The Economic Cost of Exploiting Coal in China:

Converting to Clean Coal Energy

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ECON-480-001H

Senior Research Seminar

SIS-498-004H

Environmental Issues in China

December 14, 2007

Abstract

Coal has contributed to China's economic success and its prosperity. However, it has also resulted in negative effects on the environment and economy in China by creating a number of negative externalities such as damage to human health, agriculture and forestry. Although there have been many studies about the relation between coal consumption and environmental effects, there has been relatively little empirical research on coal consumption and its economic and environmental cost. This research project uses data mostly from the International Energy Agency (IEA) and Chinese Statistics 2005, which is a statistical database based on information from the Chinese government. The statistical results do not demonstrate strong evidence that coal consumption has a negative effect on agricultural production and forest area. However, coal consumption has a positive and statistically significant effect on the death rate from respiratory diseases in rural areas and the total death rate that is included both in rural and urban areas. It is predicted that as coal consumption increases by one million tons, the total death rate from respiratory diseases will increase by 45.436 (the death of 5,906,680 people) on average from 2010 to 2011.

I. Introduction

Coal is the reason how China is mortgaging its long term economic security with cheap energy. This spring break, I went to Beijing, where the Olympics will be held next year. Smoke, pollution, and gray skies – these are exactly what I witnessed, and these poignant scenes made a mark on my memory. In fact, while I was staying there, I did not see any blue skies with sun.

This study investigates the question of the economic cost of using conventional coal in China. Although a great deal of study on coal and Chinese environment has been done so far, scholars and the government have not agreed on whether China needs to keep consuming large amount of coal. While some scholars argue that coal is necessary for China's economic growth, some others insist that China needs to take steps to use an alternative energy or cleaner coal energy instead of conventional coal.

If this research finds results that explain the causal relationship between coal consumption and its human costs of productivity, it can significantly advance the study on coal and Chinese environment. In addition, if this is the case, by promoting a cleaner coal energy not only people living in polluted areas in China, but also people in neighboring countries, would enjoy better air-quality and quality of life. Moreover, it is possible that promoting clean coal energy in China would contribute the prosperity of the world economy by slowing down Chinese environmental destruction and preventing global warming. Thus, energy transformation in China is an important issue in the fields of both economics and international relations.

This research has four parts. First, it includes a literature review on coal and cleaner coal energy. Second, it will describe the economic model based on the theory of externality and three hypotheses. All of them will assist in answering the research question: How much is the economic cost of using conventional coal? Third, it will explain the econometric model for regression analysis by defining independent variables and dependent variables in order to test the research question. Finally, it will draw conclusion based on the results.

II. Literature Review

Coal has contributed to great economic growth in China. Now, there are many coal industries in both urban and rural cities, and they symbolize economic success in China. Since China has a great number of coal resources, it has consumed a countless number of them. In fact, coal consumption in China occupies 34 percent of coal consumption in the world (Nersesian 2007, 92). China is not the only country that experienced this rapid success, partly derived from coal industries. India experienced the same situation: heavy industrialization and rapid economic development. Currently, many developing countries in the world are still heavily dependent on coal energy in order to achieve rapid economic development. As of 2005, China and India depended on coal for the majority of their total energy, while coal occupies less than a quarter of total energy in developed countries such as the United States and European countries (Nersesian 2007, 93-94).

Coal consumption is quite a controversial issue among scholars since it has positive and negative economic aspects. One of the most significant economic benefits is employment created by coal consumption. Nersesian (2007) emphasizes coal miners particularly in China and India: "While there are 7 million coal miners in the world, five millions of those are in China and another half million are in India" (Nersesian 2007, 85). In addition, coal consumption has alleviated poverty particularly in rural or remote areas, creating employment opportunities for people living there, and provided poor communities with affordable welfare and energy (Shi 2006, 314). Furthermore, coal is relatively cheap compared to other energies. For instance, the price per ton of oil exceeded $400 while the price per ton of coal was only about $60 in 2005 (Nersesian 2007, 91). For these reasons, many Chinese scholars have argued that there is a promising future for the coal industry (Shang 2001 and Li 2003).

However, while coal consumption has benefits, it also has negative aspects. For instance, coal consumption threats occupational safety and sometimes promotes disease. People who work in mines often become sick or die because of harmful working environment. World Combined Services (2003) observed that black lung, a lung disease caused by breathing coal dust, killed 55,000 miners between 1968 and 1990 and continues to kill 1,000 miners each year.

Although coal miners' health condition is a serious problem of coal consumption, the problem focus has shifted to environmental issues. Coal is one of the primary environmental pollutants and it has destroyed many natural resources in China. For instance, the coal industry emits nitrogen oxide, sulfur dioxide (SO_2) and carbon dioxide (CO_2), and causes air pollution and acid rain (Yanli and Min 2007, 14). This pollution affects not only nature itself but also crops, animals, plants and humans. As they are valuable sources for economic development, environmental issues will slow down the economy in China.

Since these environmental problems have emerged not only in China but also in many other parts of the world, a number of international environmental regulations were created in the late 20th century in order to solve the problem. The main international environmental regulations that relates to coal are the 1979 United Nations Convention on Long-Range Transboundary Air Pollution, the 1985 Sulphur Protocol, the 1992 UN Framework Convention on Climate Change

(UNFCCC), the 1997 Kyoto Protocol to the UNFCCC (the Kyoto Protocol) and the 1998 Nitrogen Oxides Protocol (Shi 2006, 316). Regulations on pollutants such as sulfur dioxide, nitrogen oxide and carbon dioxide have negatively affected the coal industry, which has had to limit or alter the coal consumption. Particularly, the effect of regulations on carbon dioxide is significant because coal consumption generates the largest amount of carbon dioxide per unit (Shi 2006, 316). One example is the Kyoto Protocol. Although major carbon emission countries such as China and the U.S. have not signed up for the commitment, it required countries to reduce carbon dioxide emissions.

Because of these regulations, many scholars consider the future for the coal industry to be unpromising (Keay 2003). In China, "the view that the coal industry is *XiYang Gongye* ("the setting sun", that is, hopeless) is widely held (Shi 2006, 315). A similar view could be found in the 1960s and 1970s in the United States because the government was trying to enforce regulation on pollution (Shi 2006, 315).

One would expect that the increasing the number of regulations for emissions would decrease coal consumption. However, this is not necessarily true. In fact, in recent years, world coal consumption has increased. Nersesian emphasizes this trend: "World coal consumption, essentially stagnant during the 1990s, surged by 30 percent between 2000 and 2004. Not only is the world consuming more coal, but its share of the energy pie increased from 23.4 percent in 2000, its historical low point, to 27.8 percent in 2005" (Nersesian 2007, 68). Why is the trend happening? One of the main reasons is that emission of pollutants can be reduced by switching from conventional coal to cleaner coal energy.

In many countries, cleaner coal energy is becoming common. They use it instead of conventional coal in order to decrease pollutant emissions. For instance, sulfur emission has decreased 2-3 percent per year in the U.S. by using scrubbers to remove sulfur and relying on low sulfur coal (Nersesian 2007, 98). The Chinese government seems to have a positive attitude toward this cleaner coal energy, and regards it as an important factor in the development of the energy supply. In fact, the Chinese government emphasized this energy in the Ninth Five Year Plan documents on clean coal technologies in China and describes its goals for the China's clean coal technology development. Its goals are "to develop economical, efficient and practical coal technology; to achieve energy conservation and rational use of resources, to reduce 'secondary pollution' in coal mining and utilization, and to diversify coal products by shifting away from the single product in coal production" (Jin and Liu 1999, 6).

The Chinese government has incentives to implement the use of cleaner coal energy, and imports of clean coal equipment to China are increasing, mainly from the U.S., Germany, Russia, Japan, Finland, France, U.K., Sweden, Canada and Italy (Jin and Liu 1999, 14). However, the development of its technology expansion has so far been sluggish. During 1993-1996 the capacity of new coal washing plants increased less than coal mining capacity. The lack of proper incentives created such condition. Glomsrod (spelling?) and Tayuan explain that there is a cycle where "producers claim that cleaned coal demand is too low while consumers complain about unreliable supply" (Glomsrod and Tayuan, 2003, 3).

Indeed, when the demand for cleaner coal energy is low, it would be costly to provide it. However, washing coal has relatively low costs and produces environmental conservation benefits by reducing the amount of sulfur and ash content in the coal (Ohshita and Ortolano 2006, 78). While washing coal is predominant in developed countries such as in the United States, Europe and Japan, it is not widespread in most of developing countries. This is because they do not have enough capital to establish washing facilities for coals (Nersesian 2007, 101).

Nevertheless, China does not lack capital because it has saving from a large trade surplus. In addition, by law every coal mine must have a washing facility in China. In spite of these facts, "only around 30 percent of China's coal is properly rinsed of ash (which adds to pollution) and tailings (that reduce energy efficiency)" (Ansfield 2007).

Therefore, the Chinese government needs more incentives to advance cleaner coal energy technologies such as coal washing facilities. One significant incentive that it should realize is that the consumption of conventional coal that causes air pollution will eventually lead to economic loss by damaging human health, crops and forests. Hence, this research paper focuses on these environmental costs caused by coal consumption in order to demonstrate why conventional coal should be transformed into cleaner coal energy.

III. Economic Model

The economic model of externality describes the negative external effect of air pollution caused by coal consumption and identifies the benefits to society of cleaner coal energy. For each unit of conventional coal consumed, a certain amount of air pollutants such as NO_2 and CO_2 enter the atmosphere. Yanli and Min (2007) emphasize the amount of air pollutants produced by coal consumption in China:

> In 2006 nearly 26 million metric tons of sulfur dioxide were discharged into the air in China, of which 90 percent came from coal burning. The country also emitted nearly 20 million tons of particulate matter and other smog-forming pollutants, 70 percent of it from coal. In addition, coal contributed to 67 percent of total national nitrogen oxide (NOx) emissions and 70 percent of China's 4.7 billion tons of carbon dioxide emissions…Coal-fired power plants and other coal-burning facilities also discharge roughly 495 tons of mercury each year, a total that is expected to increase by 20 to 30 tons annually for the next several years (Yanli and Min 2007, 14).

As these chemicals enter into the atmosphere, they cause air pollution as well as more serious problems such as acid rain. In recent years, the level of air pollution in China has been rapidly increasing. Hertsgaard (2000) states that "In 1996, China boasted five of the world's 10 most air-polluted cities; by 1998, its share had jumped to nine out of 10" (Hertsgaard 2000, 27). In addition, Watt (2006) highlights the fact that the majority of cities in China are suffering from air pollution: "In a survey of 341 major cities in China in 2003 … 27% suffered from serious pollution, 32% had light pollution, and 41% enjoyed good air quality" (Watt 2006, 1761).

Air pollution creates negative effects on the economy and environmental productivity. Hertsgaard (2000) states that the "damage caused by pollution in China is estimated to cost $54 billion annually: amounting to close to 8% of gross domestic product (GDP)" (Hertsgaard 2000, 27). This number might seem small, but it is not. It is almost the same as economic growth in terms of GDP (Kim 2007, 3), implying that economic growth in China will stop in the future if this trend continues. Managi and Kaneko (2006) also stress that "TFP[1] for environmental outputs decreases by about 27.3% and 16.0% or a mean rate of 2.0% and 1.1% decrease per year, respectively" (Managi and Kaneko 2006, 9).

The reason for loss of productivity is that air pollution creates a health risk for citizens, damages agricultural production and slows forest growth. When people breathe low-quality air that includes chemical emissions such as NO_2 and CO_2, they will likely acquire respiratory diseases later in life. Smil (2004) states that "at least 200 million Chinese are exposed to annual particulate concentration of above 300 ug/m^3, and at least 20 million are exposed to twice that level… , These very high exposures … contribute to higher incidence of respiratory diseases, ranging from upper respiratory infections to lung cancer" (Smil 2004, 183). Thus, people who live in air-polluted areas with air pollution often wear dust masks to reduce exposure to contaminants to prevent suffering from the respiratory diseases.

However, wearing masks is not sufficient enough to completely eliminate the possibilities of acquiring disease. In fact, "specialists estimate that the number of asthma cases in China has risen by 40% in the past 5 years" (Watts 2006, 719). In addition, "one recent study, undertaken by the Ministry of Health in 2000 and released on June 15, 2001, concluded that lung cancer and other respiratory diseases in Benxi result not only from smoking but also from high air pollution level" (Yu et al. 2006, 36). Thus, a number of scholars support the idea that air pollution causes high rate of respiratory diseases, which would lead to a loss of worker's productivity.

In addition, air pollution decreases agricultural production by causing soil degradation and loss of farmland. Air pollutants such as sulfur dioxide and carbon dioxide acidify the soil, and damage the roots of the crops, and eventually reduce total yields (*Terra Daily* 2006). Smil (2004) emphasizes how big the loss of farmland in China is: "Cumulative loss of arable land during the past forty years has been larger than Germany's total farmland, and the annual loss has averaged about half million hectares since 1980" (Smil 2004, 185). Crops themselves also suffer from air pollution. According to Monastersky (1999), "the highest ozone readings in the study occurred in Linan[2], which sits in the Yangtze River Delta, one of China's most important agricultural regions. The timing of the air-pollution problems threatens the delta's winter wheat crop, which supplies 20 percent of China's total wheat harvest" (Monastersky 1999). Air pollution negatively impacts forests as well as crops. Zheng and Shimizu (2003) emphasizes one example of damaged forests:

> Nanshan is a mountain adjacent to the southeast of Chongqing City and impacted by pollutants from the city. Nanshan has c. 2000 [hectare] of forests, mainly Pinus massoniana Lamb[3]. It has been reported that since the beginning of the 1980s, more than half of these trees have died and 85% of the remaining pine trees show some degree of injury (Zheng and Shimizu 2003, 131).

Moreover, Gao (2007) warns that the amount of forest in China is decreasing. From 1986 to 1999 “Many areas adjusted the canopy density rate used to define a “forest” downwards from 0.3 to 0.2” (Gao 2007). Thus, the damaged forest and the loss of forest would negatively affect the forestry in China, and it will lead to economic loss of productivity.

When these negative externalities exist in the market for coal, marginal social cost is higher than the private cost, as Figure 1 shows. This graph is the economic model that demonstrates negative externality and its effect on coal market in China. Although the market quantity equilibrium still remains at the same point, negative externality creates the optimal quantity that is preferred by social planners and people in areas with air pollution.

Therefore, social planners usually would choose the optimal quantity by internalizing the negative externality so that they can give buyers and sellers incentives to take account of the negative externality: air pollution. Because of this effect, the supply (private cost) curve shifts up to the line of the social cost curve. In this way, the quantity of coal decreases (Q market to Q optimum), while the price of coal increases (from P1 to P2). Thus, the equilibrium for the coal market moves to the upper-left.

One way to internalize the negative externality is the use of a tax. If social planners impose a tax on coal suppliers (producers), suppliers then have to take the costs of air pollution into account when deciding how much of the coal they produce because for each unit of coal, they have additional tax cost. Because of the effect of this tax, producers would increase the price of coal, and the market price would increase. By reflecting the rise of the coal price, consumers of coal would have incentive to use smaller quantities, which is shown by the optimal quantity on the graph.

The other way to internalize negative externality is through environmental regulation that limits the use of conventional coal. The same economic logic applies to this case. When there is no environmental regulation that limits the use of coal, the equilibrium point would be at the Q market, where the supply curve and demand curve crosses, because no one would take the cost of negative externalities into account when producing or consuming coal, and the public would eventually have to assume the cost by suffering from air pollution. Therefore, the social cost would lie above the supply curve. However, environmental regulation would limit the use of coal; therefore, the supply curve shifts to the left and the quantity of coal supplied would decrease. Because there is excess demand for coal, the price of coal would increase, and quantity equilibrium would move to optimal quantity.

Although environmental regulations that limit the use of conventional coal have already been passed in China, the government (which is the social planner in China) has not enforced the law strictly. Because of this effect, the supply (private cost) curve does not shift up enough to meet the social cost curve. In this way, the price of coal remains cheap, and the demand for coal would not decrease. Therefore, the market for coal in China is inefficient. The Chinese government needs to strictly enforce the law that limits the use of conventional coal so that it can encourage coal industries to use cleaner coal.

This research paper examines the details of negative externalities in order to demonstrate how significant the negative externality of air pollution caused by coal consumption is. By doing so, it will also demonstrate how significant the reduction of externality caused by transforming into cleaner coal is.

Therefore, I expect that as coal consumption increases, the negative externalities (the economic costs of air pollution) such as deterioration of public health, loss of agricultural production, and loss of forest area increase. This could be divided into three hypotheses.

- Hypothesis 1: As coal consumption rises, the deterioration of public health increases.

- Hypothesis 2: As coal consumption rises, agricultural production decreases.
- Hypothesis 3: As coal consumption rises, forest area decreases.

IV. Empirical Results

1. Econometric Model

Economic costs include various types. It does not only include the losses of products and services but also include the deterioration of public health. Since it is difficult to estimate all of these economic costs, this research focuses on three of them: the deterioration of public health and the reduction in both agricultural output and forest area.

- Hypothesis 1: As coal consumption rises, the deterioration of public health increases.

Since coal consumption emits chemical elements into the air, it causes air pollution, and this air pollution negatively affects people's health in China by causing them to have respiratory diseases such as asthma and lung cancer. Therefore, as coal consumption rises, deterioration of public health increases, and this relation is causation that can be rearrested by a linear regression line. Coal consumption is the independent variable (X variable), while the death rate from respiratory diseases is the dependent variable (Y variable). However, this research needs to constrain some factors to prevent error.

First, not only coal consumption but also oil consumption negatively affects the death rate caused by respiratory diseases. This is because oil consumption also emits chemical elements such as NO_2 and CO_2, although oil consumption does not emit chemical elements as much as coal consumption does (Higgins 2005, 1). In addition, health expenditures may also affect the death rate from respiratory diseases. An increase in health expenditures does not necessarily decrease the death rate; however, it is possible that as the government spends more money on the health sector, the health sector would have more money to improve their assets such as physicians and medical equipment technology. Moreover, cigarette consumption affects the death rate by causing people to have respiratory diseases. The more cigarettes people consume, the more risks there are of contracting of lung cancer in the future (Thun et al. 2002, 1). Therefore, this research needs to take these variables into account.

What is more, coal, oil and cigarette consumption would not affect the death rate in the short term but in the long term. There is a long-term correlation between coal consumption and the death rate from respiratory diseases because it takes a while for the effect to appear. For instance, the time duration between exposure to air pollution and the onset of respiratory diseases is one factor that correlates in the long term because people need to be exposed in areas with air pollution for a significant duration of time in order to succumb to respiratory disease. The other reason for the long term correlations is the time duration between respiratory disease onset and death because patients of respiratory disease can survive for a long time with proper medical treatment. This is also true in the case of cigarette consumption and death. People who often smoke do not die soon after they smoke, although the probability of acquiring respiratory diseases and dying increases. The effect usually appears in the long term. These time durations are difficult to estimate since they would change depending on the environment that people are surrounded in. Ebi-Kryston (1988) indicates the time duration between respiratory disease and death:

> Relationships between various measures of respiratory impairment and 10-year mortality from chronic respiratory diseases, cardiovascular disease and all causes have been investigated in 17,717 male London civil servants aged 40–64 years…65% predicted was

significantly associated with mortality from respiratory and cardiovascular diseases (Ebi-Kryston 1988)

Thus, I assume that there is at least a 10 year-long duration between coal consumption and death caused by respiratory disease.

Judging from these points, the equation for this hypothesis is the following.

$Yt = a + bC(t-10) + cO(t-10) - dHt + eCI(t-10) + \varepsilon t$ <Equation 1>

Y = Death rate from respiratory diseases

t = Year

C = Coal consumption

O = Oil consumption

H = Health expenditure

CI = Cigarette consumption

- Hypothesis 2: As coal consumption rises, agricultural production decreases.

As the coal consumption increases, so does air pollution. An increase in air pollution decreases agricultural production by causing soil degradation and loss of farmland. Therefore as coal consumption rises, agricultural production decreases. A negative linear regression line explains the relation. Agricultural production includes various products such as grain, wheat and cereal. As long as agricultural products are something common which grow without exception in China, it can be used as the dependent variable. This research uses grain which is one of the most common agricultural products in China. Therefore, coal consumption is the independent variable (X variable), while yield of grain is the dependent variable (Y variable). This hypothesis also needs to take some factors into consideration.

First, the area of cultivated land possibly affects agricultural production. As the more cultivated land a province has, the more the province can distribute arable land for grain, and it would likely to have higher yields of grain. In addition, as the total power of agricultural machinery increases, productivity for agricultural production such as yield of grain increases thanks to technological progress. Therefore, this factor also needs to be controlled. Moreover, natural disasters often occur in China, affecting its agricultural production. According to *Inside China Mainland* (2006), "natural disasters…in recent years [have] made meeting grain production goals a challenge each year" (*Inside China Mainland* 2006, 1). Therefore, this research needs to take the negative effect of natural disasters into account.

Judging from these points, the equation for this hypothesis is the following.

$Yp = a + bCp + cCLp + dPAMp - eNDp + \varepsilon p$ <Equation 2>

Y = Yield of Grain Output

p = Province (or city)

C = Coal consumption

CL = Cultivated Land

PAM = Power of Agricultural Machinery

ND = Natural Disaster

- Hypothesis 3: As coal consumption rises, forest area decreases.

Coal consumption causes air pollution. An increase in air pollution reduces forest area because air pollutants damage and kill trees. Therefore, as coal consumption rises, forest area decreases. A negative linear regression line represents this correlation. With this hypothesis coal consumption by area (province or city) is the independent variable (X variable), while forest area by each province is the dependent variable (Y variable). The hypothesis also needs to consider some factors.

Fist, this research should take forest fire into account. It is quite natural that as forest fire increases, forest area decreases. The same theory applies to forest diseases and pests. The more trees acquire forest disease and pests, the more forests become damaged. Therefore, forest area decrease as the cases of disease and pests increase.

Judging from these points, the equation for this hypothesis is the following.

$Yp = a + bCp - cFFp - dFDPp + \varepsilon p$ <Equation 3>

Y = Forest Area

p = Province (or city)

C = Coal consumption

FF = Forest Fire

FDP = Forest Disease and Pest

If these hypotheses 1-3 are correct, economic costs of coal consumption would increase.

2. Description of Data

- Hypothesis 1: As coal consumption rises, the deterioration of public health increases.

For hypothesis 1, this research uses annual data, demonstrated in Tables 1-1 to 1-5. Table 2 demonstrates its statistical data, including the number of observations, mean and standard deviation. The data of coal consumption (Table 1-1) and oil consumption (Table 1-2) are from the International Energy Agency (IEA). The IEA has the data of coal consumption and oil consumption from 1980 to 2006. In China coal consumption has been generally increasing, although it has decreased from 1996 to 2000. While in 1980 its coal consumption was only about 690 million short tons per year, in 2005 it increased to about 2333 million short tons per year, which is over three times than what it was 25 years ago. As Table 2 demonstrates, its mean is 1243 and standard deviation is 396, implying that the data have a high variability. Oil consumption also has been increasing since the 1980s except from 1989 to 1990. While in 1980 oil consumption in China was only 1765 thousand barrels per day, in 2006 it increased to 7273 thousand barrels, which is over four times consumption in 1980. Its mean is 3447 and standard deviation is 1689, which is about half of the mean. This standard deviation is very high and implies that the oil consumption varies significantly, depending on the year.

The death rate from respiratory diseases (Table 1-3) is from the Ministry of Health of the government of China. Since the World Health Organization (WHO) does not have the annual data of respiratory disease in China, this research uses the data collected by the Chinese government. However, the data do not have proper credibility because the Chinese government sometimes manipulates and overstates its statistics data. Lu emphasizes its overstated numbers on output data on agricultural products: "Chinese statistics show large discrepancies between output and household consumption for meat, eggs, and aquatic products. More interestingly, the discrepancies have grown rapidly since the 1980s" (Lu 1999, 2). In addition, although this research needs to have a larger sample for the death rate from respiratory diseases in order to reduce its standard error, the Ministry of Health of the Chinese government only allows researchers to see the data in recent years (from 1999 to 2006). Moreover, since the Ministry of Health does not have the data in 2000 and 2004, the death rate was calculated by the average of the surrounding years (e.g., the death rate in urban areas in 2000 is calculated by the average death rate of 1999 and 2001).

In urban areas the death rate from respiratory diseases basically has been decreasing, although it peaked in 2002 (89.9 for every 100,000 people). On the other hand, in rural areas the death rate has a strange tendency. It did not change much between 1999 and 2001, remaining about 133 for every 100,000 people; however, it rapidly dropped from 2001 to 2002, and then increased until 2005. But again, it decreased by about 40 from 2005 to 2006. The mean of the death rate in urban areas is 76 and its standard deviation is about 7, while the mean of the death rate in rural areas is 105 and it standard deviation is about 30 (refer to Table 2). This implies that the death rate from respiratory diseases is generally higher in rural areas than in urban areas, and the data in rural areas have a much higher variability than in the urban areas. The standard deviation of the total death rate is about 28, which is close to that of rural areas.

The data for health expenditure (Table 1-4) are from a report of the WHO. Because of its limited data availability, this research predicts the data in 2004 and 2005 by calculating the growth rate since 1993. It has been slowly increasing since 1997 and in 2003 it increased to 5.6 percent of the GDP in China. The mean of the data is about 4.8 and the standard deviation is only about 0.76 (refer to Table 2). This implies that the data have low variability and are more static than other variables.

The data for annual cigarette consumption is from the World Watch Institute. Its original source is the U.S. Department of Agriculture, Production, Supply, and Distribution Database. The annual cigarette consumption per capita had been decreasing from 1980 to 1990. In 1980 it was only 772 cigarettes per person, while it became 1429 cigarettes. In 1990 this number is about twice than it was ten years before. However, it dropped from 1990 to 1991, and it has been around 1350 for last fifteen years. The mean of cigarette consumption is about 1256 and the standard deviation is about 193, which implies the data does not have a high variability (refer to Table 2). This is because of aforementioned static data of the last fifteen years.

- Hypothesis 2: As coal consumption rises, agricultural production decreases.
- Hypothesis 3: As coal consumption rises, forest area decreases.

For Hypothesis 2 and 3, this research uses the same data source except for coal consumption (refer to Tables 3-1 to Table 4-3). Table 5 demonstrates its statistical data, including the mean, standard deviation, and the number of observations. The data of coal consumption (Table 3-1) are from the Korean Industrial Federation, while other data (from Table 3-2 to Table 4-3) are from China Statistics 2005. However, China Statistics is under the administration of the Chinese government; therefore, I presume that the data are not quite reliable.

Because of the limited data availability, the Chinese government and other international institutions do not have the annual data for both the yield of grains and forest area. On the other hand, the Korean Industrial Federation and the China Statistics 2005 have regional statistics for major provinces and cities in 2004; thus for hypothesis 2 and 3 this research uses regional data instead of annual national data.

According to Table 3-1, coal consumption varies significantly depending on the region. In fact, the standard deviation for coal consumption is about 1339, while the mean is 745 (refer to Table 5). Particularly one province, Shanxi, has enormous coal consumption, exceeding 7,000 million tons per year, while it is less than 100 million tons in some provinces such as Fujian and Guangdong. Because coal consumption in Shanxi is much higher than in other areas, it becomes an outlier, and its standard deviation is higher than the mean. In fact, the coal consumption in Hebei province, the second highest in coal consumption is only 1595 million tons, which is less than one-fourth of that of Shanxi.

The other variables also have a high variability because most of their means are close to their standard deviations or even less (refer to Table 5). For instance, the mean of grain yield is about 1514, while its standard deviation is about 1146. This implies that the data has very high variability. This is because some provinces such as Henan and Shandong have a high yield of grain (refer to Table 3-2, yields of 4260 in Henan, 3516 in Shandong), whereas some areas such as Beijing and Qinghai have very small yield of grain (Beijing = 70.2, Qinghai = 88.5).

3. Results of Statistical Analysis

- Hypothesis 1: As coal consumption rises, the deterioration of public health increases.

Since the data of the death rate from respiratory diseases are available for both urban and rural areas, this research can represent not only the regression line for each area but also a third regression line with the total death rate, which is the sum of the death rate in urban and rural areas.

Table 6 represents the statistical result for hypothesis 1. In urban area the relation between the independent variable and dependent variable is quite weak because the adjusted R square is only 0.21, which is relatively small. It implies that the regression of independent variables (coal consumption, oil consumption, health expenditures and cigarette consumption) explains only 21 percent of the variation in the dependent variable, the death rate in urban areas.

In addition, none of the independent variables are statistically significant. This implies that none of them can explain the dependent variable, and the relation is quite weak. Figure 2 represents the scatter plot and the regression line of the statistical test. The result does not support hypothesis 1 because it is a negative regression, implying that the death rate in urban areas decreases, as the coal consumption increases.

On the other hand, the statistical result of death rate from respiratory diseases in rural areas (refer to the third column in the table) demonstrates different results from the ones in urban areas. The relation between independent variables and dependent variables is exceptionally strong because adjusted the R square is 0.832. This means that the regression line composed by the independent variables explains about 83 percent of the variation of the dependent variable, the death rate from respiratory diseases in rural areas.

Furthermore, as expected, the total death rate from respiratory diseases is positively associated with the coal consumption, demonstrating the statistically significant result. In this case, the slope of regression for coal consumption (referred to as *b* in Equation 1) is 0.738. In other words, as the coal consumption increases by one million tons, the death rate from respiratory diseases in rural areas 10 years later increases by 0.738 on average. According to the table, although oil consumption and cigarette consumption are negatively associated with the death rate, both of them are not statistically significant ($p>0.05$), and it is possible that these relations (between oil consumption and the death rate, between cigarette consumption and the death rate) are caused by chance. One notable thing is that the relation between health expenditures and the death rate from respiratory diseases is quite strong, as it shows statistical significance ($p<0.05$), and the health expenditure is negatively associated with death rate (B= -121.7). Therefore, the regression line (Figure 3) is negative, although coal consumption is positively associated with the death rate.

Similar cases also apply to the total death rate. The fourth column of the table demonstrates strong relationships between the independent and the dependent variable, as the adjusted R square is 0.936, which is significantly high. This implies that the regression explains 94 percent of variation in the total death rate.

Moreover, the coal consumption, oil consumption, and the health expenditures (except the cigarette consumption) demonstrates the statistically significant result ($p<0.05$). This implies that the relations between the independent and dependent variables are unlikely to occur by chance. As expected, the coal consumption is positively associated with the death rate, while other independent variables are negatively associated with the death rate. These results and the negative regression line (Figure 4) are quite similar to the case in rural areas. In this case, the slope of regression for coal consumption (referred to as *b* in Equation 1) is 0.614. In other words, as the coal consumption increases by one million tons, the total death rate from respiratory diseases 10 years later increases by 0.614 on average.

Judging from these points mentioned above, hypothesis 1 (As coal consumption increases, deterioration of public health increases) applies not to the death rate in urban areas, but in rural areas and the total death rate.

But why do these results happen? One possible reason is that coal consumption in rural areas is much larger than in urban areas. In fact, Shanxi province, which is considered as rural, has exceptionally large coal consumption. In addition, nearly all rural residents use coal for household cooking and heating, while an only shrinking fraction of urban residents use coal in China (Zhang and Smith, 2007). Thus, higher consumption of coal in rural area affects the deterioration of public health.

- Hypothesis 2: As coal consumption rises, agricultural production decreases.

Table 7 represents the statistical result for hypothesis 2. The relation between the independent and dependent variable is very strong because the adjusted R square is 0.782. This means that the regression line composed by independent variables (coal consumption, cultivated land, power of agricultural machinery, and natural disasters) explains about 78 percent of the variation in the dependent variable, the yield of grain.

However, the relation between coal consumption and the yield of grain is not very strong. Although some other independent variables such as cultivated land and the total power of agricultural machinery have a strong relationship with the yield of grain (both of them are statistically significant), they do not help to prove the hypothesis. In addition, the regression line, presented in Figure 5, is horizontal, and this does not support the hypothesis, either.

Since the result of horizontal regression was possibly because of the outlier, I tested the hypothesis again without outlier (the outlier is the Shanxi province that has the highest coal consumption in all provinces and cities). Although the slope of the regression line became positive (refer to Figure 6), it does not assist in proving the hypothesis. What is more, as the third column of the table demonstrates, the adjusted R square for coal consumption did not have a remarkable change, increasing by only about one percent (from 0.782 to 0.794). Moreover, the result is not statically significant, either. Thus, there is weak evidence that supports the hypothesis. Therefore, it is difficult to conclude hypothesis 2 (as coal consumption rises, agricultural production decreases) is correct.

- Hypothesis 3: As coal consumption rises, forest area decreases.

A similar case also applies to hypothesis 3. According to the regression result for all data (refer to the second column of Table 8), the relation between the independent and dependent variables is not very strong because the adjusted R square is 0.473. This number implies that the regression line composed by independent variables (coal consumption, forest fire, forest diseases and pests) explains about 47 percent of the variation in the dependent variable, forest area. Moreover, the coefficient of the consumption is not statistically significant. In contrast, other independent variables such as forest fire and forest diseases and pests demonstrate statistically significant results. However, they are not even likely to explain the results because they are associated with positive results. These results are contrary to what the hypothesis predicted.

The regression line, presented in Figure 7, is slightly negative; however, this too is probably because of the aforementioned outlier. Thus, I tested the hypothesis again without the outlier. Although the regression line became slightly positive (refer to Figure 8), it does not support the hypothesis. In addition, the coefficient for coal consumption became positive (0.039), which is the contrary to what the hypothesis predicted. Moreover, the coefficients of other independent variables, as well as the adjusted R square did not have any remarkable change. Hence, it is also difficult to conclude that the hypothesis 3 (as coal consumption rises, forest area decreases) is correct.

V. Conclusion

These results do not demonstrate all the economic costs of using conventional coal; however, they can demonstrate part of these economic costs. For instance, using hypothesis 1 (which demonstrated the strong relation), it can be calculated that as the coal consumption increases by one million tons, the total death rate from respiratory diseases will increase by 45.436 percent (the death of 5,906,680 people) on average from 2010 to 2011[4]. Although this number is difficult to demonstrate in terms of monetary value, the economic costs will very likely increase by decreasing workers' productivity. What is more, economic costs will continue to increase, as coal consumption has been increasing for the last five years.

In addition, coal consumption in China creates additional negative externality and economic cost because it affects not only the domestic environment but also the environment in neighboring countries. For instance, one country that is receiving negative externality from China is Japan. This August, photochemical smog, which is created by exhaust from cars and factories in China, appeared in Japanese cities for the first time in thirty years and caused severe health effects. A reporter from *International Business Week*, Fujioka, explains its serious health effects in detail: “Warnings for high levels of hazardous smog have been issued in a record 28 prefectures so far this year, from sparsely populated isles in southern Japan to Niigata, western Japan, where 350 people have suffered stinging eyes and throats” (Fujioka 2007)

Moreover, air pollution in China is drifting across the Pacific Ocean and now threatening the West Coast of the United States. Bradsher and Barboza announced that certain chemicals such as sulfur dioxide and carbon dioxide from China reached California: “Researchers in California, Oregon and Washington noticed specks of sulfur compounds, carbon and other byproducts of coal combustion coating the silvery surfaces of their mountaintop detectors” (Bradsher and Barboza 2006). Therefore, air pollution caused by coal consumption in China is threatening the world’s environmental security.

Furthermore, coal consumption in China may be accelerating global warming (climate change). Tucker (2006) argues that coal consumption is a major contributor to global warming, and coal-burning countries such as China and the U.S. need to mandate coal powered plants to use “integrated gasification combined cycle technology” in order to make a breakthrough in the energy dilemma (Tucker 2006, 15). In fact, about two-thirds of China's greenhouse gases originate from burning fossil fuels such as coal or oil (Oster, 2007). The climate change negatively will affect China in the future. Oster (2007) stresses the effect of climate change in China: “the country is particularly vulnerable to climate change because it has scarce land and water resources, and many of its major economic centers sit in low-lying coastal areas" (Oster 2007, 6). Thus, coal consumption also creates negative externality though climate change.

Since the Olympics will be held in Beijing next year, international concern over environmental problems in China is rising. The low air quality in Beijing could hamper athletes' performance. In fact, China received a warning from the Olympic Committee this past summer. According to Dickle and Blitz (2007), "China was put on notice [by the International Olympic Committee] ... that if it did not address its air pollution problems before the 2008 Beijing Olympics, it could see games organisers ordering some endurance events to be rescheduled" (Dickle and Blitz 2007). Thus, negative externalities derived from coal consumption and air pollution in China seem to be innumerable; therefore, the economic cost of coal consumption will become exceptionally high in the long term.

In recent years, China seems to understand these negative externalities and has the incentives to enforce the law that encourages cleaner coal technology by limiting the use of conventional coal. Shapiro (2001) emphasizes the Chinese government's positive attitude toward implementing such technology: "Many leaders are aware of studies showing that costs of environmental degradation through disease, lost productivity, and cleanup costs have effectively wiped out China's rapid economic growth rate, and there is eager acceptance of green technologies if they come at low cost and contribute to economic development" (Shapiro 2001, 208). The Chinese government seems likely to encourage coal industries to transform the conventional coal into cleaner coal energy as long as it is not too costly.

However, it is still questionable whether China can completely solve the problems on its own. Even if it begins to put in serious effort to tackle the problem, it would not be able to handle its environmental problems by itself because environmental degradation has already become too severe. Therefore, other actors such as foreign governments, international environmental NGOs, international organizations (e.g. the United Nations, the World Bank) need to help solve these problems, which are now having global ramifications.

In fact, these efforts are already underway (Nankivell 2006). For instance, the Japanese government has been providing the Official Development Assistance (ODA) for cleaner coal energy so that China can increase its air quality by reducing the amount of chemicals derived from coal consumption. According to Yasutaka (2003), "Through cooperation with the Official Development Assistance (ODA), transfer of technology to China – such as the establishment there of the flue gas desulfurization system and briquette production plants that process coal into a handy and clean fuel – has been achieved" (Yasutaka 2003, 242).

These actors are contributing to environmental protection in China to ensure that environmental conditions at a minimum do not worsen. Saving China's environment by transforming conventional coal energy into clean coal energy will eventually help to save the world's environment.

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Tables

Table 1-1: Coal Consumption in China

Year	(Million Short Tons)
1980	689.744
1981	679.907
1982	725.981
1983	768.224
1984	844.846
1985	911.212
1986	962.279
1987	1,027.102
1988	1,097.727
1989	1,113.362
1990	1,124.129
1991	1,164.875
1992	1,199.480
1993	1,275.598
1994	1,389.839
1995	1,494.763
1996	1,508.581
1997	1,450.414
1998	1,392.011
1999	1,342.594
2000	1,282.296
2001	1,356.596
2002	1,412.964
2003	1,720.236
2004	2,056.718
P2005	2,332.908

Source: Energy Information Administration, International Energy Statistics Team. International Energy Annual 2005 <http://www.eia.doe.gov/pub/international/iealf/table14.xls>

Notes: Data for the most recent year are preliminary. Coal includes anthracite, subanthracite, bituminous, subbituminous, lignite, brown coal. Sum of components may not equal total due to independent rounding.

Table 1-2: Oil Consumption in China

Year	(Thousand Barrels per Day)
1980	1,765.00
1981	1,705.00
1982	1,660.00
1983	1,730.00
1984	1,740.00
1985	1,885.00
1986	2,000.00
1987	2,120.04
1988	2,275.00
1989	2,379.52
1990	2,296.40
1991	2,498.80
1992	2,661.60
1993	2,959.49
1994	3,160.61
1995	3,363.16
1996	3,610.09
1997	3,916.27
1998	4,105.83
1999	4,363.60
2000	4,795.71
2001	4,917.88
2002	5,160.71
2003	5,578.11
2004	6,437.48
P2005	6,720.00
P2006	7,273.29

Source: Data from Energy Information Administration, International Energy Statistics Team. World Petroleum(Oil) Consumption, Most Recent Annual Estimates,1980-2006 <http://www.eia.doe.gov/emeu/international/RecentPetroleumConsumptionBarrelsperDay.xls>

Table 1-3: Death Rate from Respiratory Diseases (1/100000 person) in China

_	urban area	rural area	Total
1999	81.68	133.69	215.37
2000	77.16	133.56	210.715
2001	72.64	133.42	206.06
2002	89.9	63.8	153.7
2003	77.3	70.9	148.2
2004	73.15	97.35	170.5
2005	69	123.8	192.8
2006	69.3	84.9	154.2

Source: Ministry of Health, the Government of China, at <http://www.moh.gov.cn/>

Notes: Because of limited data availability, the rates for the years 2000 to 2004 are the averages calculated from data of the adjacent years. (eg. Urban area for 2000 is calculated by the average death rate between 1999 and 2001)

Table 1-4: Total Expenditure on Health as percent of GDP

Year	% of GDP
1993	4
1994	3.8
1995	3.7
1996	4
1997	4.3
1998	4.7
1999	4.9
2000	5.1
2001	5.2
2002	5.5
2003	5.6
2004	5.6
2005	5.7

Source: The Commission on Macroeconomics and Health, Geneva, World Health Organization, 2006 Health Expenditure Trends in Selected Countries, (China) p4 <http://www.who.int/macrohealth/documents/Electronic_Annex_C.pdf>

Notes: Because of limited data availability, this paper projected data in 2004 and 2005 by calculating the growth rate since 1993.

Table 1-5: Cigarette Consumption Per Person in China

Year	Consumption (per capita)
1980	772
1981	869
1982	931
1983	942
1984	1,019
1985	1,113
1986	1,204
1987	1,328
1988	1,399
1989	1,415
1990	1,429
1991	1,368
1992	1,378
1993	1,380
1994	1,376
1995	1,386
1996	1,352
1997	1,344
1998	1,332
1999	1,314
2000	1,330
2001	1,323
2002	1,338
2003	1,376
2004	1,368

Source: World Watch Institute, at <http://www.worldwatch.org/>

Notes: Data modified from 2000 onwards with new USDA data.

Table 2: Descriptive Statistics for Hypothesis 1

	Mean	Standard Deviation	Number of Observation
Coal Consumption	1243.25	396.12	26
Oil Consumption	3447.36	1689	27
Death Rate (Urban Area)	76.27	6.98	8
Death Rate (Rural Area)	105.18	29.57	8
Total Death Rate	181.44	27.98	8
Health Expenditure	4.84	0.76	14

Cigarette Consumption Per Capita	1255.48	192.89	25

Source: See Table 1-1 to 1-5

Table 3-1: Coal Consumption in Provinces and Cities

Region	Coal Consumption (million ton)
Beijing	361.23
Tianjin	337.14
Hebei	1595.85
Shanxi	7300.00
Inner Mongolia	926.00
Liaoning	1015.04
Jilin	217.50
Heilongjiang	380.76
Shanghai	751.50
Jiangsu	457.03
Zhejiang	57.77
Anhui	426.37
Fujian	67.33
Jiangxi	323.73
Shandong	997.31
Henan	769.75
Hubei	512.35
Hunan	386.55
Guangdong	90.72
Guangxi	152.17
Hainan	n/a
Chongqing	181.37
Sichuan	764.48
Guizhou	645.12
Yunnan	904.24
Tibet	896.12
Shaanxi	n/a
Gansu	144.20
Qinghai	n/a
Ningxia	80.63
Xinjiang	130.59

Source: Federation of Korean Industries (FKI) at <http://www.fki.or.kr/en/>

Table 3-2: Yield of Grain

Region	Yield of Grain (10 000 tons)
Beijing	70.2
Tianjin	122.8
Hebei	2480.1
Shanxi	1062.0
Inner Mongolia	1505.3
Liaoning	1720.0
Jilin	2510.0
Heilongjiang	3001.0
Shanghai	106.3
Jiangsu	2829.1
Zhejiang	834.9
Anhui	2743.0
Fujian	736.4
Jiangxi	1663.0
Shandong	3516.7
Henan	4260.0
Hubei	2100.1
Hunan	2640.0
Guangdong	1390.0
Guangxi	1398.5
Hainan	190.1

[1] TFP stands for the total factor productivity

[2] Linan city lies to the South of Tianmu mountain, which is in the Northwest of Zhejiang province.

[3] Pinus massoniana Lamb is Chinese red pine.

[4] Since coal consumption is only available for national data, this research used the total death rate. According to this theory, as coal consumption increased rapidly since 2000, the total death rate would increase rapidly from 2010 onwards. The change in coal consumption from 2000 to 2001 is 74 million tons, and the slope of the regression for the total death rate is 0.614. Therefore, the change in the total death rate from 2010 to 2011, (which can be calculated by multiplying these numbers) is 45.436. Since the death rate is calculated by 1/100,000 and the population in China is 1.3 billion, 45.436 × 13,000,000,000/100,000=5,906,680 additional people would die in 2011, according to the result.

Chongqing	1144.5
Sichuan	3146.7
Guizhou	1149.6
Yunnan	1509.5
Tibet	96.0
Shaanxi	1040.0
Gansu	805.8
Qinghai	88.5
Ningxia	290.5
Xinjiang	796.5

Source: China Statistics 2005 at <http://www.allcountries.org/china_statistics/index.html>

Note: the National Bureau of Statistics of the Peoples Republic of China and are subject to revision by the National Bureau of Statistics of China

Table 3-3: Cultivated Land

Region	Cultivated Land (Total Area) (1 000 hectare)
Beijing	343.9
Tianjin	485.6
Hebei	6883.3
Shanxi	4588.6
Inner Mongolia	8201.0
Liaoning	4174.8
Jilin	5578.4
Heilongjiang	11773.0
Shanghai	315.1
Jiangsu	5061.7
Zhejiang	2125.3
Anhui	5971.7
Fujian	1434.7
Jiangxi	2993.4
Shandong	7689.3
Henan	8110.3
Hubei	4949.5
Hunan	3953.0
Guangdong	3272.2
Guangxi	4407.9
Hainan	762.1
Chongqing	n/a

Sichuan	9169.1
Guizhou	4903.5
Yunnan	6421.6
Tibet	362.6
Shaanxi	5140.5
Gansu	5024.7
Qinghai	688.0
Ningxia	1268.8
Xinjiang	3985.7

Source and Note: See Table 3-2

Table 3-4: Total Power of Agricultural Machinery

Region	Total Power of Agricultural Machinery (10 000 kw)
Beijing	340.0
Tianjin	608.1
Hebei	8135.6
Shanxi	2186.5
Inner Mongolia	1772.3
Liaoning	1619.5
Jilin	1319.8
Heilongjiang	1952.2
Shanghai	105.2
Jiangsu	3052.5
Zhejiang	2026.7
Anhui	3784.4
Fujian	981.0
Jiangxi	1465.2
Shandong	8751.9
Henan	7521.1
Hubei	1763.6
Hunan	2923.9
Guangdong	1798.7
Guangxi	1814.3
Hainan	243.9
Chongqing	728.3
Sichuan	2006.8

Guizhou	797.2
Yunnan	1608.5
Tibet	191.6
Shaanxi	1307.0
Gansu	1321.2
Qinghai	325.8
Ningxia	528.5
Xinjiang	1046.5

Source and Note: See Table 3-2

Table 3-5: Area Affected by Natural Disaster

Region	Area Affected by Natural Disaster (1000 hectare)
Beijing	10
Tianjin	30
Hebei	797
Shanxi	441
Inner Mongolia	1711
Liaoning	757
Jilin	967
Heilongjiang	1086
Shanghai	3
Jiangsu	173
Zhejiang	385
Anhui	304
Fujian	220
Jiangxi	596
Shandong	771
Henan	864
Hubei	894
Hunan	581
Guangdong	523
Guangxi	914
Hainan	50
Chongqing	388
Sichuan	656
Guizhou	291

Yunnan	446
Tibet	11
Shaanxi	457
Gansu	1153
Qinghai	87
Ningxia	297
Xinjiang	436

Source and Note: See Table 3-2

Table 4-1: Forest Area

Region	Forest Area (1000 hectare)
Beijing	37.88
Tianjin	9.35
Hebei	328.83
Shanxi	208.19
Inner Mongolia	2050.67
Liaoning	480.53
Jilin	720.12
Heilongjiang	1797.50
Shanghai	1.89
Jiangsu	77.41
Zhejiang	553.92
Anhui	331.99
Fujian	764.94
Jiangxi	931.39
Shandong	204.64
Henan	270.30
Hubei	497.55
Hunan	860.79
Guangdong	827.00
Guangxi	983.83
Hainan	166.66
Chongqing	183.18
Sichuan	1464.34
Guizhou	420.47
Yunnan	1560.03

Tibet	1389.61
Shaanxi	670.39
Gansu	299.63
Qinghai	317.20
Ningxia	40.36
Xinjiang	484.07

Source and Note: See Table 3-2

Table 4-2: Forest Fire

Region	Forest Fire (1000 hectare)
Beijing	0.10
Tianjin	0.01
Hebei	1.35
Shanxi	1.84
Inner Mongolia	5.13
Liaoning	0.43
Jilin	0.33
Heilongjiang	185.55
Shanghai	n/a
Jiangsu	0.50
Zhejiang	19.25
Anhui	2.07
Fujian	22.45
Jiangxi	23.20
Shandong	0.12
Henan	0.50
Hubei	5.06
Hunan	23.24
Guangdong	6.25
Guangxi	23.77
Hainan	0.38
Chongqing	0.29
Sichuan	1.33
Guizhou	8.52
Yunnan	11.28
Tibet	0.29

Shaanxi	0.29
Gansu	0.04
Qinghai	0.37
Ningxia	0.00
Xinjiang	0.29

Source and Note: See Table 3-2

Table 4-3: Forest Disease and Pest

Region	Forest Disease and Pest (1000 hectare)
Beijing	34.95
Tianjin	26.65
Hebei	287.96
Shanxi	363.85
Inner Mongolia	552.48
Liaoning	532.68
Jilin	197.17
Heilongjiang	175.70
Shanghai	13.51
Jiangsu	45.08
Zhejiang	52.67
Anhui	219.23
Fujian	338.48
Jiangxi	170.42
Shandong	332.94
Henan	391.61
Hubei	222.69
Hunan	293.73
Guangdong	786.01
Guangxi	186.55
Hainan	44.97
Chongqing	101.91
Sichuan	634.10
Guizhou	236.97
Yunnan	295.73
Tibet	n/a
Shaanxi	315.92

Gansu	105.66
Qinghai	117.78
Ningxia	109.03
Xinjiang	217.03

Source and Note: See Table 3-2

Table 5: Descriptive Statistics for Hypothesis 2 and 3

_	Mean	Standard Deviation	Number of Observation
Coal Consumption	745.46	1338.85	28
Yield of Grain	1514.42	1145.61	31
Cultivated Land	4334.64	2943.78	30
Total Power of Agricultural Machinery	2065.41	2202.69	31
Area affected by Natural Disaster	525.77	401.18	31
Forest Area (1000 hectare)	610.96	548.56	31
Forest Fire (1000 hectare)	11.47	33.89	30
Forest Disease and Pest (1000 hectare)	246.78	189.39	30

Source: See Table 3-1 to 4-3

Table 6: Regression Result for Hypothesis 1

Dependent Variable is Death Rate from Respiratory Disease	Urban Areas	Rural Areas	Total Death Rate (Urban and Rural Areas)
_	Coefficient (B)	Coefficient (B)	Coefficient (B)
Coal Consumption	-0.124	0.738*	0.614*
Oil Consumption	0.025	-0.21	-0.185*
Health Expenditure	18.39	- 121.77*	-103.38*
Cigarette Consumption	0.093	-0.278	-0.185
N	8	8	8
R-squared (Adjusted)	0.210	0.832	0.936

Note: * indicates p<0.05.

Table 7: Regression Result for Hypothesis 2

Dependent Variable is Yield of Grain	All Data	Without the Outlier
_	Coefficient (B)	Coefficient (B)
Coal Consumption	-0.12	-0.515

Cultivated Land	0.277**	0.286**
Total Power of Agricultural Machinery	0.222**	0.252**
Area affected by Natural Disaster	-0.448	-0.476
N	25	24
R-squared (Adjusted)	0.782	0.794

Note: ** indicates p<0.01.

Table 8: Regression Result for Hypothesis 3

Dependent Variable is Forest Area (1000 hectare)	All Data	Without the Outlier
_	Coefficient (B)	Coefficient (B)
Coal Consumption	-0.066	0.039
Forest Fire (1000 hectare)	8.362**	8.44**
Forest Disease and Pest (1000 hectare)	1.574**	1.506**
N	25	24
R-squared (Adjusted)	0.473	0.463

Note: ** indicates p<0.01.

Figures

Figure 1: Economic Model for Coal Market in China

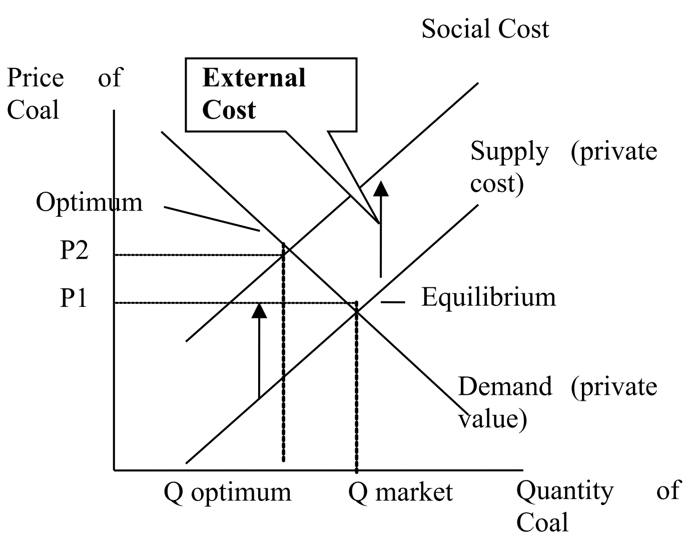


Figure 2: Regression Line for Hypothesis 1 (Death Rate in Urban Area)

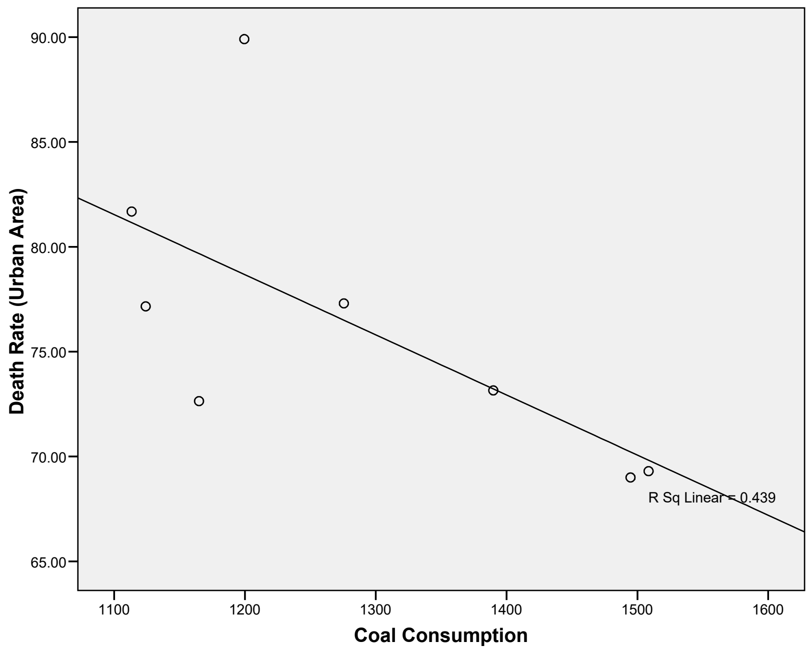


Figure 3: Regression Line for Hypothesis 1 (Death Rate in Rural Area)

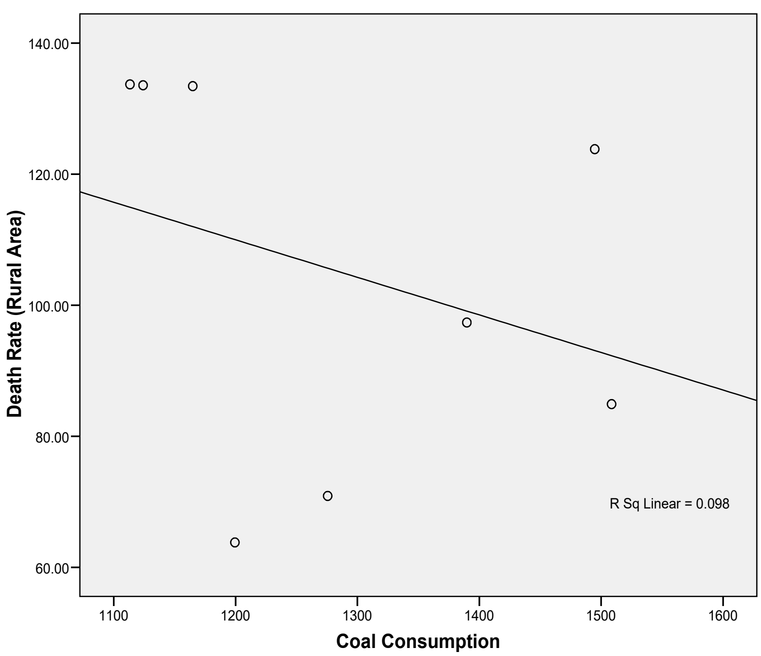


Figure 4: Regression Line for Hypothesis 1 (Total Death Rate)

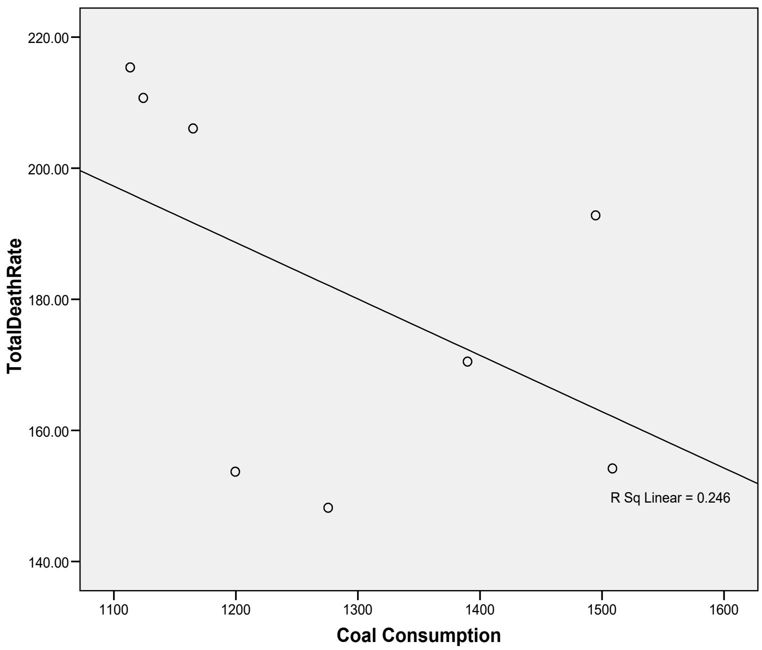


Figure 5: Regression Line for Hypothesis 2

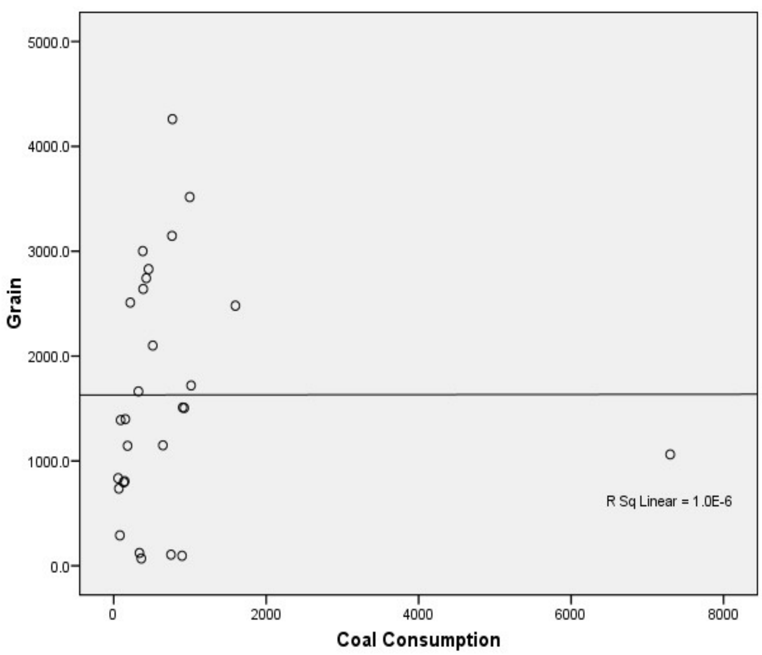


Figure 6: Regression Line for Hypothesis 2 (without outlier)

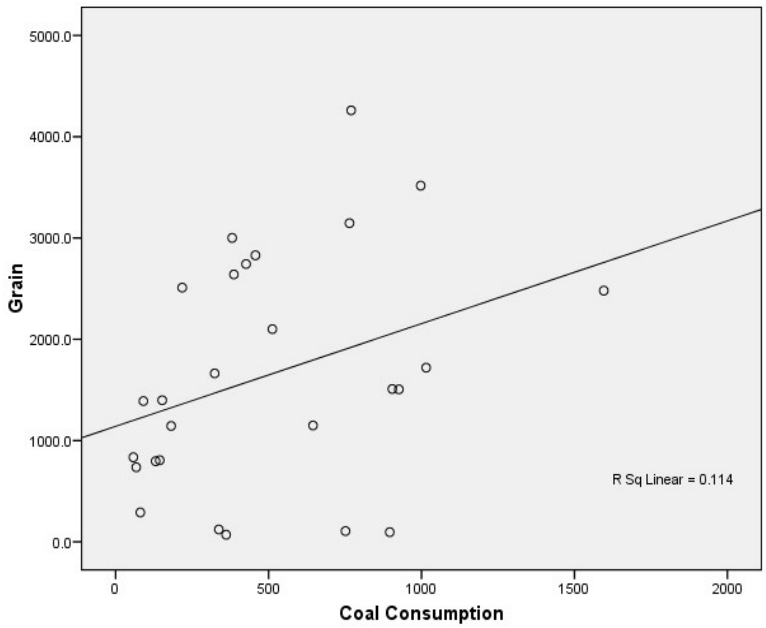


Figure 7: Regression Line for Hypothesis 3

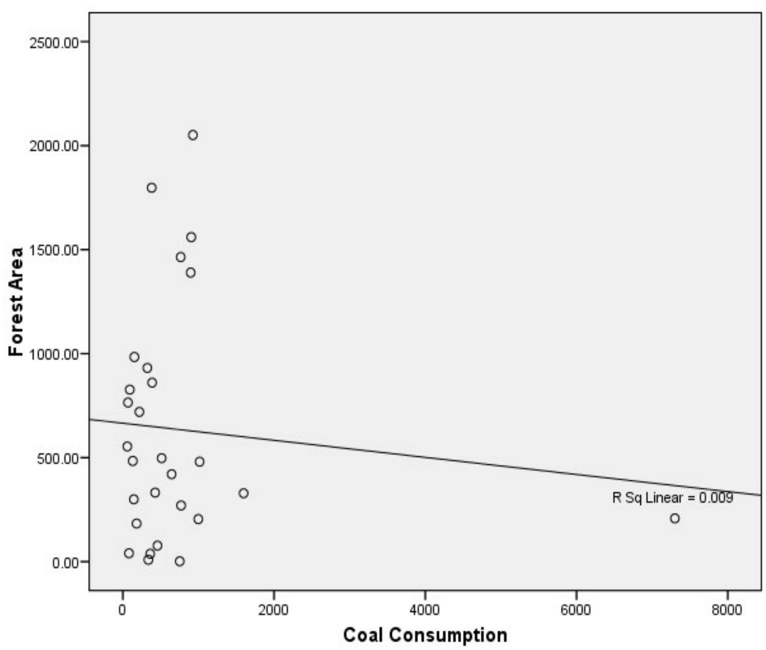
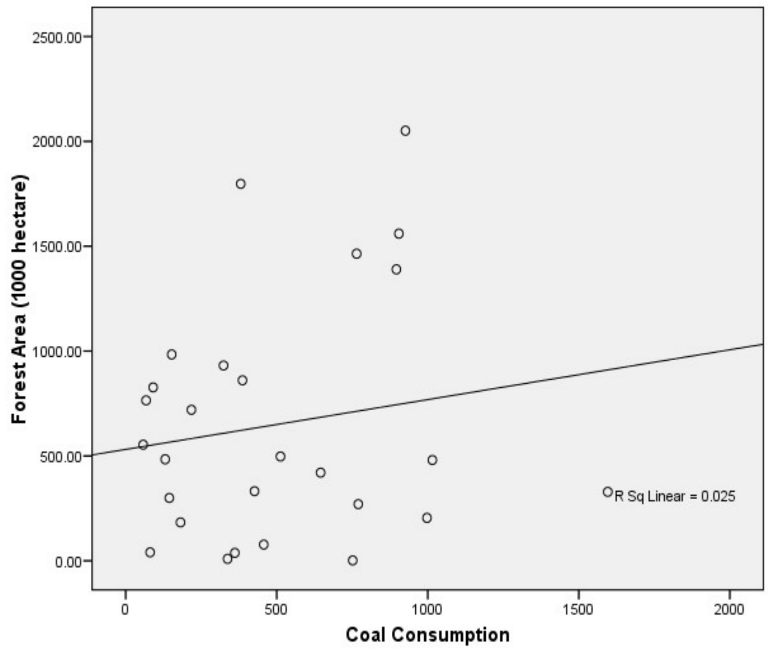


Figure 8: Regression Line for Hypothesis 3 (without outlier)



Appendix

Appendix 1: Dataset for Hypothesis 1

	Coal Consumption	Oil Consumption	Death Rate from Respiratory Diseases (1/100000 person)		Health Expenditure	Growth Rate of Health Expenditure	Annual Cigarette Consumption per capita
Year	(Million Short Tons)	(Thousand Barrels per Day)	urban area	rural area	% of GDP	_	_
1980	689.74	1,765.00	_	_	_	_	771.78
1981	679.91	1,705.00	_	_	_	_	868.61
1982	725.98	1,660.00	_	_	_	_	930.87
1983	768.22	1,730.00	_	_	_	_	942.09
1984	844.85	1,740.00	_	_	_	_	1,018.93
1985	911.21	1,885.00	_	_	_	_	1,113.41
1986	962.28	2,000.00	_	_	_	_	1,204.26
1987	1,027.10	2,120.04	_	_	_	_	1,327.93
1988	1,097.73	2,275.00	_	_	_	_	1,399.16
1989	1,113.36	2,379.52	_	_	_	_	1,415.32
1990	1,124.13	2,296.40	_	_	_	_	1,428.87
1991	1,164.88	2,498.80	_	_	_	_	1,367.68
1992	1,199.48	2,661.60	_	_	_	_	1,377.88
1993	1,275.60	2,959.49	_	_	4.00	_	1,380.35
1994	1,389.84	3,160.61	_	_	3.80	-0.05	1,376.15
1995	1,494.76	3,363.16	_	_	3.70	-0.03	1,386.42
1996	1,508.58	3,610.09	_	_	4.00	0.08	1,351.62

1997	1,450.41	3,916.27	_	_	4.30	0.08	1,344.17
1998	1,392.01	4,105.83	_	_	4.70	0.09	1,332.45
1999	1,342.59	4,363.60	81.68	133.69	4.90	0.04	1,314.13
2000	1,282.30	4,795.71	77.16	133.56	5.10	0.04	1,330.16
2001	1,356.60	4,917.88	72.64	133.42	5.20	0.02	1,322.73
2002	1,412.96	5,160.71	89.90	63.80	5.50	0.06	1,338.11
2003	1,720.24	5,578.11	77.30	70.90	5.60	0.02	1,375.77
2004	2,056.72	6,437.48	73.15	97.35	5.64	0.04	1,368.19
P2005	2,332.91	6,720.00	69.00	123.80	5.70	_ 0.04	_
2006	N/A	7,273.29	69.30	84.90		_	_

Appendix 2: Dataset for Hypothesis 2

Region	Coal Consumption (million ton)	Grain (yield of output) (10 000 tons)	Cultivated Land (Total Area) (1 000 hectare)	Total Power of Agricultural Machinery (10 000 kw)	Area Affected by Natural Disaster (1000 hectare)
Beijing	361.23	70.2	343.9	340.0	10
Tianjin	337.14	122.8	485.6	608.1	30
Hebei	1595.85	2480.1	6883.3	8135.6	797
Shanxi	7300.00	1062.0	4588.6	2186.5	441
Inner Mongolia	926.00	1505.3	8201.0	1772.3	1711
Liaoning	1015.04	1720.0	4174.8	1619.5	757
Jilin	217.50	2510.0	5578.4	1319.8	967
Heilongjiang	380.76	3001.0	11773.0	1952.2	1086
Shanghai	751.50	106.3	315.1	105.2	3
Jiangsu	457.03	2829.1	5061.7	3052.5	173
Zhejiang	57.77	834.9	2125.3	2026.7	385
Anhui	426.37	2743.0	5971.7	3784.4	304
Fujian	67.33	736.4	1434.7	981.0	220
Jiangxi	323.73	1663.0	2993.4	1465.2	596
Shandong	997.31	3516.7	7689.3	8751.9	771
Henan	769.75	4260.0	8110.3	7521.1	864
Hubei	512.35	2100.1	4949.5	1763.6	894
Hunan	386.55	2640.0	3953.0	2923.9	581
Guangdong	90.72	1390.0	3272.2	1798.7	523

Guangxi	152.17	1398.5	4407.9	1814.3	914
Hainan	n/a	190.1	762.1	243.9	50
Chongqing	181.37	1144.5	n/a	728.3	388
Sichuan	764.48	3146.7	9169.1	2006.8	656
Guizhou	645.12	1149.6	4903.5	797.2	291
Yunnan	904.24	1509.5	6421.6	1608.5	446
Tibet	896.12	96.0	362.6	191.6	11
Shaanxi	n/a	1040.0	5140.5	1307.0	457
Gansu	144.20	805.8	5024.7	1321.2	1153
Qinghai	n/a	88.5	688.0	325.8	87
Ningxia	80.63	290.5	1268.8	528.5	297
Xinjiang	130.59	796.5	3985.7	1046.5	436

Appendix 3: Dataset for Hypothesis 3

Region	Coal Consumption (million ton)	Forest Area (1000 hectare)	Forest Fire (1000 hectare)	Forest Disease and Pest (1000 hectare)
Beijing	361.23	37.88	0.10	34.95
Tianjin	337.14	9.35	0.01	26.65
Hebei	1595.85	328.83	1.35	287.96
Shanxi	7300.00	208.19	1.84	363.85
Inner Mongolia	926.00	2050.67	5.13	552.48
Liaoning	1015.04	480.53	0.43	532.68
Jilin	217.50	720.12	0.33	197.17
Heilongjiang	380.76	1797.50	185.55	175.70
Shanghai	751.50	1.89	n/a	13.51
Jiangsu	457.03	77.41	0.50	45.08
Zhejiang	57.77	553.92	19.25	52.67
Anhui	426.37	331.99	2.07	219.23
Fujian	67.33	764.94	22.45	338.48
Jiangxi	323.73	931.39	23.20	170.42
Shandong	997.31	204.64	0.12	332.94
Henan	769.75	270.30	0.50	391.61
Hubei	512.35	497.55	5.06	222.69
Hunan	386.55	860.79	23.24	293.73
Guangdong	90.72	827.00	6.25	786.01
Guangxi	152.17	983.83	23.77	186.55
Hainan	n/a	166.66	0.38	44.97

Chongqing	181.37	183.18	0.29	101.91
Sichuan	764.48	1464.34	1.33	634.10
Guizhou	645.12	420.47	8.52	236.97
Yunnan	904.24	1560.03	11.28	295.73
Tibet	896.12	1389.61	0.29	n/a
Shaanxi	n/a	670.39	0.29	315.92
Gansu	144.20	299.63	0.04	105.66
Qinghai	n/a	317.20	0.37	117.78
Ningxia	80.63	40.36	0.00	109.03
Xinjiang	130.59	484.07	0.29	217.03

Endnote