measured in tons, and "P Traffic" refers to passenger traffic, measured by 10,000 persons.

Table 22: The effects of SO_2, Soot and Wastewater emissions on Average Wage

	1	2	3	4	5	6
SO2	3.988	5.336	-0.113	5.163	-1.026	-0.519
	(1.01)	(1.51)	(-0.06)	(1.88)	(-1.05)	(-0.57)
Soot	-19.27*	-19.69*	9.068*	-17.51*	6.306	5.503
	-(2.25)	-(2.24)	-(2.32)	-(2.27)	-(1.29)	-(0.70)
Wastewater	56.48***	25.02	21.08*	81.53**	4.911	2.654
	(3.44)	(1.46)	-(2.04)	(3.27)	-(0.44)	-(0.18)
Population	-2.216**	1.908*	-0.651	73.74***	-1.375	-9.684
	-(2.62)	(2.28)	(-0.91)	(4.07)	(-0.18)	(-0.95)
GDP per capita	0.261***	0.314***	0.207***	0.574***	0.158***	0.208**
	(16.30)	(22.35)	-(16.34)	(18.88)	-(5.28)	-(2.84)
F Traffic	0.123*	0.0730*	0.0622	0.0497	-0.000971	0.0106
	(2.53)	(2.07)	-(1.58)	(1.73)	(-0.07)	-(0.71)
P Traffic	0.0637***	0.0243	0.0494***	-0.0386	0.0172	-0.00356
	(3.33)	(1.33)	-(3.48)	-(1.46)	-(1.52)	(-0.28)
Constant	13586.1***	13390.5***	7185.6***	-77262.6***	(10412.70)	(12418.10)
	-34.56	-19.29	-10.62	(-3.75)	-1.94	-1.91
Fixed Effects	No	Regional	Regional	City	City	City
Time Trend	No	No	Regional	No	Regional	City
N	1226	1178	1127	1219	1127	1219
adj. R-sq	0.567	0.65	0.877	0.838	0.957	0.967

* $p <.05$; ** $p < .01$; *** $p < .001$

“Population” is measured by 1,000 persons, GDP per capita is measured in Yuan, “F Traffic” refers to Freight traffic, measured in tons, and “P Traffic” refers to passenger traffic, measured by 10,000 persons.

Stata Do-File Code:

```
//China City Statistical Yearbook
//AverageWage

quietly reg AverageWage SO2 population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store m1
xi: quietly reg AverageWage SO2 population GDPPerCapita FreightTraffic
PassengerTraffic   i.Region, robust
estimates store m2
quietly reg AverageWage SO2 Soot Wastewater population GDPPerCapita
FreightTraffic PassengerTraffic  , robust
estimates store m3
xi: quietly reg AverageWage SO2 Soot Wastewater population GDPPerCapita
FreightTraffic PassengerTraffic   i.Region, robust
estimates store m4
quietly reg AverageWage SO2 population GDPPerCapita FreightTraffic
PassengerTraffic i.r i.r#c.t, robust
estimates store m5
quietly reg AverageWage SO2 Soot Wastewater population GDPPerCapita
FreightTraffic PassengerTraffic i.r i.r#c.t, robust
estimates store m6
quietly reg AverageWage SO2 population GDPPerCapita FreightTraffic
PassengerTraffic i.cit i.r#c.t, robust
estimates store m7
quietly reg AverageWage SO2 Soot Wastewater population GDPPerCapita
FreightTraffic PassengerTraffic i.cit i.r#c.t, robust
estimates store m8
quietly reg AverageWage SO2 population GDPPerCapita FreightTraffic
PassengerTraffic i.cit i.cit#c.t, robust
estimates store m9
quietly reg AverageWage SO2 Soot Wastewater population GDPPerCapita
FreightTraffic PassengerTraffic i.cit i.cit#c.t, robust
estimates store m10

esttab m1 m2 m3 m4 m5 m6 m7 m8 m9 m10, ar2

//PreSchool



quietly reg PreSchool SO2 population GDPPerCapita FreightTraffic PassengerTraffic
, robust
estimates store m1
```

```
xi: quietly reg PreSchool SO2 population GDPPerCapita FreightTraffic
PassengerTraffic   i.Region, robust
estimates store m2
quietly reg PreSchool SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store m3
xi: quietly reg PreSchool SO2 Soot Wastewater population GDPPerCapita
FreightTraffic PassengerTraffic   i.Region, robust
estimates store m4
quietly reg PreSchool SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.r i.r#c.t, robust
estimates store m5
quietly reg PreSchool SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.r i.r#c.t, robust
estimates store m6
quietly reg PreSchool SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.cit i.r#c.t, robust
estimates store m7
quietly reg PreSchool SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.cit i.r#c.t, robust
estimates store m8
quietly reg PreSchool SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.cit i.cit#c.t, robust
estimates store m9
quietly reg PreSchool SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.cit i.cit#c.t, robust
estimates store m10


esttab m1 m2 m3 m4 m5 m6 m7 m8 m9 m10, ar2


//JuniorSecondary
quietly reg JuniorSec SO2 population GDPPerCapita FreightTraffic PassengerTraffic
, robust
estimates store m1
xi: quietly reg JuniorSec SO2 population GDPPerCapita FreightTraffic
PassengerTraffic   i.Region, robust
estimates store m2
quietly reg JuniorSec SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store m3
xi: quietly reg JuniorSec SO2 Soot Wastewater population GDPPerCapita
FreightTraffic PassengerTraffic   i.Region, robust
estimates store m4
```

```
quietly reg JuniorSec SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.r i.r#c.t, robust
estimates store m5
quietly reg JuniorSec SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.r i.r#c.t, robust
estimates store m6
quietly reg JuniorSec SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.cit i.r#c.t, robust
estimates store m7
quietly reg JuniorSec SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.cit i.r#c.t, robust
estimates store m8
quietly reg JuniorSec SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.cit i.cit#c.t, robust
estimates store m9
quietly reg JuniorSec SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.cit i.cit#c.t, robust
estimates store m10


esttab m1 m2 m3 m4 m5 m6 m7 m8 m9 m10, ar2
//Primary
quietly reg Primary SO2 population GDPPerCapita FreightTraffic PassengerTraffic  ,
robust
estimates store m1
xi: quietly reg Primary SO2 population GDPPerCapita FreightTraffic
PassengerTraffic   i.Region, robust
estimates store m2
quietly reg Primary SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store m3
xi: quietly reg Primary SO2 Soot Wastewater population GDPPerCapita
FreightTraffic PassengerTraffic   i.Region, robust
estimates store m4
quietly reg Primary SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.r i.r#c.t, robust
estimates store m5
quietly reg Primary SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.r i.r#c.t, robust
estimates store m6
quietly reg Primary SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.cit i.r#c.t, robust
estimates store m7
quietly reg Primary SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.cit i.r#c.t, robust
estimates store m8
```

```
quietly reg Primary SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.cit i.cit#c.t, robust
estimates store m9
quietly reg Primary SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.cit i.cit#c.t, robust
estimates store m10


esttab m1 m2 m3 m4 m5 m6 m7 m8 m9 m10, ar2
//College
quietly reg College SO2 population GDPPerCapita FreightTraffic PassengerTraffic  ,
robust
estimates store m1
xi: quietly reg College SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.Region, robust
estimates store m2
quietly reg College SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store m3
xi: quietly reg College SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic   i.Region, robust
estimates store m4
quietly reg College SO2 population GDPPerCapita FreightTraffic PassengerTraffic i.r
i.r#c.t, robust
estimates store m5
quietly reg College SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.r i.r#c.t, robust
estimates store m6
quietly reg College SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.cit i.r#c.t, robust
estimates store m7
quietly reg College SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.cit i.r#c.t, robust
estimates store m8
quietly reg College SO2 population GDPPerCapita FreightTraffic PassengerTraffic
i.cit i.cit#c.t, robust
estimates store m9
quietly reg College SO2 Soot Wastewater population GDPPerCapita FreightTraffic
PassengerTraffic i.cit i.cit#c.t, robust
estimates store m10


esttab m1 m2 m3 m4 m5 m6 m7 m8 m9 m10, ar2

//Visibility
```

```
//AverageWage


quietly reg AverageWage Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    , robust
estimates store w1
xi: quietly reg AverageWage Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.Region, robust
estimates store w2
xi: quietly reg AverageWage Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.Region R#c.t, robust
estimates store w3
xi: quietly reg AverageWage Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit R#c.t, robust
estimates store w5
xi: quietly reg AverageWage Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit, robust
estimates store w4
quietly reg AverageWage Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit R#c.t, robust
estimates store w6
esttab w1 w2 w3 w4 w5 w6, ar2
//PreSchool

quietly reg PreSchool Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    , robust
estimates store w1
xi: quietly reg PreSchool Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.Region, robust
estimates store w2
xi: quietly reg PreSchool Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.Region R#c.t, robust
estimates store w3
xi: quietly reg PreSchool Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit R#c.t, robust
estimates store w5
xi: quietly reg PreSchool Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit, robust
estimates store w4
quietly reg PreSchool Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit R#c.t, robust
estimates store w6
esttab w1 w2 w3 w4 w5 w6, ar2
//College
```

```
quietly reg College Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    , robust
estimates store w1
xi: quietly reg College Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.Region, robust
estimates store w2
xi: quietly reg College Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.Region R#c.t, robust
estimates store w3
xi: quietly reg College Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit R#c.t, robust
estimates store w5
xi: quietly reg College Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit, robust
estimates store w4
quietly reg College Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit R#c.t, robust
estimates store w6
esttab w1 w2 w3 w4 w5 w6, ar2
//Primary

quietly reg Primary Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    , robust
estimates store w1
xi: quietly reg Primary Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.Region, robust
estimates store w2
xi: quietly reg Primary Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.Region R#c.t, robust
estimates store w3
xi: quietly reg Primary Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit R#c.t, robust
estimates store w5
xi: quietly reg Primary Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit, robust
estimates store w4
quietly reg Primary Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    i.cit R#c.t, robust
estimates store w6
esttab w1 w2 w3 w4 w5 w6, ar2
//Junior Secondary

quietly reg JuniorSec Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic    , robust
estimates store w1
```

```
xi: quietly reg JuniorSec Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic     i.Region, robust
estimates store w2
xi: quietly reg JuniorSec Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic     i.Region R#c.t, robust
estimates store w3
xi: quietly reg JuniorSec Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic     i.cit R#c.t, robust
estimates store w5
xi: quietly reg JuniorSec Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic     i.cit, robust
estimates store w4
quietly reg JuniorSec Visibility   Population GDPPerCapita FreightTraffic
PassengerTraffic     i.cit R#c.t, robust
estimates store w6
esttab w1 w2 w3 w4 w5 w6, ar2

//China Statistical Yearbook

//AverageWage

quietly reg AverageWage PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w2
xi: quietly reg AverageWage PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w7
quietly reg AverageWage NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w3
xi: quietly reg AverageWage NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w8
quietly reg AverageWage PM__10 NO__2 SO__2  Population GDPPerCapita
FreightTraffic PassengerTraffic  , robust
estimates store w1
xi: quietly reg AverageWage PM__10 NO__2 SO__2   Population GDPPerCapita
FreightTraffic PassengerTraffic   i.City, robust
estimates store w6
quietly reg AverageWage  DaysIIAQ  Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w5
xi: quietly reg AverageWage DaysIIAQ   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w10
```

```
xi: quietly reg AverageWage SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w9
quietly reg AverageWage SO__2 Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w4
quietly reg AverageWage PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w11
quietly reg AverageWage NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w12
quietly reg AverageWage SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w13
quietly reg AverageWage PM__10 NO__2 SO__2   Population GDPPerCapita
FreightTraffic PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w14
quietly reg AverageWage DaysIIAQ   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w15


esttab w1 w2 w3 w4 w5 w6 w7 w8 w9 w10 w11 w12 w13 w14 w15, ar2

//PreSchool

quietly reg PreSchool PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w2
xi: quietly reg PreSchool PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w7
quietly reg PreSchool NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w3
xi: quietly reg PreSchool NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w8
quietly reg PreSchool PM__10 NO__2 SO__2  Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w1
xi: quietly reg PreSchool PM__10 NO__2 SO__2   Population GDPPerCapita
FreightTraffic PassengerTraffic   i.City, robust
estimates store w6
```

```
quietly reg PreSchool  DaysIIAQ  Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w5
xi: quietly reg PreSchool DaysIIAQ   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w10
xi: quietly reg PreSchool SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w9
quietly reg PreSchool SO__2 Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w4
quietly reg PreSchool PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w11
quietly reg PreSchool NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w12
quietly reg PreSchool SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w13
quietly reg PreSchool PM__10 NO__2 SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w14
quietly reg PreSchool DaysIIAQ   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w15


esttab w1 w2 w3 w4 w5 w6 w7 w8 w9 w10 w11 w12 w13 w14 w15, ar2

//College

quietly reg College PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w2
xi: quietly reg College PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w7
quietly reg College NO__2   Population GDPPerCapita FreightTraffic PassengerTraffic
, robust
estimates store w3
xi: quietly reg College NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w8
```

```
quietly reg College PM__10 NO__2 SO__2  Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w1
xi: quietly reg College PM__10 NO__2 SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w6
quietly reg College  DaysIIAQ  Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w5
xi: quietly reg College DaysIIAQ   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w10
xi: quietly reg College SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w9
quietly reg College SO__2 Population GDPPerCapita FreightTraffic PassengerTraffic  ,
robust
estimates store w4
quietly reg College PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w11
quietly reg College NO__2   Population GDPPerCapita FreightTraffic PassengerTraffic
i.cit i.cit#c.t, robust
estimates store w12
quietly reg College SO__2   Population GDPPerCapita FreightTraffic PassengerTraffic
i.cit i.cit#c.t, robust
estimates store w13
quietly reg College PM__10 NO__2 SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w14
quietly reg College DaysIIAQ   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w15


esttab w1 w2 w3 w4 w5 w6 w7 w8 w9 w10 w11 w12 w13 w14 w15, ar2

//Primary

quietly reg Primary PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w2
xi: quietly reg Primary PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w7
```

```
quietly reg Primary NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w3
xi: quietly reg Primary NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w8
quietly reg Primary PM__10 NO__2 SO__2  Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w1
xi: quietly reg Primary PM__10 NO__2 SO__2   Population GDPPerCapita
FreightTraffic PassengerTraffic   i.City, robust
estimates store w6
quietly reg Primary  DaysIIAQ  Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w5
xi: quietly reg Primary DaysIIAQ   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w10
xi: quietly reg Primary SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w9
quietly reg Primary SO__2 Population GDPPerCapita FreightTraffic PassengerTraffic
, robust
estimates store w4
quietly reg Primary PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w11
quietly reg Primary NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w12
quietly reg Primary SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w13
quietly reg Primary PM__10 NO__2 SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w14
quietly reg Primary DaysIIAQ   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w15


esttab w1 w2 w3 w4 w5 w6 w7 w8 w9 w10 w11 w12 w13 w14 w15, ar2

//JuniorSecondary
```

```
quietly reg JuniorSec PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w2
xi: quietly reg JuniorSec PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w7
quietly reg JuniorSec NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w3
xi: quietly reg JuniorSec NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w8
quietly reg JuniorSec PM__10 NO__2 SO__2  Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w1
xi: quietly reg JuniorSec PM__10 NO__2 SO__2   Population GDPPerCapita
FreightTraffic PassengerTraffic   i.City, robust
estimates store w6
quietly reg JuniorSec  DaysIIAQ  Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w5
xi: quietly reg JuniorSec DaysIIAQ   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w10
xi: quietly reg JuniorSec SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.City, robust
estimates store w9
quietly reg JuniorSec SO__2 Population GDPPerCapita FreightTraffic
PassengerTraffic  , robust
estimates store w4
quietly reg JuniorSec PM__10   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w11
quietly reg JuniorSec NO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w12
quietly reg JuniorSec SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w13
quietly reg JuniorSec PM__10 NO__2 SO__2   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w14
quietly reg JuniorSec DaysIIAQ   Population GDPPerCapita FreightTraffic
PassengerTraffic   i.cit i.cit#c.t, robust
estimates store w15
```

```
esttab w1 w2 w3 w4 w5 w6 w7 w8 w9 w10 w11 w12 w13 w14 w15, ar2
```