

Environmental Resources and Economic Growth

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1. Introduction

The purpose of this chapter is to assess the nature and degree of environmental degradation and resource depletion in China and its relationship to economic activity and environmental policies. This includes a description of regulatory and other policies and a preliminary analysis of their political economy determinants. Inasmuch as this objective can only be partially achieved, we hope to contribute to a research agenda for environmental and resource economics in China.

Environmental economics in Western countries is sometimes called “P-based” due to its primary emphasis on the regulation of pollution within static economic models. In contrast, environmental management questions in the context of economic development are “R-based” and related to the management of environmental resources over time. Section 2 reviews evidence on air and water pollution. Environmental Kuznets Curves for three major air pollutants are presented. In Section 3, we discuss available statistics on air and water pollution and some directions for their improvement. Section 4 follows with an R-based discussion related to the management of natural resources over time. In Section 5, we discuss how China’s Green Gross National Income (GGNI) differs from the country’s Gross National Income (GNI) and related implications for China’s future economic growth. Adjusting national income accounting to reflect changes in the natural environment makes national income a better indicator of economic welfare. Based on the evidence available, it appears that while GGNI is substantially less than GNI, these adjustments do not adversely compromise existing estimates of economic growth. In this section we also present an Environmental Kuznets Curve for China’s natural resources, and relate its shape to the GGNI discussion. Section 6 reviews the current policy environment, emphasizing both accomplishments and shortcomings. Section 7 concludes.

2. Pollution

2.1 Air Pollution

The three air pollutants of concern are currently sulfur dioxide (SO₂) from the burning of coal for power generation; nitrous oxides (NO_x), mainly from motor vehicle emissions; and total suspended particles (TSP) due in part to the growing desertification of (in the northwest and

energy production and in the South). Due to China's dependence on coal (68 percent of energy consumption, SO₂ emissions account for more than 13 percent of sulfur deposits in South Korea and up to 50 percent in Japan (Wishnick 2005). Higher incomes have led to increased car ownership (but still less than 2 percent), and motor vehicles account for 45-60 percent of NO_x emissions and 85 percent of CO₂ emissions in cities (Wishnick 2005). One-third of the total land area is prone to desertification, including 262 million hectares of pastoral and oasis land in the Xinjiang, Inner Mongolia, Tibet, Gansu and Qinghai provinces.

Air pollution is a major health issue in the country. Ambient and indoor air pollution has been blamed for the high incidence of premature deaths (World Bank 1997). Particulate matter with a diameter less than 10 microns (PM-10) is the most damaging air pollutant in terms of health costs. In 2002, SEPA tested the air quality in over 300 cities and found that two-thirds did not meet standards set by the World Health Organization (WHO) for acceptable levels of TSP's (Economy 2004). In 1995, the World Bank estimated that health damages due to air pollution accounted for 7.1 percent of national income. This estimate may be inflated, however, inasmuch as the methodology infers the value of life in China from US estimates without accounting for the extent of overpopulation (see e.g. Dasgupta 1993, 2001).

The most recent report from the State Environmental Protection Administration (SEPA 2004) asserts that air pollution in major cities has been either improving or that the speed of deterioration has decreased, with falling emission levels and improved efficiency in plants. Total levels of NO_x, as shown in Figure 1, have fallen recently. Statistics show that SO₂ and TSP have been declining in the major cities since the mid-1980's, as shown in Figures 2 and 3. These figures represent ambient concentrations of the three major pollutants for 11 of China's major cities¹. With China's rapid development, a natural question arises regarding how these levels have fallen given increased production and economic output over this same time period. For example, SEPA asserts that in 2002, national environmental quality was maintained at the level of the previous year, while the national GDP grew by 8 percent. Furthermore, SEPA (2004) reports reduced levels of dust and sulfur dioxide, stable water quality, and improved air quality in some cities.

<Figure 1 here>

<Figure 2 here>

<Figure 3 here>

2.2 The Environmental Kuznets Curve

The Environmental Kuznets Curve (EKC) is a stylized fact according to which air pollution first increases with per capita income and then falls. The standard explanation is that environmental quality is a luxury good and that political economy induces environmental regulation accordingly. The rise and fall of the manufacturing sector relative to the whole economy and the

comparative advantage that low income countries have in the exportation of “dirty goods” are also cited. (Grossman and Krueger 1991; Panayotou 1993; Lieb 2002).

Figures 1-3 depict the weighted average ambient concentration levels for NO_x, SO₂, and TSP for 11 cities from 1981-2001. The majority of these 11 cities are major population centers. In order to investigate whether these pollutants followed the stylized EKC shape, we conducted a fixed-effects regression analysis for three pollutants in 80 cities from 1990-2001. Results for the three regressions are presented in Table 1 and are illustrated in Figures 4-6. While the order of emissions reaching their turning points in other countries is typically SO₂, TSP, then NO_x (Brown 2005), for China we find that the NO_x turns first around 28,000 Yuan (approximately 3,461 USD), followed by TSP around 44,000 Yuan (approximately 5,440 USD), then finally SO₂, which is just reaching the flat portion of its curve around 58,000 Yuan (or approximately 7,171 USD). The order of the turning points appears to be different from Western countries, presumably due to the early fall in NO_x.

<Table 1 here>

<Figure 4 here>

<Figure 5 here>

<Figure 6 here>

The shape of the NO_x curve seems implausible given the dramatic increase in automobile ownership during the same period. Mobile sources are believed to comprise approximately 45-50 percent of the total NO_x emissions (Walsh 1998). However, in our data period (1990-2001) NO_x is largely dominated by industry and manufacturing. The rapid growth in automobile ownership did not begin until close to 2002. In 2002 the demand for cars increased by 56 percent. The next year demand grew to 75 percent, before slowing in 2004 (when the government tightened rules on credit for car purchases) to around 15 percent². Our data does not capture likely increases in NO_x due to the extremely rapid increase in automobiles in recent years. One can hypothesize that there will be another phase of the EKC for NO_x as the number of automobiles increases.

The EKC for TSP takes the expected shape and the turning point is consistent with other studies. The fact that per capita emissions are declining despite heavy industrial and manufacturing growth implies that either the country’s reforestation efforts are indeed working, or perhaps there is an issue with seasonal measurements (see Section 3.3 for further discussion of this). There is also the issue of the exact makeup of TSP. While the smaller particles that are more detrimental to human health (less than 10 ppm) have begun showing up as separate measurements, it is not clear how the total composition had changed over time. Another issue that may be leading to the decrease in reported emissions is that manufacturing activities have to some extent moved away from city centers even though the receptors that monitor pollution have remained relatively fixed.

Finally, SO₂ appears to just be reaching the flat portion of its EKC. This was also found to be the case for CO₂ by Auffhammer et al. (2004). This study shows that most areas in China are likely

approaching the flat portion of the curve, therefore emissions will no longer be driven by increases in China's per capita income. Instead, increases in CO2 emissions may be accelerated by population growth or changes in technology.

2.3 Water Pollution

While air quality may be increasing, much less progress has been made with respect to water quality improvements. Water pollution problems are particularly severe in the north, particularly in the catchments of the Huai, Hai, and Huang (Yellow) Rivers. The last decade has brought improvement to some of the larger rivers, while the remainder continue to deteriorate. It has been said that even if all point sources that empty into these northern rivers complied 100 percent with national discharge standards, the river systems would still be environmentally overloaded. Freshwater lakes and coastal water quality have not improved, and there is evidence groundwater pollution may be increasing (World Bank 2001). The most problematic pollutant is organic material from industrial and domestic sources.

Table 2 shows water quality³ in some major rivers. The rivers evaluated include the southeast, southwest, and northwest systems, and the Songhua, Liao, Hai, Huai, Huang, Chang (Yangtze), Changjiang, and Zhu (Pearl) Rivers. These rivers drain over 45 percent of total land area and account for more than 54 percent of its freshwater resources. While the total length of the rivers evaluated continues to increase, the percentage "above standard" remains fairly constant, signaling falling water quality in more water bodies.

<Table 2 here>

If we were to separate these percentages for the north and south, the percentage of poor class water bodies would be significantly higher in the north. The incidence of Class V and worse tends to be about three times higher in the north (World Bank 2001). Rapid industrialization of the north, with its accompanying population growth means that more people are relying on increasingly worse water supplies. The number and probably the proportion of people using the poorer classes of water are likely to be rising. Similar trends can be observed in the country's lakes.

<Table 3 here>

A recent New York Times article (Yardley, Sept. 12 2004) depicts the situation in rural areas, where people are found boiling black water and scraping off the scum that accumulates on the top for drinking and cooking. Class V and worse water continues to be used by households and agriculture, posing dire health risks. SEPA samples do not include smaller rivers, which are said to be in extremely poor shape as a result of the TVIE's (Township-village industrial enterprises). Water quality in the Huai River is reportedly getting worse again, despite considerable effort by the government. In Guiyu, in the Guangdong Province, levels of lead in the water were 2,400 times higher than WHO drinking guidelines (Economy 2004).

Furthermore, total wastewater discharge is increasing, particularly in the residential sectors. Although increased regulations have helped industrial discharge, the total amount of wastewater is increasing. Confounding the problem is the increasing reality of water shortages. More waste in less water is creating significant water pollution issues. This situation is illustrated in Figure 7.

<Figure 7 here>

Given that there are no comprehensive time-series data on groundwater quality, information concerning groundwater quality is anecdotal. Groundwater usage is poorly controlled and overextracted, and is becoming a particular problem in the north. Anecdotal evidence suggests that quality is deteriorating, especially in near-surface aquifers and in the vicinity of major cities (World Bank 2001).

3. The Statistics

It has long been noted that statistical reporting in China has suffered at times from incentive compatibility problems (Rawski 2001, Roumasset 2003). Pressures on statistical agencies to deliver good news may be easily accommodated by the adjustment of sampling and other methods. Accordingly, it may be possible to increase the utility of environmental statistics by developing more cautious measurement protocols.

The statistical picture of pollution trends contrasts starkly with bleak qualitative reports by authors such as Economy (2004). What additional data might give a more complete picture of the trends in air pollution? Three areas of possible improvement are discussed below. The first issue pertains to the measurement of TSP and NO_x concentrations. A second issue concerns the decentralization of polluting industries, and the lack of solid source-receptor data. Last is the issue of protocol for measurement of ambient concentrations.

3.1 TSP and NO_x measurement

The measurement of TSP concentrations is complicated by its ambiguous components. Since TSP is the general name for particulate matter up to 40 microns in diameter, authorities measure the concentration of TSP per cubic meter of air. We cannot say anything about the small vs. large particles within this cubic meter. The problem is that the most accurate measure of serious particulate pollution is fine particulate matter, or PM-10. While the United States monitors particulates as small as PM-2.5, PM-10 monitoring data in China are scarce (although daily monitoring of PM-10 has recently begun in some cities). Based on correlations between PM-10 and TSP in other data sets, a World Bank study (2001) found that PM-10 is the most damaging air pollutant in China in terms of health complications. The leading cause of death is chronic obstructive pulmonary disease due to atmospheric pollution, especially from particulate levels.

The smaller particles are directly emitted from the combustion of fossil fuels and also result from post-production photochemical reactions. The larger particles are the result of fugitive dust from wind and soil erosion, and particles from industrial processes such as metal and fiber production. So while total TSP emissions appear to be falling, it is unclear how the composition of the fine vs. coarse particulates is changing. Concentrations of PM-10 may actually be increasing, even as

TSP is decreasing. If the TSP being captured by current measurement is composed of a majority of large particles, if the smaller ones are in fact increasing, the total does not change as much, although health will be severely affected. Because we don't know the composition of TSP measurements, it is possible that the smaller, more harmful particles may be increasing despite the falling trend of total TSP.

There is a similar problem with the measurement of nitrous oxides. NO_x is measured as any combination of N and O, whether it be NO or NO₂ (again, authorities have begun measuring NO₂ separately, although not on a large scale basis across the country). Uncertainty about the composition makes levels of NO_x difficult to compare with NO₂ gas concentrations reported in the United States and referred to widely in the literature on air pollution epidemiology and health. Researchers have found that NO₂ level averages two-thirds of the NO_x level in China (US Embassy 1998).

3.2 Decentralization of industry

In recent years, the government has begun to decentralize the polluting industries⁴. But as industry moves out of cities, the pollution data is still largely collected in these cities. It is possible then that total emissions may be increasing, but are more decentralized. Although it appears that we have approached or turned the corner on the three major pollutants, we only have data on major cities. The information we need is the level of these pollutants in the areas to which industries and households are dispersing. Additionally, because source-receptor data are unavailable it is hard to know how pollution created by specific industries affects various provinces. Some will end up concentrated within the same city it was produced in; other polluters will have their emissions blown out of the region, with adverse impacts instead affecting surrounding provinces. It is not clear these issues have been taken into account by present policies.

On the other hand, although the statistics may be biased towards large cities, the trend towards decentralization does have an important economic justification. Falling emissions in the cities means less people may be exposed to the pollution, therefore health damages may be significantly reduced due to decentralization policies.

3.3 Measurement protocols

An essential factor in air pollution measurement is the impact of seasonal variations. Pollution in China has a seasonal pattern. In the winter, more coal is burned, especially in the north. Annual averages, then, tend to conceal these fluctuations, which can severely influence health. Brajer and Mead (2004) use pollution data from 38 cities and China-based epidemiological functions to estimate the economic benefit of reducing urban air pollution, by quantifying the expected number of statistical lives saved. When SO₂ and TSP were broken down into their seasonal levels and specifically identified each pollutant's seasonal effects, the number of averted mortality cases tripled. They find that in Beijing's winter, SO₂ is 2.7 times more damaging to health than average, and 14.2 times worse than in Beijing's summer. This illustrates the need for specifying appropriate seasonal protocols. One possibility is to adjust for seasonality by using indices to weight health risks.

Additionally, cities sample air pollution on a daily basis, and report annual daily averages as official statistics. Since concentration levels could vary widely due to factors such as wind, rain, and other natural weather conditions, there should be a method for accounting for these fluctuations, which may not accurately reflect true pollution levels. Because damages tend to vary over the year, instead of simply taking an average over time and space, it may be useful complement these statistics with estimates of economic damages that result from different exposures to pollutants in different seasons.

The validity of statistics may also be an issue. As recently as 1998, China's analysts complained that the system of statistics has become entangled in a "wind of falsification and embellishment" (Rawski 2001, p. 350). Rawski goes on to point out that in 1998, the National Bureau of Statistics (NBS) rejected provincial GDP data, dismissing it as "cooked local figures" (Xu 1999). However, since this time, the NBS has offered no explanation to the public on how they actually derive the figures that represent the official growth of the country.

To summarize, because small airborne particles present such a grave concern to health, PM-10 and PM-2.5 should be considered for independent measurement in all cities, in order to get a better grasp on true levels of harmful suspended particulates. The same can be said for the measurement of NO_x concentrations. Focusing on collecting data on the health damaging NO₂ will allow for more pertinent policy decisions concerning nitrous oxides. Paying more attention to small city data collection and bridging the gap between source and receptor data may reveal pollution trends that may not be apparent today. Finally, measurement protocols, which take into account fluctuations in both weather and seasonality, would help clear up some serious ambient concentration ambiguities.

4 Natural Resource Depletion

4.1 Forests

The current state of forest reserves is disputed. Government statistics (www.stats.gov.cn/english) suggest there is no evidence that forest stocks are decreasing. According to the 5th national forestry census (1994-1998), the total forested area was 158 million square hectares. Compared to the 4th census, the total acreage increased by 2 million square hectares. Additionally, there was an increase of 8 million square hectares from the 3rd to the 4th census. Table 4 depicts the trend in forest resources from 1934-1993.

<Table 4 here>

Other sources suggest a different trend. According to Economy (2004), forest resources are characterized by decreasing forest reserves and illegal logging. The first years of economic reform (78-86) brought with it a lack of regulations, and logging increased by 25 percent. The country is now the world's second largest consumer of timber. This contributes to growing desertification and increased sandstorms in the north⁵.

During the reforms of the 1980's, leaders designed a set of policies targeted at encouraging afforestation and limiting overharvesting. These policies were of two types. The first aimed for changing the management practices of the state enterprises, while the other set was intended to influence the actions of farmers and other forest dwellers. There is great disagreement about the success of these reforms. An 8.5 percent increase in national forest cover between 1980 and 1988 is frequently cited as evidence of success (Yearbook), while others have cited a negative impact. Rozelle et al. (1998) provide evidence that policy changes in the state sector did stimulate reforestation, but provided few incentives to curtail high rates of harvesting. The increase in forest cover does not undo the sharp drop in forest volume, most of which was caused by rapid harvesting of old growth forests. While total area of forested land may be increasing, timber biomass is decreasing. Furthermore, the quality of timber is declining, as the old growth forests have been deforested, and high quality hardwoods are being replaced by fast growing species.

In a later study, Rozelle et al. (2003) found further evidence that the 15 percent increase in aggregate forest cover experienced between 1980 and 1993 came at the expense of forest diversity. With natural forests transformed into plantations, the ability to provide environmental services such as habitat for species declines. The change in forest structure may also affect the livelihoods of certain populations.

With the increasing conversion of prime agricultural land to urbanization, a program of offsets was initiated to supplement the loss of agricultural land. This led to the opening up of many more, albeit lower quality, newly cultivated areas. The attempt to offset increased urbanization with the opening up of more land for agriculture was unsuccessful in that quality was sacrificed for quantity. Research by Rozelle et al. 2005 shows a near wash in productivity from this tradeoff.

In response to this loss of forest cover, the government started the conservation set-aside (or offset) program "Grain for Green" in 1999. Easily one of the largest conservation set-aside programs in the world, its main objective was to increase forest cover on sloped cropland in the upper reaches of the Yangtze and Yellow River Basins to prevent soil erosion. When available in their community, households set aside all or parts of certain types of land and plant seedlings to grow trees. In return the government compensates the participants with in-kind grain, cash payments and free seedlings. By the end of 2002, officials expanded the program to 25 (of 30) provinces. To date, 7 million hectares of cultivated land has been converted to forest and pasture land. While this certainly has affected the supply of food, the land that was removed was of such low quality (much lower quality than the average land that was opened up during the 1980s and 1990s) that it had only a marginal impact on overall food prices since the program started (Rozelle et al. 2005).

Additionally, afforestation campaigns, which have had a long history in the country, are often undertaken with inappropriate technologies and poor oversight. Trees planted too close together, a lack of forest management, and no consideration of the viability of species in local ecosystem characterizes these types of efforts.

As for the forestry management regime, it is split between the state and local communities. The state managed part only covers about 20 percent of the total resources, although this area contains the higher quality trees. Problems contributing to this management sector include underpricing, lack of incentives for forest managers, and the narrow focus on production. The collectively managed forests, which are owned by local communities and operated by village leaders, manage the remaining reserves, and have produced almost 75 percent of the value of forestry output (Rozelle et al. 1999). Data suggests that collective entity manages resources appreciably better than the state sector.

4.2 Grasslands

Grasslands cover approximately 400 million hectares, or 40 percent, of total land area. These grasslands, in general, are not highly productive (World Bank 2001). About two-thirds of the total have an annual dry matter production potential of less than 1,000 kilograms per hectare.

In recent years, livestock management and production have been changed in response to economic objectives. Herds and grazing land have been privatized, and grazing has become more intensive. These developments have negatively impacted ecosystem stability, resulting in severe grassland degradation. Grassland degradation reduces productive capacity of the land, as well as reducing other benefits such as biodiversity, watershed maintenance, and air quality.

Furthermore, most of the newly opened cultivated land discussed in the forestry section above came at the expense of wetlands and pasture areas in Heilongjiang, Jilin and Eastern Inner Mongolia (Rozelle, personal communication). From Figure 8, the numbers of grassland hectares experiencing degradation have been increasing since the late 1980's.

<Figure 8 here>

4.3 Water

While the quantity of total water resources appear steady, rapid growth has led to increased demand for water, and a shifting of sources of their increasing water pollution. Although the national supply of freshwater, 2,500 cubic meters per capita, is above the World Bank's definition of a water scarce country, this does not account for substantial regional disparities in water access.

Water distribution is highly uneven; availability is greatest in the south, as average rainfall in the southeast is nine times greater than the northwest. The northern rivers have far less assimilative capacity than southern rivers, due to lower flows. Distribution of groundwater resources is also skewed – the south gaining four times more than the north. Most of the water is directed towards agriculture (85 percent arable land in north is irrigated, compared to 10 percent in US). The total level of water resources is most likely increasing due to investment in water resources engineering. As of 2000, 85 thousand dams have been constructed with a total storage capacity of 518 billion m^3 , of which 397 are large-sized with a total storage capacity of 326.7 billion m^3 and 2634 are medium-sized with a total storage capacity of 72.9 billion m^3 . Their engineering projects also include 270 thousand km of embankments and 98 flood storage or detention zones

for the Yangtze, Yellow and Huai rivers, with a total area of 34,500 km² and a total storage capacity of 100 billion m³ (Ministry of Water Resources).

<Table 5 here>

Surface water in the above table refers to the water volume from rivers, lakes, and glaciers, i.e., the surface runoffs of natural rivers, lakes, etc. Groundwater is the water from precipitation and surface water that seeps into the ground. The total water resource figure is found by summing the surface water and groundwater, then deducting the overlapping portion.

Swift economic growth and a growing population have driven water use to unprecedented levels. The government is trying to accommodate the increasing consumption by raising the level of water storage, however they are running out of the capacity to do so. Utilization may be rising faster than storage capacity. From Tables 5 and 6, we observe that although stocks of water may be steady or rising, the available supply of water to the population is decreasing.

<Table 6 here>

Table 6 describes the national supply of water. Water supply refers to the gross supply of water to the consumers from the water projects, including the transportation loss. Statistically, it is calculated by summing surface water, groundwater and the other water resources (from water recycling and rain collection projects). The direct consumption of seawater is not included in the water supply.

There is evidence that the water tables, especially in the northern regions, are falling. A study conducted in 2001 by the Geological Environmental Monitoring Institute in Beijing reported that under Heibei Province, the average level of the aquifer dropped 2.9 meters in 2000 (<http://www.thestudentzone.com/articles/chinawater.html>). In some cities around the province, it fell by nearly 6 meters. The water deficit in the north may now exceed over 40 billion tons per year.

The most recent water demand projections suggest that irrigation use will decline from 73 percent of total consumption to 50 percent in 2050 (World Bank 2001). Consumption for industrial and urban purposes, however, is expected to increase substantially. Since both of these forms of consumption lead to emissions of polluted water, it is likely this pressure will increase in the future as well. The UNDP, UNEP, World Bank and the World Resources Institute define water scarcity as 1,000 m³/person or less. The water consumed per person (from both surface and groundwater) includes not only what is normally classified as domestic/residential water consumption per capita, but also the individual's share of national water consumed for productive activities – agriculture and industry – and the individual's share of water required for ecosystem needs. Using this definition of water scarcity, the country as a whole will be classified as water scarce by 2010 at the current rate of population growth (Shalizi 2004).

4.4 Soil

Since the 1990's, desertification⁶ has been a major land resource concern. Desertification is occurring on about 262 million hectares, giving China the highest potential-actual desertification ratio in the world (World Bank 2001). The north (including the capital of Beijing) has been covered in dust for days at a time, dust that travels as far as Japan, Korea, and the United States. It has been estimated that 5 billion tons of topsoil is lost every year⁷.

The mid-1990's saw a quest for grain self-sufficiency. In 1994 Lester Brown published *Who will feed China* – predicting a severe declining capacity for grain production, with a surging demand for food, which would produce soaring levels of grain imports and increase the price of food worldwide. Brown estimated that 900 square miles of land go to desert every year⁸. The response was a series of government sponsored policies designed to increase grain production, but these only exacerbated problems in land-use practices. A 1994 policy required all cropland used for construction be offset by land reclaimed elsewhere (in order to reverse trend of industrialization of agricultural land). The policy was followed by an unfortunate result – coastal provinces paid other provinces to plow land to offset losses, and these provinces reclaimed vast tracts of grasslands and continued to plow more land, worsening soil erosion, water shortages, and desertification. Overall, the campaign failed to achieve results, creating system of perverse incentives, encouraging officials and farmers to worsen an already bad situation.

Peter Lindert (2000) examined one aspect of Brown's question: can China feed itself? Lindert's analysis suggests Brown's findings are somewhat exaggerated. Soil loss should not be directly translated into productivity loss. Lindert shows econometrically that productivity does not necessarily go down with soil loss. There are a number of additional factors that would prevent loss of productivity despite loss of soil, e.g. sufficient depth of soil.

This is not to suggest that there is not a problem. While on-site damage from lost soil may be low, off-site damage may be considerable, and may include siltation in irrigation systems, water transport systems, increased water pollution, near shore effects, and health complications from increased wind-blown dust. These concerns, not productivity, are the real issue. Furthermore, Brown's question, can China feed itself, may be misleading. While the country has increased imports, this is a sign of comparative advantage, not of an inability to produce enough for themselves.

Nevertheless, the laws of thermodynamics imply Brown may be on to something. By the first law, when the soil blows away from China, it does not disappear, but moves someplace else. But the second law suggests that it will move away from high valued locations to low or negatively valued locations, leading to the siltation of dams and other such tribulations.

However, as cultivated land increases, agriculture has become more intensified, with higher yields per hectare, greater input use, and more irrigation. Quality improvements such as land leveling accompany this intensification.

4.5 Energy

As the world's largest consumer of coal, the main source of air pollution is energy consumption. Most sulfur dioxide and all soot emissions come from the burning of coal. Rapid growth has led to a 5 percent annual increase in energy consumption, a number four times higher than the world average. In 2000, the stock of petroleum per capita was 2.6 tons, natural gas per capita was 1074 m³, and coal per capita was 90 tons. Those numbers are 11.1%, 4.3% and 55.4% of the world average (www.cei.gov.cn).

According to official statistics, the past decade has witnessed an increase in the ratio of oil to coal use, although very recently, that trend has abated. Coal use in both the residential sector (since as early as 1988) and in the industrial sector (since 1995) has declined, until at least 2002. Figure 9 illustrates this trend. The decline in residential use was much more severe. For instance, 175 million metric tons of coal was used in the residential sector in 1988. It declined⁹ to 68 million metric tons in 2002.

<Figure 9 here>

Civilian coal use is forbidden in many large cities, and gasoline is largely being replaced with natural gas as the fuel for buses and taxis. But such a policy is far from being a comprehensive, especially for industry. Coal is still one of the major raw resources in most industry, although electricity utilities are relying on it less than before.

Furthermore, in August 2001 the U.S. Embassy Beijing reported that despite reports of declining coal use and thus decreasing greenhouse gas emissions, there is evidence that these have in fact not fallen in absolute terms. The report notes that Chinese official statistics are often unreliable and subject to political manipulation. In 1998, reported growth of GDP and electricity output (whose levels had historically followed very similar trends) suddenly diverged, with GDP rising 7.8 percent and electrical output growing by less than 3 percent¹⁰. Since this time, the two data sets have resumed their parallel relationships. Official figures also show that coal consumption fell by more than a fifth from 1996 to 1999, while industrial output grew 31 percent and electricity generation (primarily from coal) increased 15 percent. As shown in Table 7, the production of coal is also on the rise.

<Table 7 here>

China is now the world's second-largest coal exporter after Australia, having jumped from 32 million tons in 1998 to more than 90 million tons of exports in 2001¹¹. Important factors behind their rapid export growth is government assistance to state-owned coalmines, export incentives, relatively low cost, proximity to Asian markets, expanded production capacity, and the desire of some Asian coal buyers to diversify their sources of supply.

<Table 8 here>

Despite the switch from complete reliance on coal and other traditional fuels for power to some substitution of oil and natural gas, pollution problems have a ways go before being resolved. Table 8 shows total and industry SO₂ emissions from 1997-2003. From the late 1990s, SO₂

emissions wavered, with the lowest point appearing in 1999, followed by 2002. Waste gas emissions declined for quite a few years before rebounding in 2003. During this time period, cleaner fuel policy was increasingly adopted. Prior to 2003, one might want to correlate these trends, attributing clean air to the switch in energy. However, this association is unlikely. The high growth rate of industrial production can easily nullify the coal-oil-pollution hypothesis, which is proven by the return high levels of pollution in 2003. According to the official analysis from the government, the explanation for higher pollution emissions that year was the rapid growth of the heavy polluting, high resource-consuming industries, for which the demand for electricity and coal is far beyond the supply, and the production of industrial raw materials such as steel, electrolyzed aluminum, and cement are soaring. Using cleaner burning oil is likely only a small portion of the cleaner air story.

Gains in energy efficiency may also be driving the shape of the Environmental Kuznets Curves in air pollution. For at least two reasons the economy is shifting to cleaner burning technologies. First, as discussed earlier, with income elasticity in the country greater than one, the environment is becoming a luxury good. Second, energy per output of certain technologies is falling (see Figure 10). While efficiency of technology is increasing, the emissions from technology are declining. An example of this is the use of coal for residential and industrial heating. There are two ways to use coal for heat – either by directly burning coal, or by using coal to produce electricity (so the heat would be using coal indirectly here). On a micro level, efficiency (as measured by declining energy/output) is increasing under both technologies. However, indirect use of coal is more efficient, despite the fact that there exist two sources of efficiency losses – with the production of energy and then the production of heat. Additionally, the emissions related to indirect production of heat from coal are lower. The higher price of coal and the higher (implicit) shadow price of pollution induce some production to shift from coal-based to electricity based. This saves both coal and pollution, even if coal is used to produce the electricity.

<Figure 10 here>

Environmental costs of this high level of coal use have been estimated. 40 percent of the coal is burned to generate electricity power. In 2001, the total emission of SO₂ was 19.48 million tons, 98 percent of which was produced in the process of coal burning for power generation. Burning one ton of high sulfur coal produces 20 to 30 kg of SO₂. The treatment cost of that amount of SO₂ is at least 50 RMB. A one percent increase of sulfur per ton of coal burning will lead to the loss of at least 4.71 RMB and at most 10.73 RMB. Therefore, a unit ton emission of SO₂ could cause an economic loss close to 5,000 RMB.

Although the country has begun using more oil¹² than coal, the country's consumption and production of coal continue to increase. Adhering to increased energy regulations, industries have slowly begun the process of substituting power for more traditional sources. In order to change its energy structure, China has been increasing their production of natural gas. In 2003, the total production was 34.128 billion cubic meters, an increase of 6.8 percent from 2002. It is estimated that the natural gas demand in 2005 will be 61 billion cubic meters, and the percentage consumed will increase by 5 percent.

Another possibility is the use of photovoltaic, or solar energy, especially in remote southern areas. This would cut down on transmission costs, and provide a clean alternative to the other options. Wind power is another source of energy policymakers are seriously considering. In order to tap into the wind resources across the country, the country has invested \$3.7 million a year since 2003 to assess wind resources in different regions in order to best place the wind mills, especially in the northern regions of the country (www.chinaview.cn, Aug. 11 2005).

4.6 Minerals

As of early 2003, mineral reserves included 158 detected minerals, with 10 energy minerals, 54 metal minerals, 91 non-metal minerals, and 3 liquid-gas minerals¹³. Table 9 shows ensured reserves of some of China's important minerals over time.

<Table 9 here>

The country is one of abundant metal minerals such as iron ore stock, although the quality of the iron ore is relatively low. By the end of 1996 the total iron ore reserve was 46.3 billion tons, ranked number 5 in the world (after Russia, Australia, Canada, and Brazil). Iron ore is found throughout the country, with the exception of Shanghai and Hong Kong. The northeast and Huabei areas have the richest reserves, followed by Southwest. As far as the provinces are concerned, Liaoning ranks first in the approved reserves, followed by Hebei, Sichuan, Shanxi, Anhui, Yunan, Inner Mongolia. Lean ore (ore that is hard to extract iron from) is the main part of the iron ore reserves, while rich ore (easy to extract iron from) only comprises 2.53 percent of total reserves.

While reserves of highly demanded minerals have been depleted, reserves of rare minerals such as tungsten, stibium, and rare earth elements are plentiful. Reserves of manganese, gold, and silver have been increasing steadily since the 1950's. In particular, total gold reserves between 1991-1995 increased by over 300 percent. By the end of 1994, the reserve of rare earth elements¹⁴ was 107.35 billion tons, the most in the world. Figures 11-13 reflect these trends.

<Figure 11 here>

<Figure 12 here>

<Figure 13 here>

The main problem with mineral resources is that per capita reserves are very low, and falling. By 2020, dependence on imported crude oil is expected to rise to 60 percent, and natural gas to 40 percent. According to projections of future supply and demand, by 2020, domestic resources will fully supply only 9 of 45 varieties. In particular, crude oil, iron ore, copper, bauxite, items essential to national economic security, are all in long-term deficit. Of 415 large and medium mines nationwide, half experience a crisis of depleted reserves or face closure, while 47 mining cities face resource exhaustion. (You and Qi 2004).

The same is increasingly true for the ratio of income and manufacturing output to domestic mineral resources. Future growth will require large imports of a variety of mineral products. The scale of future imports and the range of minerals needed implies that China may need to establish a wide network of trade partners to supply these mineral demands. Declining mineral reserves implies that the country will become increasingly dependent on trade for non-renewable resources. This dependence may result in a force towards increased economic cooperation (Rawski, personal communication).

4.7 Fisheries

4.7.1 A growing industry

China is the largest fish producer in the world and has the largest number of fishing boats. The species of marine living resources in the seas are very abundant, with about 1,700 fish, 100 cephalopod, 300 shrimp, and 600 crab species¹⁵. About 200 species are economically important in marine fisheries. Since 1990, fish production has ranked first in the world, reaching around 40 million tons in 1999 and accounting for 30 percent of the world total. But fishing resources have dwindled significantly in the country because of years of over-fishing and water pollution.

The sector has experienced one of the highest growth rates since the reform period. As can be seen in Table 10, since 1996 the fishery industry has been in the leading position, with growth rates much higher than other agricultural sectors. As for structural changes, the share of fishery in agricultural sectors increased from 2 percent in 1980 to 11 percent in 2000.

<Table 10 here>

4.7.2 The emergence of aquaculture

Aquaculture development has been increasing dramatically since the 1980's. Total aquaculture production increased from 1.60 million tons in 1978 to 25.78 million tons in 2000. Aquaculture production as a percentage of total fisheries production has also been escalating from 27 percent in 1978 to 60 percent in 2000 (Li 2003).

<Figure 14 here>

The emergence of aquaculture has had a profound impact on the structure the fishery sector. Since 1978, the area of ponds, lakes, reservoirs, and marine areas used for aquaculture has steadily increased. In 1999, the farming area reached 7.75 million ha, a threefold increase from 1978. There has also been a notable movement of labor to aquaculture from agriculture/capture fisheries. By 1990, over 2 million people switched to aquaculture from agriculture and other industries. Total fishery (cultivation plus capture) labor in 2000 reached 18.6 million, of which full-time employment in the aquaculture sector reached 3.7 million, a seven-fold increase over 1978 level (Li 2003). Other important contributions from aquaculture include improvements in

fisheries techniques and yields, diversification of farmed species, and diversification in modes of farming.

4.7.3 Resource challenges

First, the natural fish resource is in decline. In marine capture fisheries, from the mid 1970s, low valued species gradually took over from commercially important bottom species. It was reported that since the 1980s, pelagic species accounted for a larger share of production. Survey statistics between 1982 and 1988 showed that small pelagic fishes accounted for 60 percent of the total biomass. From 1992 to 1993 marine invertebrates declined by 39 percent and fish spawning biomass fell to only 30 percent compared to that of 10 years earlier. Biomass of commercially important species like perch, herring, sole, sea bream, flounder, shrimp and crab decreased to 29 percent while anchovies increased by 2.4 times. Data from 1998 again revealed that biomass in the Bohai Sea was down to 11 percent of that in 1992. As for the East China Sea, some species remained stable in amount but their populations tended to be younger and smaller (Yang 2003). Furthermore, most fish resources in inland waters have been over-developed by improper production modes, threatening fresh water ecosystems and biodiversity.

The fishery resource faces other challenges. The water environment itself has greatly deteriorated. It is reported that among the 1200 rivers, 850 are polluted, and 61 percent of the lakes are estimated to be eutrophic (Yang 2003). A lack of advanced technologies is another problem in the fishery industry. Apart from a few modernized fishing fleets and fish farms, scattered fishermen and fish farmers dominate both capture fisheries and aquaculture. For example, only 30 percent of landed fish are processed compared to 70 percent in developed countries.

An overall lack of good breeding stocks has marked the country's experience in aquaculture. Only a few breeding stocks have been strictly selected for aquaculture. Thus far, 70 percent of stocks of Chinese carps that are the major aquaculture species are simply taken from the wild. Disease is another challenge. In 1992, China was the largest producer of cultured shrimp in the world, but experienced a major setback after 1993 due to the outbreak of disease. It is recorded that there are 400-500 kinds of aquatic diseases in China, and it is estimated that 15-20 percent of the total production and over US\$ 1 billion is lost annually as a result of the lack of control in the disease management (Li 2003).

4.7.4 Fisheries policy

In 1991, China began to adopt measures to control the number of fishing boats. In addition, the country adopted a policy of "zero growth" of offshore fishing in 1999, and "negative growth" in 2002.

In 1999, the government decided to maintain a zero increase in the production of marine capture fisheries. The decrease in wild marine fish stocks from traditional grounds had focused policies on expanding aquaculture as a key strategy for meeting changing national demand and consumer patterns due to the rapid changes in population structure and rising living standards.

Thirty thousand fishing boats are expected to be cut in over the next eight years to limit its total fish catch and better protect offshore fishery resources, according to the Ministry of Agriculture (www.china-embassy.org/eng). The ministry released a regulation recently to decrease the number of fishing boats to 192,000 by 2010 from 222,000 in 2002. The total power of fishing boats in the country will be decreased to 11.4 million kilowatts from 12.7 million kilowatts, down by 10 percent.

The ministry also speculates that it will develop catch quotas in the near future.

5 Green Net National Product

A central pillar of the sustainability movement is the call to include environmental accounting in standard measures of economic performance. This increased transparency would, in principle, mitigate the temptation of economic managers and policy makers to increase growth in material consumption at the expense of the environment. Moreover, as Repetto (1989) and others have argued, deducting depreciation of produced capital from NNP but not deducting depreciation of natural capital is inconsistent and debases NNP as a possible indicator of welfare. In addition to deducting the depreciation in natural capital, the correct indicator, known as GNNP (green NNP), treats pollution in a correct fashion. While defensive expenditures to limit pollution are counted as production in current NNP accounting, correct practice is to deduct both defensive expenditures and pollution, valued at its marginal damage cost. (Accordingly defensive expenditures must be deducted twice from the standard accounts.)

The theoretical framework for GNNP requires consideration of three separate categories: nonrenewable resources, renewable resources, and pollution (stock and fund). For nonrenewable resources in a closed economy, forces of scarcity will require that a decreasing quantity of the resource be used every year. As the resource is depleted, the price of depletion is increasing, causing the value of the resource to increase. Furthermore, depletion causes the percentage of NNP to get smaller compared to the rest of the economy. The economy is thus growing faster than the resource being depleted.

Countries that are on the increasing portion of the EKC and are likewise increasing the depreciation of natural capital will exhibit the relationship between NNP and GNNP as shown in Figure 15. An industrializing country such as China is likely to be approaching a close to constant wedge between NNP and GNNP.

For renewable resources, this theory is even more pronounced, as the price will not change as much as in the nonrenewable case. But the general idea remains – as China does more with artificial capital, and less with natural capital, the percentage of renewable resources of the total economy shrinks, thus GNNP will grow faster than NNP.

The third category to consider is pollution. The relative growth rates of income under stock pollution should follow arguments similar to natural resources described above. For fund pollution, we turn back to the shape of the EKC for guidance. Once a country has passed the

turning point on their EKC, GNNP will increase at a faster rate than will NNP. The proof in Appendix 2 outlines this argument. A comparison of growth rates for fund pollution is drawn in Figure 16. While the growth rate of GNNP is initially below that of NNP, after emissions reach their maximum (the turning point on the emissions EKC), the growth rate of GNNP for fund pollution will become faster than that of NNP. The gap between NNP and GNNP for stock pollution is similar to that of natural resources for analogous reasons.

Repetto (1989) originally conjectured that GNNP growth is much slower than NNP growth. This is not necessarily the case, however, and probably not the case for China in the 21st century. Inasmuch as China is on the flat part of its EKC, even if emissions are growing, emissions per unit of NNP are falling.

<Figure 15 here>

<Figure 16 here>

GNNP accounting is still at the experimental stage due to remaining conceptual and measurement difficulties. Nonetheless, some preliminary findings are available. As measurement improves, we expect empirical results to conform more to the theory outlined above. In any event, calculating economic growth using GNNP should produce estimates that are above traditional measures of growth.

5.1 Preliminary Green Income Estimates

Motivated by the 1993 UN Conference on Environment and Development (UNCED), the Government has begun to emphasize the importance of natural resources accounting and the importance of sustainable development. The country's goal is to develop stock and flow accounts for natural resources to facilitate the establishment of a new integrated national accounting system consistent with the UN SEEA framework (Markandya and Milborrow 1999). The SEEA (System for Integrated Environmental and Economic Accounting) contains both physical and monetary accounts, and has suggestions for converting physical data to monetary units, including market valuation and direct and indirect methods. The system emphasizes both *ex post* costs (expenditures on environmental protection) and *ex ante* (maintaining the environment at sustainable level) costs.

The first systematic attempt to quantify the economic cost of environmental degradation in China was conducted by Xiaomin Guo and Huiqin Zhang, using data from the *Sixth Five-Year Plan* published by SEPA. Total pollution damages totaled 6.75 percent of GDP (water pollution being twice as bad as air pollution), and ecological damage (degradation of agricultural land and exhaustion of timber resources) was valued at 8.9 percent of GDP. In 1994 Jianming Jin estimated that these losses were about 50 percent higher than the previous study's estimates. Vaclav Smil of the University of Manitoba published a study in 1996 for the East-West Center using 1990 data. Smil concluded that air pollution was more important than water pollution, and pointed out the importance of accounting for solid waste pollution.

Wang (of Mao et al. 1997) investigated the impact of deforestation on the desiccation of the north and northwest. By calculating the additional evapotranspiration that would occur if all potentially forestable lands were actually forested, he estimates the economic losses resulting from deforestation and its relationship with the following issues: declining lumber resources, desertification, soil erosion, siltation of reservoirs, siltation of navigable waters, and flooding and droughts. Wang estimated these factors lead to economic losses of 245.2 billion Yuan annually.

In a related report, Ning (of Mao et al. 1997) estimates economic losses from farmland deterioration, ranchland deterioration, and desertification. Ning estimated that the degradation of arable land, desertification, and a decline in the quality of rangeland lead to an economic loss of 38.9 billion Yuan in 1992. In the third independent report, Xia (of Mao et al. 1997) calculates the economic losses resulting from water, air, and solid waste pollution. Combined losses were estimated at 98.6 billion Yuan for 1992. A report by the U.S. Embassy Beijing reveals the wide range of estimates of the country's environmental degradation. Table 11 illustrates the wide range of estimates, as percent of GDP.

<Table 11 here>

As evident from Table 11, estimates of how much environmental degradation is costing China vary widely. The U.S. Embassy report points out that according to both Chinese and Western scholars, pollution may be costing the economy anywhere between 3 and 8 percent of GDP each year, while ecological damage potentially costs an additional 5 to 14 percent.

One of the first estimates of China's total green national income comes from Lei (1999). Using Leontief's input-output analysis, Lei defines Green GDP in the following manner:

$$\begin{aligned} \text{GGDP} &= \text{GDP} \\ &- (\text{total resource exhaustion from production} + \text{total environmental pollution from production}) \\ &- (\text{total resource exhaustion from resource recovery} + \text{total environmental pollution from resource recovery}) \\ &- (\text{total resource exhaustion from pollution treatment} + \text{total environmental pollution from pollution treatment}) \\ &- (\text{total resource exhaustion from final use} + \text{total environmental pollution from final use}) \\ &+ (\text{newly created value from resource recovery sector} + \text{newly created value from environmental protection sector}) \end{aligned}$$

Lei uses seven sectors (agriculture, coal excavating industry, other industry, construction industry, transportation industry, business and food industry and other service industry), in his green input-output table, one kind of resource utilization (coal) and one kind of pollution (SO₂). Using the relationship between coal combustion and SO₂ ejection and the theoretical price of treatment for SO₂, Lei arrives at a GGDP of 2.65 trillion Yuan (correcting only for coal and its emissions, not including other forms of pollution or the depreciation of other natural resources).

Other authors have attempted to calculate the GNNP for isolated sectors of the economy. By valuing the changes in forest resources, Xuelin Liu (1998) estimates the depreciation of forest

accounts in national accounts from 1976-1992. By using the net price approach (the reduction of timber volume times the stumpage value) both physical and monetary accounts are computed to derive forest depreciation. Selected results are summarized in Table 12.

<Table 12 here>

In a 1999 study by Hou et al. the value of forest resources was estimated to be between 11 and 13 trillion Yuan. This study extended Liu (1998) in that the forest's water and soil conservation roles were included. Had Liu considered these roles, his figures would have been much larger.

Du et al. (1999) calculate a "green profit" for the Dolanasyi gold deposit, by subtracting the value of environmental damage and the loss of the mineral resource from the economic profit from sales of the gold. The authors find a green profit of 2379.93 Yuan (as opposed to the unadjusted profit of 2605.12 Yuan).

Because estimates have varied so widely, we produce our own estimate of Green Income. GNI (formerly GNP) is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. Data are in 2004 U.S. dollars. Our estimate of GGNI was calculated by subtracting three components from GNI: net forest depletion, mineral depletion, and energy depletion¹⁶. See Table 13 for the value of each component.

<Table 13 here>

For net forest depletion, rent on depletion was calculated as the rent on that amount of extraction that exceeded the natural increment in wood volume. For mineral and energy depletion, rent was measured as the market value of extracted material minus the average extraction cost. Note that this preliminary estimate is a very incomplete calculation of GGNI, as it does not include areas that are likely to be important in China, such as soil erosion and degradation, water pollution, and urban air pollutants.

<Figure 17 here>

This estimate of GGNI can also be illustrated using the Environmental Kuznets structure, that is, environmental degradation as a function of per capita income. Using our estimates of GGNI, the corresponding Environmental Kuznets Curve for natural resources (particularly forests, minerals, and energy) is illustrated in Figure 18.

<Figure 18 here>

It is also noteworthy to compare relative growth rates of the conventional income measure versus the green income measure. These trends are illustrated in Figure 19. The growth rate of GGNI was 3 percent lower on average than that of GNI until 1982, at which point GGNI began to grow 1 percent faster (on average) than GNI, with a few exceptions. For example, the growth rate of

GNI rose above that of GGNI in 1999 and 2000 because energy depletion (as percent of GNI) for these two periods increased abruptly, reversing a trend that had otherwise been falling since the early 1980's. Looking at the energy data, consumption of coal had been falling through the mid to late 1990's, increasingly being replaced by oil consumption. In 2000 this trend reversed, and the consumption of coal has been on the rise ever since. Furthermore, total energy consumption (coal, oil, natural gas, and hydro-power) had been decreasing through the mid to late 1990's. This overall trend was also reversed in 2000, and total energy consumption has also been increasing since then.

<Figure 19 here>

It is also of interest to compare how China's income gap or "green deficit" compares to that of other countries. We chose four other countries for the comparison, representing different levels of income and economic development – India, Indonesia, the United Kingdom, and the United States. Figure 20 below illustrates how these countries differ in absolute GNI-GGNI differences, while Figure 21 shows how these deficits fare as a percentage of their income levels.

<Figure 20 here>

<Figure 21 here>

In April 2004 the National Bureau of Statistics reported work to set up a calculation system for Green NNP, selecting the Hainan Province and Chongqing Municipality as pilot areas for the system. China's system is expected to be created in three sequences: quantifying natural resources consumed in economic activity; quantifying environmental losses caused by economic development; and finally the evaluation of the quantity of resources and environmental loss. Consideration of the accounting methods described above will help China to get a better idea of just how large the wedge between NNP and GNNP truly is.

In light of the findings of Auffhammer et al. (2004), China's full wedge probably shows similar patterns, and the current difference of between 8-12% will remain approximately constant for the near to medium-term future. Note that inclusion of these green accounting considerations will not change the country's growth rate significantly. The effect on growth rate is probably very small, as the appropriate calculation would subtract a constant percentage off of both rates. It is the absolute number the changes with green accounting, not the growth rate. This highlights an important source of future growth – to the extent this gap can be decreased, China can increase their annual growth rate.

6 Policy environment

China's approach to environmental protection has traditionally been one of campaign mentality, reliance on local officials for environmental protection, and a view of the environment as an issue of national security. The greatest risk to national security is social unrest. Top leaders have

commented on the danger that environmental protest poses to the authority of the Communist Party and the stability of the state. Therefore, government wants not only to clean up pollution in cities but also clean up the perception of pollution in their country.

Local government officials often have close ties with local business leaders and may be part owners in local factories. Local environmental bureaus are embedded within the bureaucratic infrastructure of local government. Chinese politics have often been marked by corruption and a lack of transparency that affects all sectors of the economy, including environmental and natural resource issues (Economy 2004).

6.1 Some history of environmental policy

1949 saw the rise to power of the rural-based Communist Party under Mao Zedong. Agriculture and industry developed quickly, with little in the way of water and/or soil conservation guidelines. Factories, especially power plants, were built along rivers without treatment facilities for wastewater, waste gas, or industrial residue.

The Great Leap Forward (GLF) of 1958-1961 begun with a mass mobilization campaign designed to surpass the industrial achievements of Great Britain and the U.S. Beijing was transformed from a place with negligible industry to a city with – 700 factories and 2,000 blast furnaces. In the end, the GLF yielded 600,000 iron and steel making furnaces, 59,000 coalmines, 4,000 power stations, 9,000 cement factories, and 80,000 farm repair shops. Mao commanded a policy of backyard steel furnaces; meanwhile ten percent of China's forests were cut down to fire the furnaces.

The Cultural Revolution, from 1966-1976 was marked by an emphasis on increased industrial production, thereby creating significant waste of raw materials and energy. The few existing environmental regulations were discarded. Similarly, grain production was emphasized above the environment. Forests and pastures were destroyed, and lakes were filled. Central government gradually increased environmental regulations after the Cultural Revolution, eventually resulting in the creation of SEPA.

China's present integration into the global economy contributed to the growth of environmentally damaging industries, including petrochemical plants, semiconductor factories, and strip mining. Both environmental regulations and rising wages in most industrialized countries contributed to China's emerging comparative advantage in polluting industries. With increased industrialization, the mid-1990's saw declining grain yields and growing reliance on international grain markets, prompting food security concerns. Today, leaders are focusing on building up the western region, with massive economic development campaigns to increase standards of living and impede migration of farmers to the cities.

6.2 The Nature of Air and Water Pollution Regulations

The regulatory framework for air and water pollution is largely command-and-control based. Command-and-control instruments utilized throughout the country include discharge limits

based on both total emissions and concentrations of emissions. New manufacturing enterprises must receive certification before production can begin, and time limits are set for compliance of existing enterprises.

Newer economic incentives being tried include non-compliance fines and consumer subsidies for energy-saving products. Incentives being experimented with include a discharge permit system, sulfur emission fee, and emissions trading. Select provinces and cities have been experimenting with sulfur trading since 1997. There has also been a concerted effort to decentralize pollution by moving major sources of pollution away from city centers.

Environmental regulations have been described as piecemeal, fashioned for different industries but not necessarily consistent across industries (The Economist, August 25, 2004). For example, regulations designed to limit automobile emissions are not in line with standards designed for industry. In 2001, SEPA announced a standard for automobile pollution emissions, calling for a 30.4 percent reduction of carbon monoxide emissions, and a 55.8 percent reduction in hydrocarbon and NO emissions. Requirements for industry reductions are not so clear. In 1998, an energy law was issued, pertaining to coal, crude oil, natural gas, and electricity. However the articles in this law are general administrative regulations, containing no technical, qualitative, or quantitative limits. On January 1, 2003, another law called the “cleaner production promotions” was introduced. Again, it contains only administrative articles. The law does offer some guidelines concerning technical support, publicity of outdated technology and products, publicity of a polluters list, and some vague instructions about raw materials, packaging, and recycling (SEPA).

Two other shortcomings of the country’s pollution regulations as noted by the World Bank (2001) are the lack of enforcement and the primary focus on point source pollution. Motor vehicle emissions are another area in need of improved regulation. The government has begun to develop a national strategy for reducing emissions, including tightening emission standards, upgrading vehicle inspections, and adopting cleaner fuels.

6.3 Nature and causes of environmental policy change

The current environmental situation is the result of attitudes, approaches and institutions that have evolved over centuries. Environmental practices are shaped by economic and political reforms that have been changing the country since the late 1970’s. In the 1980’s domestic environmental and resource issues captured the attention of international actors. The World Bank initiated fishery and rural water supply projects, and the development of natural gas; the World Wildlife Fund became involved in species protection. The 1990’s brought increased world awareness of ozone depletion, and climate change placed environmental and development policies under international scrutiny – raising issues of environmental protection to higher levels on the leadership agenda.

China agreed to sign Montreal Protocol if significant financial support and transfers of technology were promised from the international community. They believed that the advanced

industrialized countries should restructure and reform their own wasteful practices, not simply look to developing countries. They also refused to consider targets or timetables for reducing greenhouse gas emissions, and are unwilling to permit other countries to undertake joint implementation activities (e.g., reforestation) within the country to fulfill their obligations within the treaty. However in 2002 China ratified the Kyoto Protocol, albeit with developing country status. This makes them eligible to earn credits by undertaking emissions-reducing activities, but they are not required to meet any emissions targets or timetables.

6.4 How policies have changed and remaining deficiencies

Policy reforms are needed to change the following:

1. Inconsistent regulations
2. Weak incentives
3. Lack of enforcement
4. Underpricing of natural resources
5. Growth at any cost philosophy

6.4.1 Inconsistent Regulations

In 2001 seven environmental protection laws were passed, and over one-hundred administrative regulations. However, most laws are said to be broad, ambiguous, or watered down (Economy 2004). Legal expert William Alford says that the laws are more like policy statements than laws in the Western sense. For example, the *Water Pollution Prevention and Control Law* states that “enterprises should eliminate serious water pollution” – while the *Clean Water Act* in the U.S. specifies in great detail the type and amount of pollution that particular sources may emit, and requires permits for the amount of each substance that can be discharged.

While larger firms are regulated, small-scale enterprises (TVIE’s) are usually not. Furthermore, local officials often accept pollution generated by TVIE’s because they need factories for jobs and money.

In SEPA’s *National Tenth Five Year Plan for Environmental Protection*, the State Council outlines “guiding principles and targets” for improving their environmental situation. The focus should be on economic development, with pollution prevention and conservation efforts in accordance with strategic economic restructuring. It seems clear that even in long term environmental planning, economic development is first priority.

6.4.2 Weak incentives

A weak incentive system exists for environmental protection. Examples are abundant. On January 1, 1998, leadership launched the three year “zero-hour operation” to clean up the Huai River. Officials closed down small factories and plants along the river, and to avoid closure, small mills banded together to evade size regulations; others closed during the day but operated at night. In fact, a third of pollution abatement facilities installed in enterprises are only switched

on during inspections, a third are never operated because they are perceived to be too costly, and only the remaining third are operating as required by regulation standards (Watson et al. 2000).

A joint effort among MIT, Qinghua University, and the Swiss Federal Institutes of Technology to improve boiler efficiency was begun in over two hundred sites in Henan, Jiangsu, and Shanxi. Provinces initially failed, despite developing a number of well-tailored and inexpensive measures for the various boiler sites. The MIT-led team found that the plant directors had no immediate incentive to upgrade the technologies in their plants. The team is now researching the linkage between pollution and local health costs to help persuade local officials of the importance of the project (Watson et al. 2000). The Watson study also found that many industries do not utilize some end-of-the-pipe technologies because of perceived additional cost. Even if multinationals provide the necessary pollution control equipment, firms may not comply because the cost is much higher than the small financial penalty they receive for exceeding pollution limits.

On the other hand, some evidence suggests that the environmental incentive system has reduced pollution discharge intensities. In Wang and Wheeler (2003, 2005) both province and plant level data on water pollution were analyzed and results suggested that discharge intensities were highly responsive to provincial levy variations. Similarly, Wang (2002) shows that plant-level expenditures on end-of-pipe wastewater treatment are strongly responsive to pollution charges. The pollution charge system has been in place for over twenty years. The main problem is that the charges are too low. If prices were increased, sensitivity to price change would likely have a significant effect on total quantity of pollution.

However other command and control regulations such as enforcement and environmental zoning have not been found to have significant impacts on abatement expenditures. Another study finds that inspections, rather than pollution levies are found to be a significant factor in explaining a firm's environmental compliance (Dasgupta et al. 2001).

6.4.3 Lack of enforcement

Enforcement of environmental regulations is inconsistent and often lax. TVIE's are especially difficult to monitor and regulate. Weak enforcement also affects willingness of firms to transfer their best technologies. Multinationals are reluctant to employ their advanced technologies, which typically adds more to the start-up costs of the venture, if they don't believe inferior technology will be penalized. As some foreign companies have argued, there would be a far greater incentive to transfer cleaner coal technology to China if regulations favored these technologies over dirtier alternatives. As it stands, multinationals believe cheaper dirty plants owned by provincial power companies will undercut their clean plants.

Furthermore, other countries (e.g., Korea) are often said to take advantage of the country's weaker laws and enforcement capacity and relocate their most polluting enterprises there. In a recent empirical study by Dean et al. (2004), the strength of such "pollution-haven behavior" is estimated by examining the location choices of equity joint venture (EJV) projects in China. Results show that EJVs from all source countries go into provinces with high concentrations of foreign investment, relatively abundant stocks of skilled workers, concentrations of potential

local suppliers, special incentives, and less state ownership. Environmental stringency does affect location choice, but not as much as might be expected. Low environmental levies are a significant attraction only for joint ventures in highly polluting industries with partners from Hong Kong, Macao, and Taiwan. In contrast, joint ventures with partners from OECD sources are not attracted by low environmental levies, regardless of the pollution intensity of the industry.

Periodic monitoring and inspection is conducted in major cities, although its scope is insufficient to cover the area (in Shanghai, a team of one hundred environmental inspectors are expected to cover over twenty thousand factories). If companies exceed pollution discharge limits, they must pay a fee (sometimes lowered if official has personal relationship with the head of enterprise).

One enforcement anomaly is illustrative. By law, a polluting firm is liable for a fine on the pollutant that exceeds the standards by the greatest amount. Up to eighty percent of the levy can be used to subsidize the pollution control project proposed by the firm (Wang et al. 2003). However, this fee is often not distributed according to regulation. Instead, most of the fee goes directly to the bureaucracy. A 2001 audit found \$73 million in misappropriations by the bureaucracy away from environmental protection and towards purchases such as housing and automobiles (www.china.org.cn/chinese/2002/Jan/97539.htm). Additionally, it is found that even when firms receive the eighty percent back for improvements, they use the money to pay for needs other than pollution prevention (Qu 1991).

Fees also create distorted incentives, e.g., in Wuhan, targets are set for fee collection, and when these targets are exceeded, the extra money goes in the pockets of environmental protection officials. Persistence of pollution problems is thus encouraged.

In a 2003 study by Wang et al., determinants of enforcement of environmental regulations are empirically examined. The determinants of firms' relative bargaining power with local environmental authorities are analyzed with respect to the enforcement of pollution charges. Results from the study suggest that private sector firms have less bargaining power than state-owned enterprises, and that firms facing adverse financial situations have more bargaining power than other firms and are more likely to pay smaller pollution charges than they should be paying. The greater the social impact of a firm's emissions, the less bargaining power it has with local environmental authorities.

6.4.4 Underpricing of natural resources

The legacy of earlier regimes, wherein electricity and water were treated as free goods, makes price increases politically difficult. In a recent *Economist* article (A Great Wall of Waste, August 19, 2004), Asian Development Bank's Bruce Murray explains that the legacy of the centrally planned economy remains; electricity and water are still treated as free goods. Due to fear of social unrest, the government is unwilling to impose price hikes in basic services. In 2000, the government of southern city of Foshan attempted to raise water prices, but their fear of public unrest and the local People's Congress and defeated the effort.

Nonetheless, water prices are beginning to rise in most areas. In November of 1999 government officials in Beijing initiated two water price hikes, although it still only costs 1.3 Yuan/cubic meter for consumers and 1.6 Yuan/cubic meter for industry. According to Holland (2000), real costs are closer to 5 Yuan/cubic meter. In early 2003, Beijing announced an increase to 3 Yuan/cubic meter.

Using data from about two thousand industrial firms, Wang and Lall (2002) estimate elasticities and marginal water values for different industrial sectors. The marginal values estimated vary from 0.05 Yuan per cubic meter for the power sector to 26.8 Yuan per cubic meter for transportation equipment, with an average for the whole industry of 2.45 Yuan per cubic meter. Water prices up, at least until the mid-90's, were only in the range of 0.70 to 1.20 Yuan, however (World Bank 1997). Further the estimated price elasticity of water demand is about -1, suggesting that pricing policies can be a potential instrument for water conservation¹⁷. Efficiency gains can be affected both by curtailing low-value uses and by relieving current shortages that ration-out high value uses.

6.4.5 Growth at any cost

The administrative structure of the government is such that even the major natural resource agencies are development oriented. These agencies, including the Ministry of Agriculture, the State Forestry Administration, and the ministry of Water Resources, emphasize pure economic development, without regard for the sustainable management of natural resources. The World Bank (2001) suggests this emphasis can be effectively changed through the State Council, who could review the legislation of the major natural resource agencies, assess the degree to which they conflict with the goal of sustainable development, and ideally suggest amendments or modifications to bring development and sustainability more in line.

6.5 Policy reforms

There is limited evidence that environmental policy, in some cases, has begun to move in a more efficient direction. Improvements have been seen in the following areas: water pricing, tradable permits, clean energy, and public disclosure.

In the water scarce city of Zhangjiakou, officials (acting on advice from the Asian Development Bank) raised the price of water by 40 percent and varied the price according to consumer type. In one year, water consumption fell by almost 14 percent, primarily due to factories that instituted water recycling (Economy 2004).

The transition to a more market-based economy has opened the door to market-based pollution controls. At a meeting in Beijing in 2001, ADB Vice President Joseph Eichenberger reinforced the message that measures such as tradable permits, carefully targeted use of the tax system, and appropriate pricing can be more effective than traditional regulatory approaches. He noted, however, that transitioning to new policies would require appropriate training of public officials. This assessment gives short shrift to the required reforms in public administration, however. For

example, emission inspectors must have both the authority and the incentive to make surprise inspections and to impose large fines on violators.

Some of these problems have been noted in previous efforts. For example, a pilot project on tradable sulfur permits failed to live up to its objectives. Limited information and regulatory problems resulted in fewer trades than expected trades. When market-based approaches are implemented, there is a distinct lack of necessary administrative, market, and enforcement mechanisms (Alford and Shu 1997). Nor have tradable permit schemes worked smoothly in experimental settings. Researchers attributed some of the difficulties to unfamiliarity among officials with transferable property rights (Economy 2004).

Despite these hurdles, the tradable sulfur project has expanded from one test case to four provinces, three cities, and one electric company, accounting for almost a third of sulfur dioxide emissions. Ideally, the government would give an optimal allocation of permits to polluters, and allow them to trade. Many policy reforms are targeted at the energy sector, including plans to develop new strategies and laws at the national level, as well as local initiatives such as developing energy efficient building codes in Chongqing. International projects aimed at reform are the World Bank's cleaner coal strategy and British Petroleum's research support at Qinghua University to develop energy strategies. The West-East gas pipeline is an important energy infrastructure project. The pipeline will transport 12-20 billion cubic meters of natural gas annually from Xinjiang to Shanghai, beginning in 2007.

Public disclosure of environmental performance is another policy program that SEPA is preparing to establish (Wang et al. 2004, Wang and Wu 2004). SEPA is interested in public disclosure because pollution problem remains severe, despite long-standing attempts to control it with traditional regulatory instruments. Since 1998, SEPA has been working to establish GreenWatch, a public disclosure program for polluters. Adopted from a program in Indonesia, the GreenWatch program rates firms' environmental performance from best to worst in five colors—green, blue, yellow, red and black. The ratings are disseminated to the public through the media. In 2000, pilot programs were implemented in Zhenjiang, Jiangsu Province, and Hohhot, Inner Mongolia. Reaction to the programs has been positive, and Jiangsu Province decided to promote province-wide implementation of GreenWatch in 2001. SEPA is currently preparing for nationwide implementation of public disclosure.

Other areas of policy reform include a ban on leaded gasoline (started in 2001) and the occasional alliance between the courts and the banking system. State-owned banks have become engaged in environmental protection through both fund-raising for environmental projects and denying credit to firms that do not maintain pollution standards. Establishing new institutions to facilitate technology transfer and environmental education may also be important means of enhancing environmental protection efforts.

Major new infrastructure projects intended to address water resource shortages include the South-North water transfer project, bringing water from the Yangtze River to Beijing and Tianjin, and the 3 Gorges Dam.

7. Conclusion

With respect to air pollution, China appears to have passed the flat part of the Environmental Kuznets Curve for two out of three major pollutants, consistent with its per capita income. There has been some improvement in air quality in major cities but this has been partly achieved as the result of decentralization. Significant gains have been made in decreasing pollution per unit of output, but these have been marginally outweighed by the rapid increase in industrial production. Despite considerable effort, there has been less success in water pollution.

The use of coal has increased, but not as fast as energy consumption, due in part to regulatory pressures. As a result, China is becoming increasingly dependent on oil imports to meet its energy demand.

Increased water demand, in accordance with economic development, has stressed the country's water resources. Past achievements in increased capacity utilization – through storage and delivery infrastructure – cannot be matched in the future. Attention must be turned to demand management.

These trends imply that the wedge between NNP and GNNP is not growing significantly and may even be shrinking. Natural resource depreciation may be declining, simply because there is less to depreciate. For example, despite considerable deforestation, the rate of depreciation is minimal. These considerations imply that economic growth, properly measured to include environmental degradation and to reflect economic welfare, is not (as has been suggested) growing more slowly than standard measures.

Nonetheless ample opportunities for improved management of the environment abound. Forestry and water resources remain underpriced and overused. While China is already making substantial progress in decentralizing pollution control, the major roadblock appears to be public administration. While China has heeded the recommendations for tradable emission permits, at least in three major cities, the bottleneck to effective implementation appears to lie in the realm of public administration. Any scheme of fines, levies, or permitting is only as strong as its implementation and current inspectors are unable or unwilling to impose effective controls.

Reforms are also needed in improving environmental accounting. For example, efficient air pollution control requires not only monitoring the quantities and types of emissions but distinguishing them according to damages by receptor-source modeling. Other more mundane reforms include sampling protocols and indexing pollution according to health risks. Similar challenges await the measurement of natural resource depreciation, e.g. accounting not only for lost hectareage but for the loss of more valuable trees and of biodiversity.

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Figures and tables

Figure 1. Ambient NO_x concentrations in 11 Chinese cities¹⁸, 1981-2001

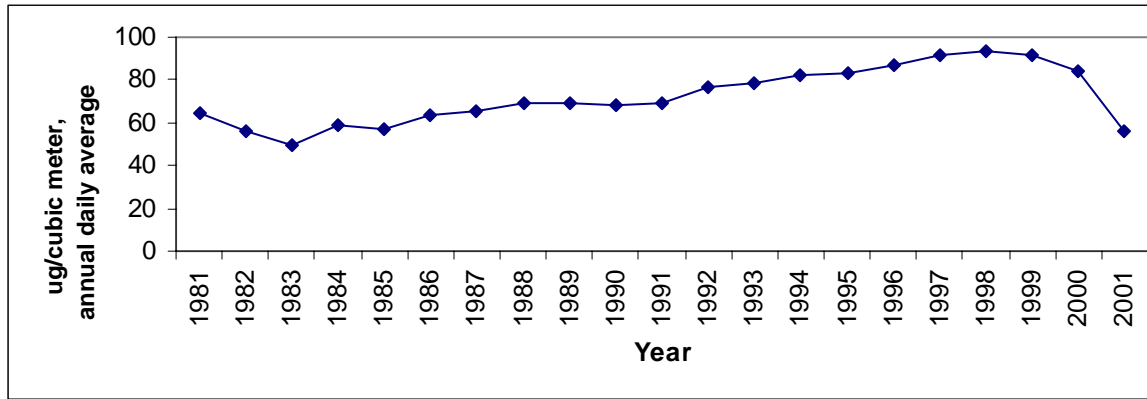


Figure 2. Ambient SO₂ concentrations in 11 Chinese cities, 1981-2001

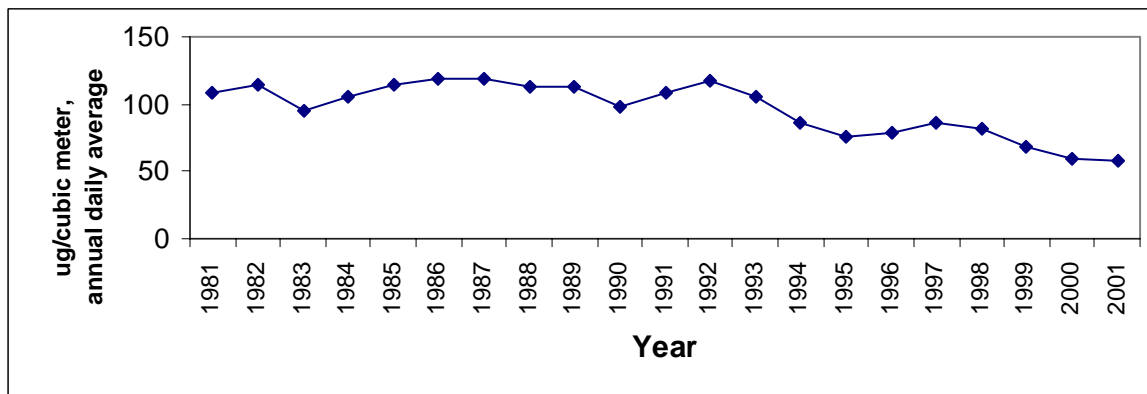


Figure 3. Ambient TSP (< 40 microns) concentrations in 11 Chinese cities, 1981-2001

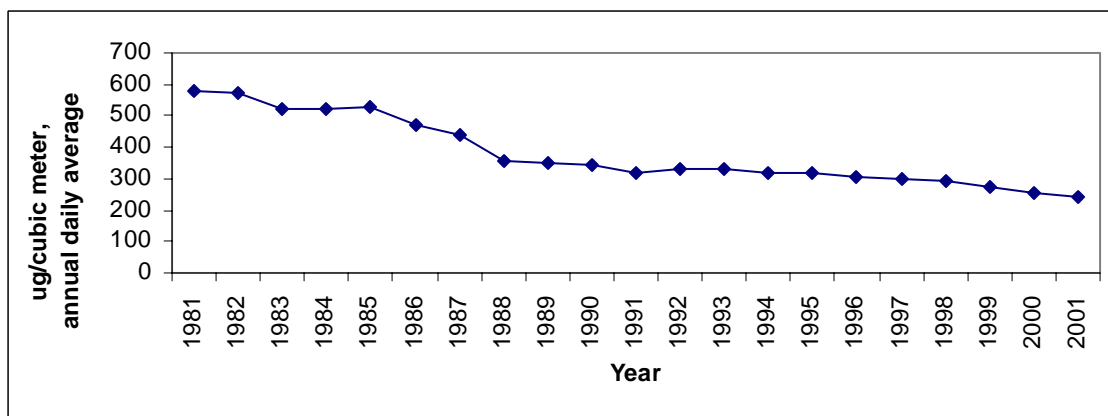


Figure 4. EKC for NOx, 80 cities 1990-2001.

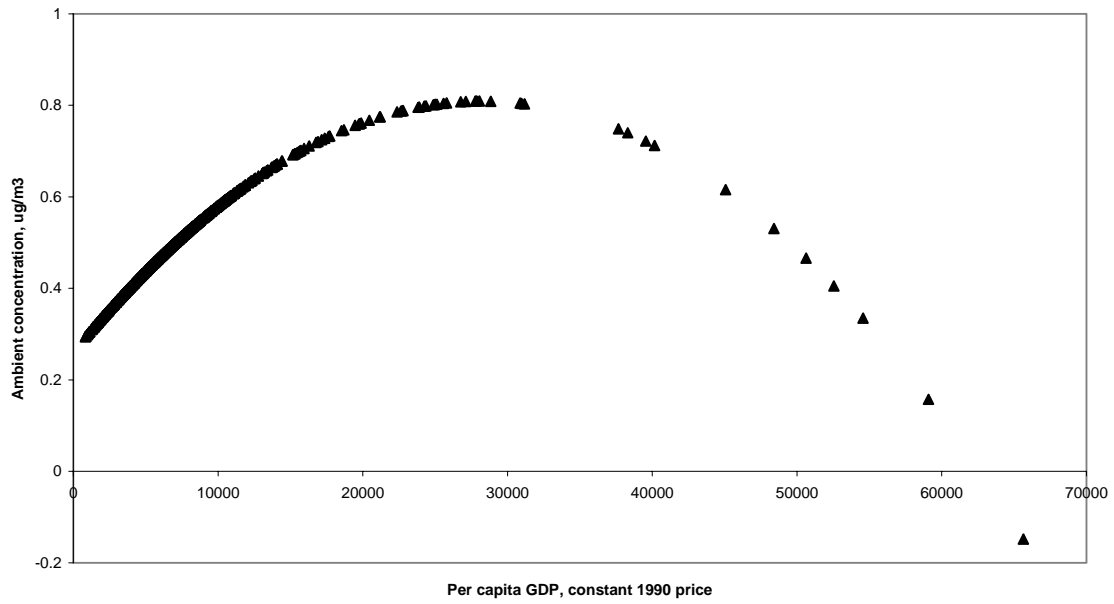


Figure 5. EKC for SO2, 80 cities 1990-2001.

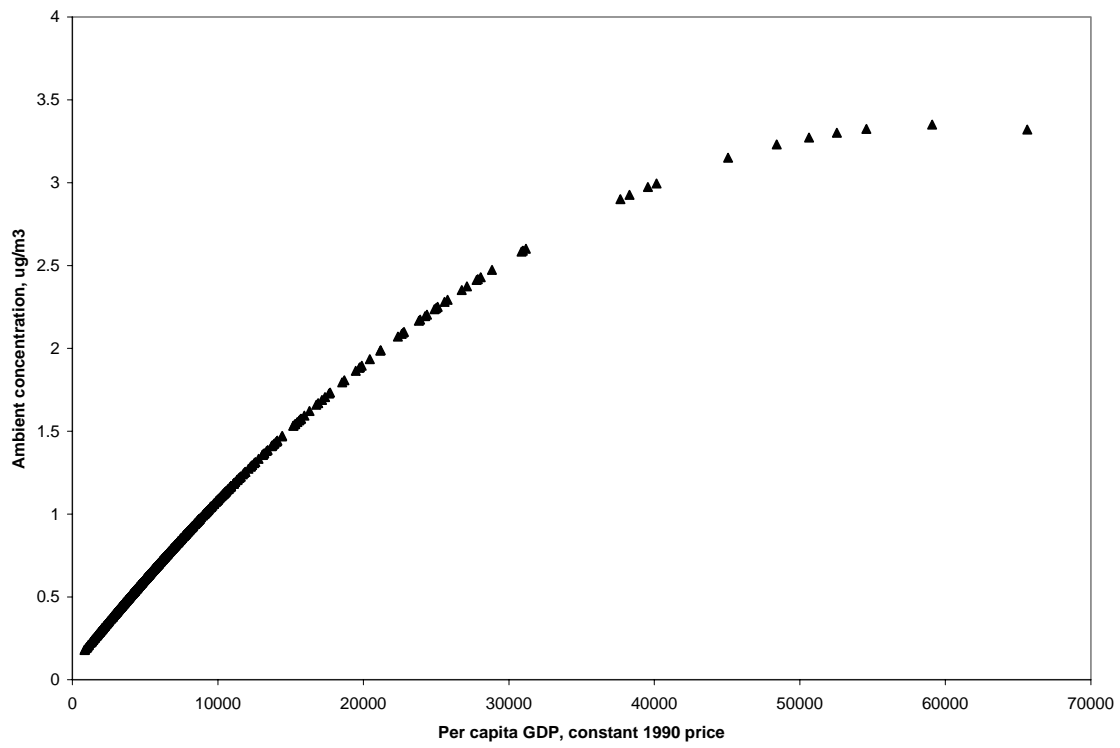


Figure 6. EKC for TSP, 80 cities 1990-2001.

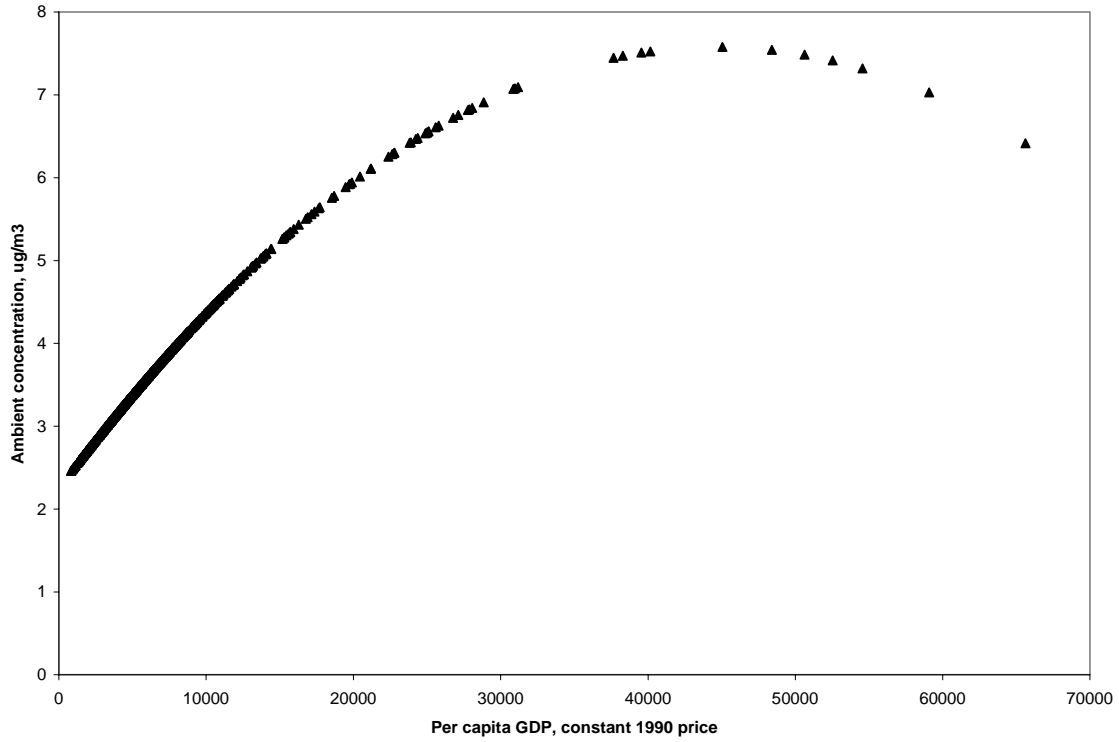


Figure 7. Wastewater trends, 1990-2003

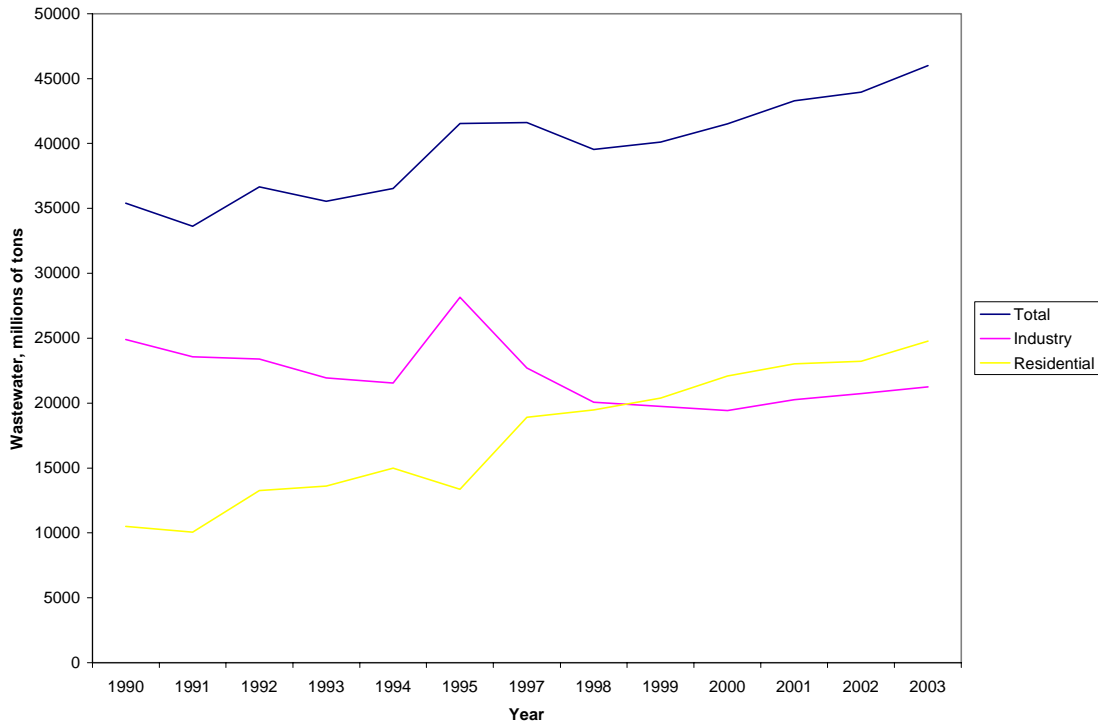
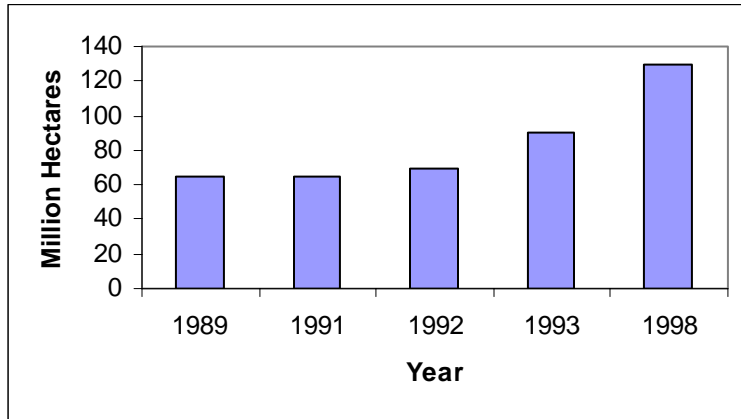
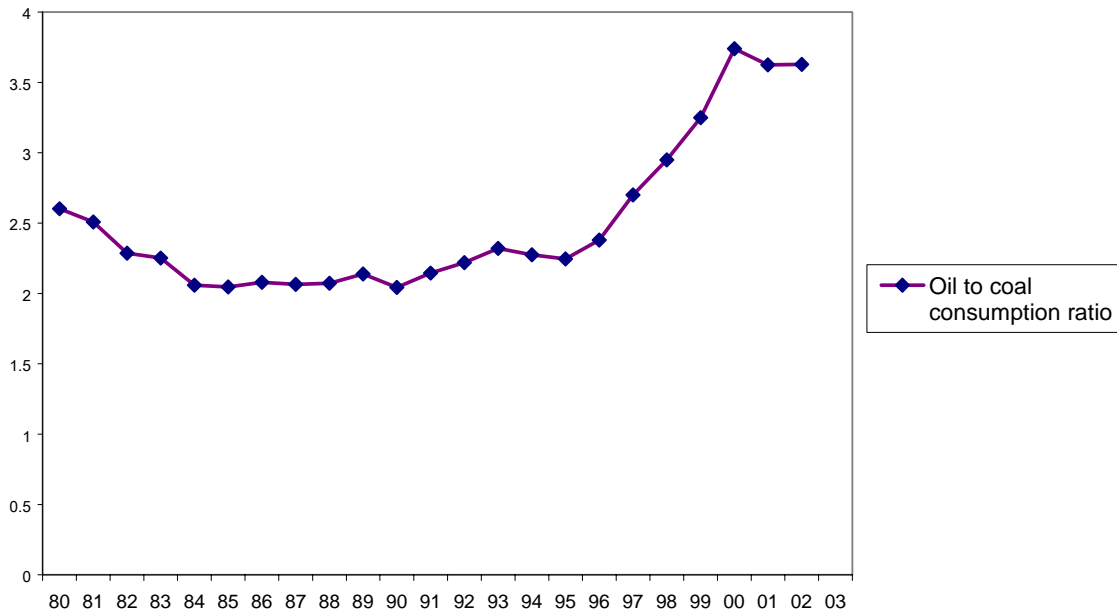


Figure 8. Extent of grassland degradation in China, 1989-1998



Source: Adapted from World Bank 2001

Figure 9. Oil to coal consumption ratio, 1980-2003.



Source: <http://www.eia.doe.gov/>

Figure 10. Efficiency gains in energy, 1978-2003.

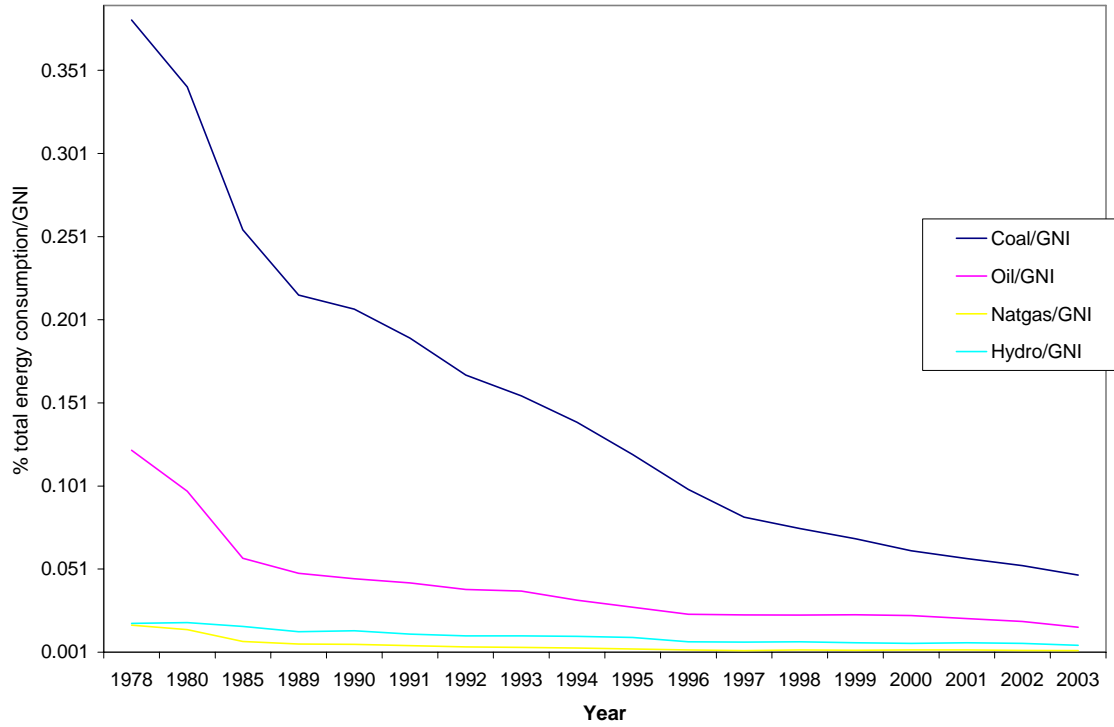


Figure 11. Reserves of manganese ore, 1955-1996

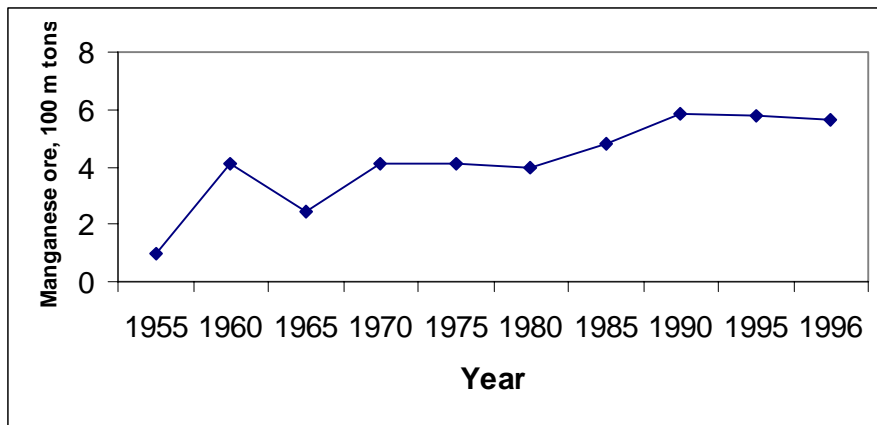


Figure 12. Reserves of gold, 1957-1995

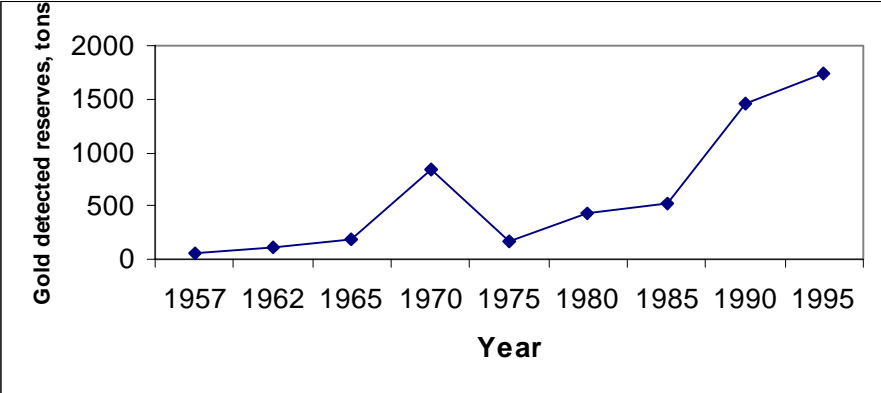


Figure 13. Reserves of silver, 1985-1996

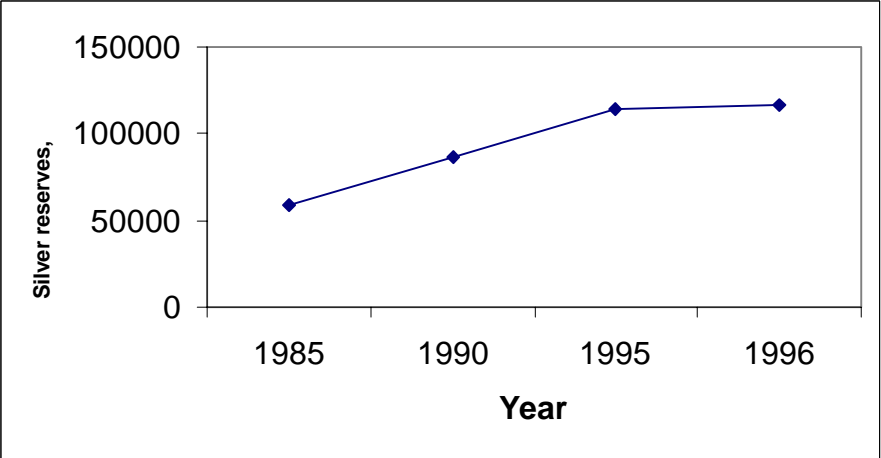
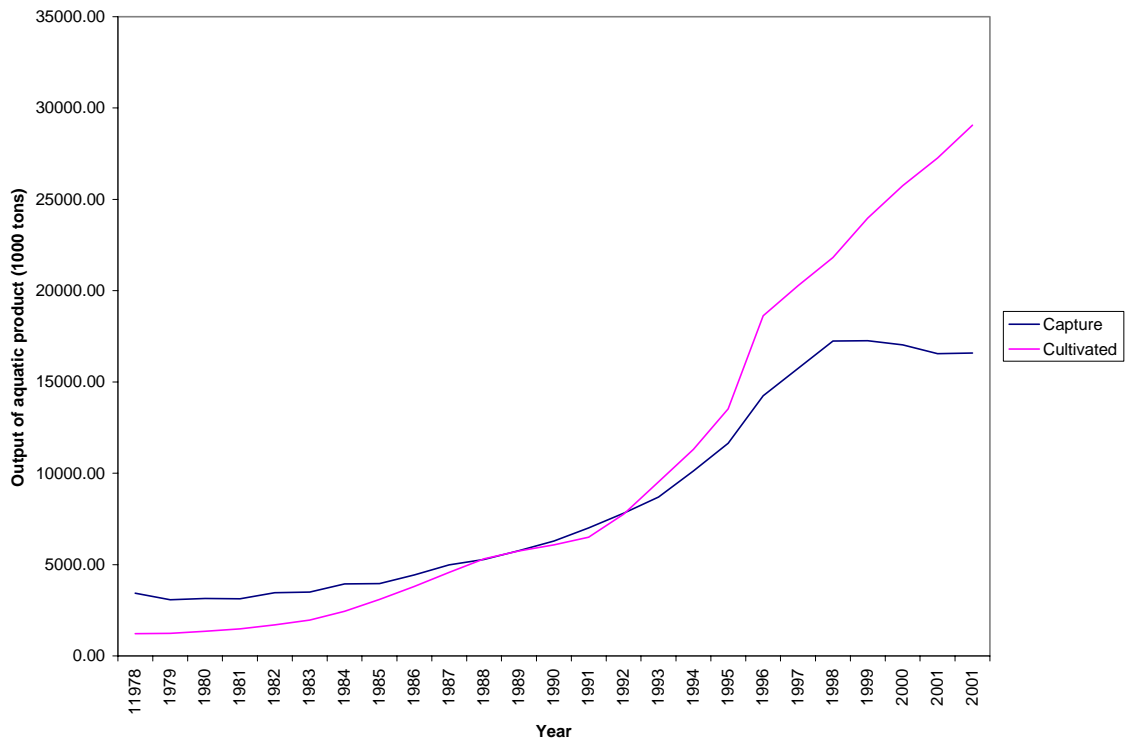


Figure 14. Capture vs. cultivated fish production, 1978 – 2001



Source: Yearbook, 1991-2003

Figure 15. The gap between NNP and GNP, natural resources

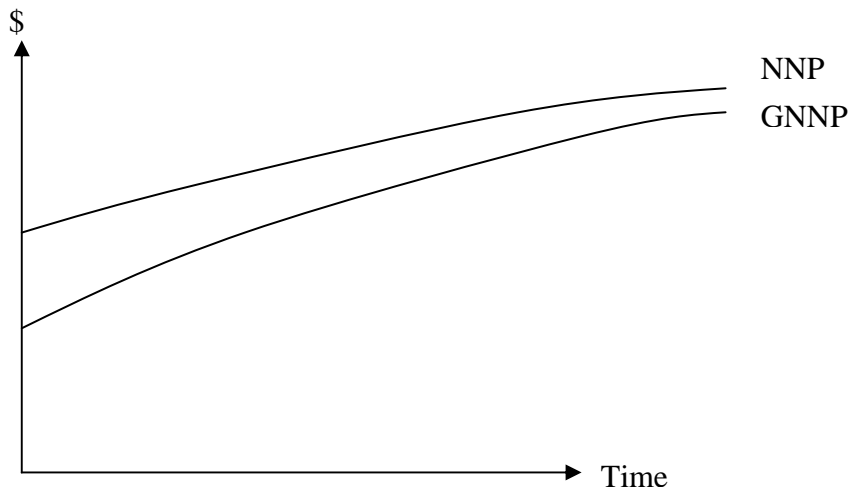


Figure 16. The gap between NNP and GNNP, fund pollution

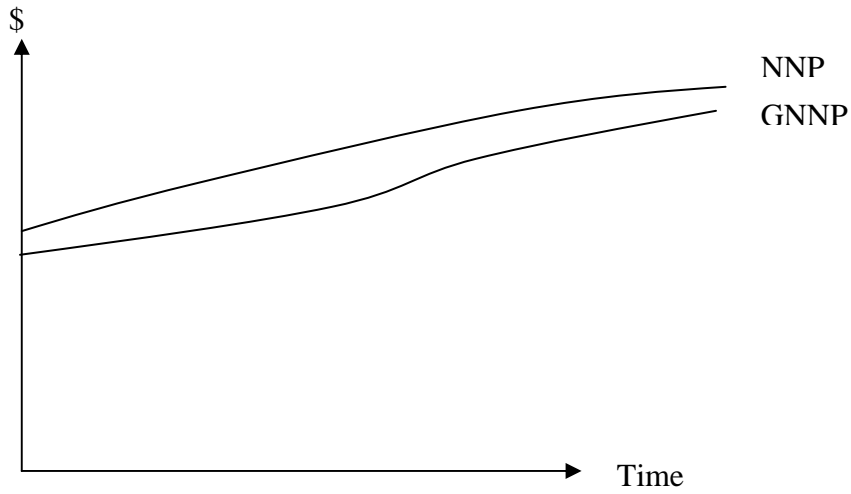
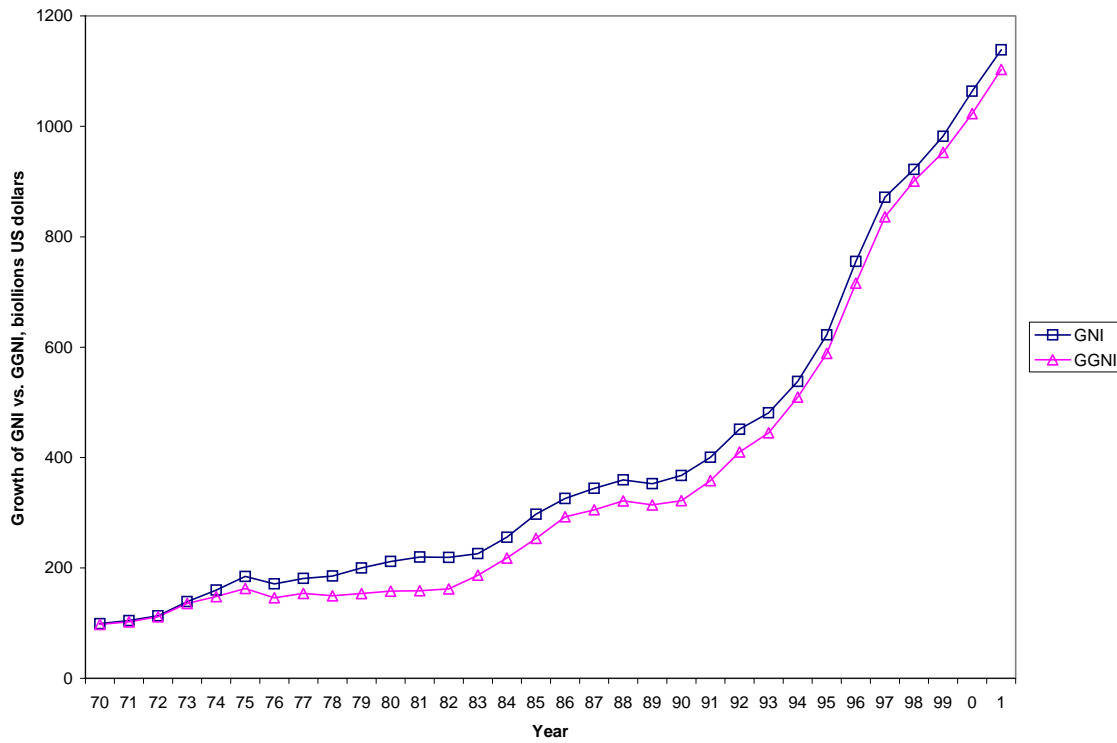
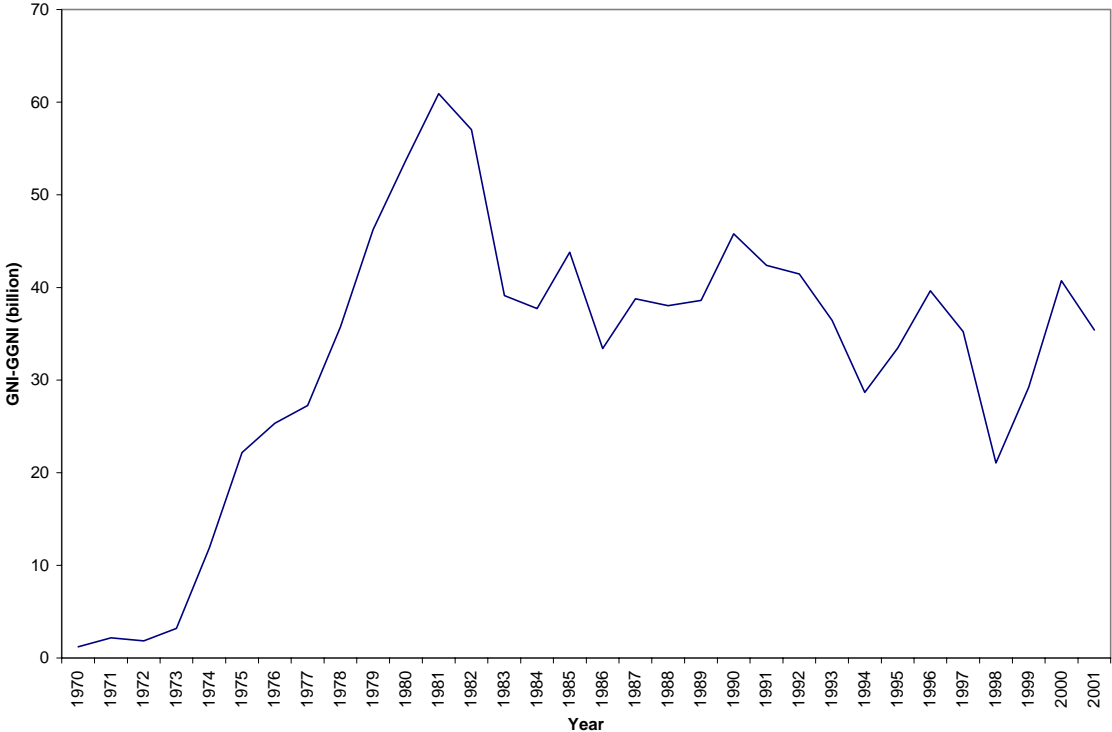


Figure 17. Growth of GNI vs. GGNI, in billions U.S. dollars



Source: World Bank, www.worldbank.org/environmentaleconomics, and GNI data from World Bank's World Development Indicators, 2004.

Figure 18. Environmental Kuznets Curve for China's natural resources. Value of GNI-GGNI, 1970-2001



Source: World Bank, www.worldbank.org/environmentaleconomics, and GNI data from World Bank's World Development Indicators, 2004

Figure 19. Growth rate of GNI vs. GGNI

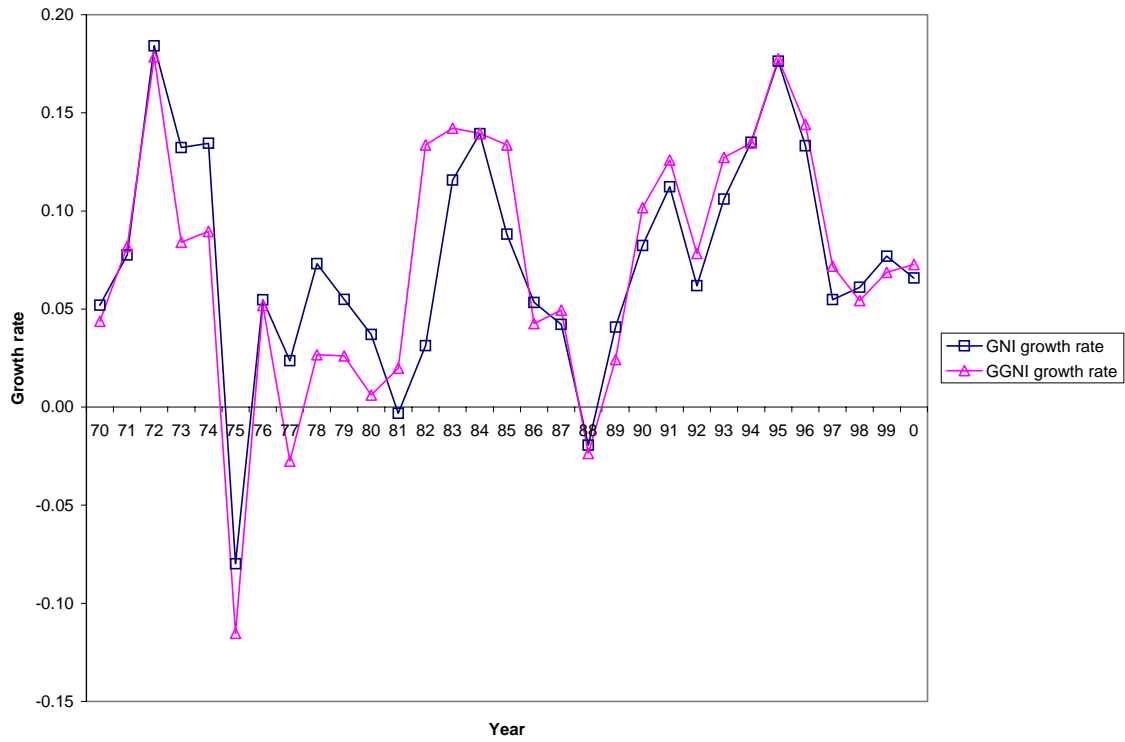


Figure 20. Environmental Kuznets Curve for 5 countries' natural resources. Value of GNI-GGNI, 1970-2001

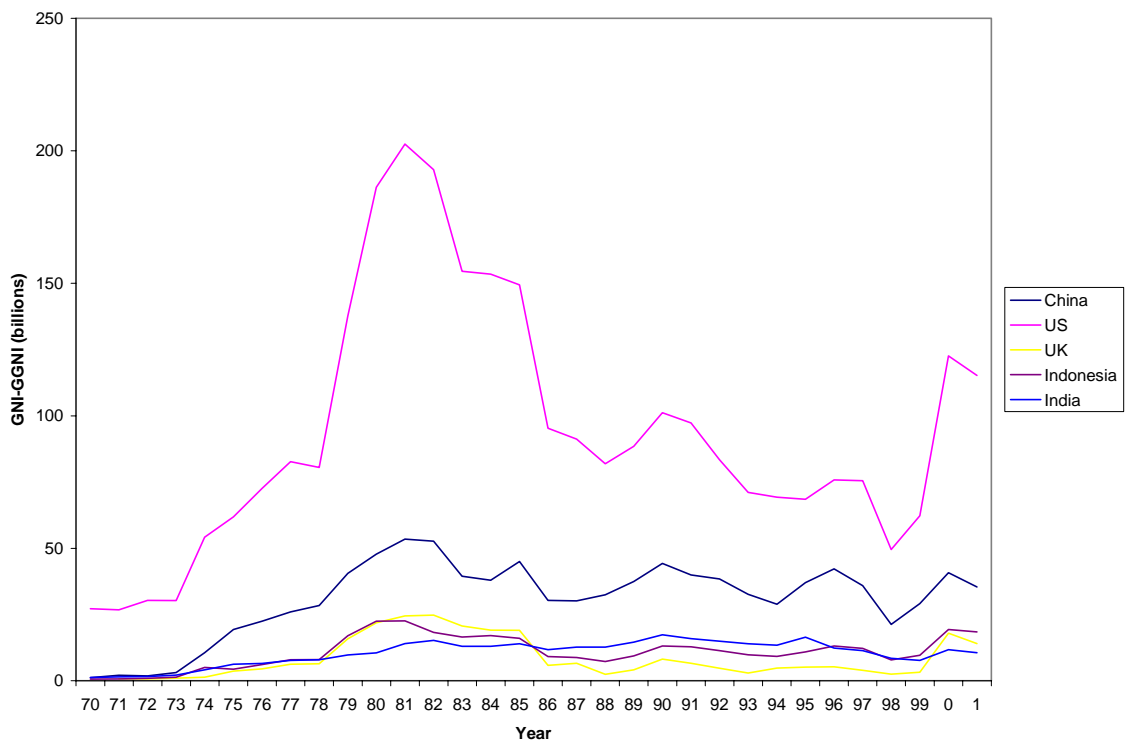


Figure 21. Green deficit (gap as a percentage of total income) in 5 countries

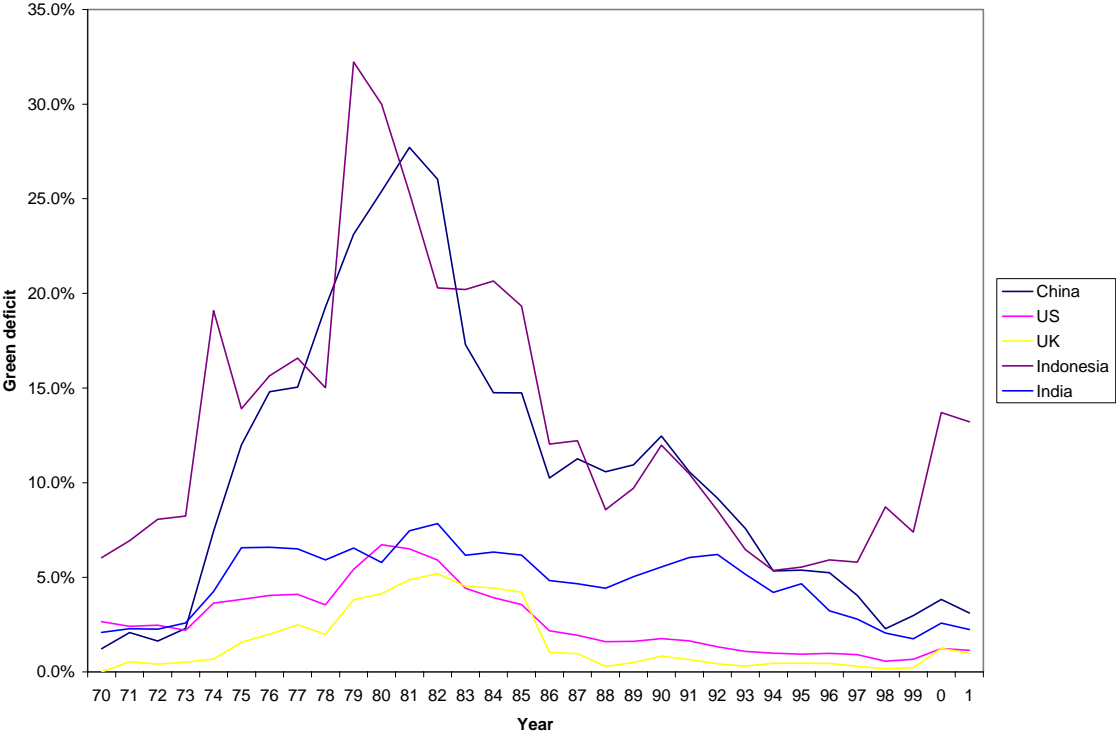


Table 1. Regression results. Standard errors in parentheses

<i>Emissions</i>	<i>NOx per capita</i>	<i>SO2 per capita</i>	<i>TSP per capita</i>
GDP per capita	0.0000387 (5.77 x 10 ⁻⁶)	0.0001089 (0.0000174)	0.0002378 (0.0000607)
GDP per capita ²	-6.85 x 10 ⁻¹⁰ (8.11 x 10 ⁻¹¹)	-9.09 x 10 ⁻¹⁰ (2.47 x 10 ⁻¹⁰)	-2.66 x 10 ⁻⁹ (8.51 x 10 ⁻¹⁰)
Year	-0.027 (0.0027)	-0.113 (0.0081)	-0.251 (0.0281)
Constant	0.263	0.089	2.265

Table 2. Water quality trends in China's rivers, 1997-2003

	Water class	1997	1998	1999	2000	2001	2002	2003
Total length of rivers evaluated (km)		65,405	109,700	113,600	114,043	121,010	122,602	134,593
% in water class	I		5.4	5.5	4.9	5	5.6	5.7
	II	32.8	24.4	24.5	24	27.6	33.1	30.7
	III	26.3	33	32.4	29.8	28.8	26	26.2
	<i>Subtotal</i> (“above standard”)	56.4	62.8	62.4	58.7	61.4	64.7	62.6
	IV		13.7	12.6	16.1	14.2	12.2	10.9
	V	27.7	6.6	7.8	8.1	7.8	5.6	5.8
	V +	15.9	16.9	17.2	17.1	16.6	17.5	20.7

Table 3. Water quality trends in China's lakes, 1998-2005

	Water class	1998	1999	2000	2001	2002	2003	Jan. 2005
Total number of lakes evaluated		16	24	24	24	24	52	52
% in water class	III or above	37.5	41.7	37.5	41.7	25	40.4	40.4
	Partially polluted	25	20.8	16.7	8.3	25	9.6	9.6
	Severely polluted	37.5	37.5	45.8	50	50	50	50

Table 4. Trends in forest resources, 1934-1993

Year	Forested area M Ha	% Forest cover	Timber area M Ha	Forest volume B m ³	Non-timber area M Ha
1934	86.3	9.0	--	--	--
1962	85.5	8.9	77.7	6.5	2.0
1976	121.9	12.7	98.0	7.7	3.1
1981	115.3	12.0	80.6	6.9	3.3
1988	124.6	13.0	80.1	6.2	3.7
1993	133.7	13.9	84.9	6.7	3.9

Source: Pei and Xu (2000) as cited by World Bank (2001)

Table 5. Total water resources in China, in billion cubic meters

Year	Precipitation	Ground water	Surface water	Overlap of ground and surface water	Total water resource
1997	5816.90	694.20	2683.50	592.20	2785.50
1998	6763.10	940.00	3272.60	810.90	3401.70
1999	5970.20	838.70	2720.40	739.50	2819.60
2000	6009.20	850.20	2656.20	736.30	2770.10
2001	5812.20	839.00	2593.30	745.50	2686.80
2002	6261.00	869.70	2724.30	768.50	2825.50

Source: Ministry of Water Resources, China

Table 6. Water supply and consumption in China, in billion cubic meters

Year	Water supply	Water consumption	Water depletion	Depletion as % of consumption
1997	562.30	556.60	317.80	57.10%
1998	547.00	543.50	306.20	56.34%
1999	561.30	559.10	302.80	54.16%
2000	553.10	549.80	301.20	54.78%
2001	556.70	556.70	305.20	54.82%
2002	549.70	549.70	298.50	54.30%

Source: Ministry of Water Resources, China

Table 7. China's production and consumption of coal, in billions of tons, 1980-2003

	1980	1985	1990	1995	2000	2001	2002	2003
Production	0.68	0.96	1.19	1.53	1.31	1.46	1.52	1.67
Consumption	0.67	0.92	1.12	1.49	1.28	1.36	1.42	1.61

Source: <http://www.eia.doe.gov/>

Table 8. SO₂ emissions, in millions of tons, 1997-2003

	1997	1998	1999	2000	2001	2002	2003
Industry	18.52	15.93	14.60	16.13	15.67	15.62	17.91
Total	23.56	20.90	18.58	19.95	19.48	19.27	21.59

Source: SEPA

Table 9. Mineral resources over time

Ensured reserves (100 M tons)	1990	1992	1994	1996	1998	2000	2002
Coal	9543.94	9833.12	10018.65	10008.50	10070.70	10063.00	3317.6
Iron ore	501.17	489.69	487.29	475.60	458.90	458.10	213.6
Phosphate	157.15	157.65	157.66	159.70	132.70	132.50	40.54
Sylvite	3.96	4.58	4.58	4.60	4.60	4.60	--
Salt	3636.00	3999.83	4024.00	4040.30	4048.20	4048.30	--

Source: Yearbook, 1991, 1993, 1995-2003

Note: 2002 data are "basic reserves" – stocks that are buried underground and can be utilized under current technology. "Ensured reserves" are the detected reserves, minus the part that has been exploited and the underground loss.

Table 10. Annual growth rates of China's agricultural economy, 1970-2000

	1970-1978 (Pre-reform)	1979-1984	1985-1995	1996-2000
Grain production	2.8	4.7	1.7	0.03
Oil crops	2.1	14.9	4.4	5.6
Fruits	6.6	7.2	12.7	8.6
Red meat	4.4	9.1	8.8	6.5
Fishery	5.0	7.9	13.7	10.2

Source: Adapted from Zhang (2003)

Table 11. Estimates of the cost of environmental damage in China (% of GDP)

Author	Year of Estimate	Air Pollution	Water Pollution	Other Pollution	Damage to ecology	Total
Guo-Zhang	1983	2.2	4.5	0.0	8.9	15.6
Jin Jianming	1985	n/a	n/a	n/a	12.5	12.5
Smil	1990	0.9	0.7	0.5	5.4	7.5
SEPA	1992	2.5	2.0	0.0	n/a	4.5
Smil-Mao	1992	2.4	1.5	0.2	13.9	18.0
CASS/EDRC	1993	1.4	1.6	0.2	6.9	10.0
Xu Songling	1993	1.1	0.9	0.8	6.9	9.7
World Bank	1995	7.1	0.6	n/a	n/a	7.7

Source : US Embassy Beijing (2000)

Table 12. Comparison of depreciation of forest accounts and adjusted NNP (selected years)

Year	GNP	NNP	Depreciation	FNNP (NNP-Depreciation)
1976	269.5	254.6	4.3	250.3
1980	455.9	434.1	2.3	431.8
1985	719.2	687.9	4.8	683.1
1990	1063.5	1019.7	5.8	1013.9
1992	1299.5	299.5	5.7	1293.8

Source : Liu 1998, FNNP : forest-adjusted NNP, Units: billion Yuan, 1980 price

Table 13. Green GNI calculations, selected years 1970-2001

Year	GNI	Net forest depletion	Mineral depletion	Energy depletion	GGNI
1970	99.04	0.01	0.50	0.72	97.82
1975	184.81	0.01	1.09	21.08	162.64
1980	211.66	0.47	2.18	51.10	157.91
1985	297.22	0.70	1.41	41.69	253.42
1990	367.61	1.29	3.13	41.37	321.82
1995	622.10	1.85	2.78	28.82	588.66
2000	1063.70	0.72	2.60	37.42	1022.97

GGNI (billions) = GNI- (net forest depletion + mineral depletion + energy depletion)

Appendix 2

Proof that the percentage growth rate of GNNP (g) is larger than that of NNP (y) when (e/y) is falling, where e represents total emissions:

When $\frac{e}{y}$ is falling over time, we have

$$\begin{aligned}\frac{d}{dt}\left(\frac{e}{y}\right) < 0 &\Rightarrow \left(\frac{\dot{y}}{y}\right) - \left(\frac{\dot{e}}{e}\right) > 0 \\ \Rightarrow e \dot{y} - y \dot{e} > 0 &\Rightarrow e \dot{y} + y \dot{y} - y \dot{y} - y \dot{e} > 0 \\ \Rightarrow y(\dot{y} - \dot{e}) - \dot{y}(y - e) > 0 &\Rightarrow \frac{(\dot{y} - \dot{e})}{(y - e)} > \frac{\dot{y}}{y} \rightarrow (A)\end{aligned}$$

$$\text{Since } g = y - e \Rightarrow \dot{g} = \dot{y} - \dot{e} \Rightarrow \frac{\dot{g}}{g} = \frac{\dot{y} - \dot{e}}{y - e}$$

$$(A) \Rightarrow \frac{\dot{g}}{g} > \frac{\dot{y}}{y}$$

i.e., % growth rate of GNNP is larger than that of NNP

¹ The sample cities include Tianjin, Guangzhou, Beijing, Shanghai, Chengdu, Changchun, Taiyuan, Anshan, Nanchang, Shenzhen, Yinchuan, and Guilin, and were chosen for their completeness of data.

² “Dream Machines,” The Economist, June 2, 2005, available at

http://www.economist.com/business/displaystory.cfm?story_id=4032842

³ The water bodies are divided into five classes according to their utilization purpose and protection objectives: Class I applies to the water from remote sources and national nature reserves. Class II consists of “protected areas for centralized sources of drinking water, the protected areas for rare fishes, and the spawning fields of fishes and shrimps,” Class III applies to the “second class of protected areas for centralized sources of drinking water, and protected areas for the common fishes and swimming areas,” Class IV covers “the water areas for industrial use and entertainment which is not directly touched by human bodies,” and Class V applies to “water bodies for agricultural use and landscape requirement.”

⁴ SEPA’s 9th Five Year Plan includes moving hundreds of polluters out of major industrial areas to curb pollution in those areas. In 2001, around 1 million square meters were cleared in Beijing as a result of relocations and another 6 million square meters are scheduled for clearing between 2001 and 2005. The city of Beijing wishes to move polluters out, making room for industrial marketing, research institutes, and more environmentally

friendly industries.

⁵ In May 2000, then Premier Zhu Rongji warned that the rapidly advancing desert would necessitate moving the capital from Beijing (Economy 2004).

⁶ Desertification has been defined by the United Nations as “land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors, including climatic variations and human activities.”

⁷ China’s Agenda 21, www.acca21.org.cn/english

⁸ Earth Policy Alert from the Earth Policy Institute by Lester R. Brown, May 23, 2001, available at <http://www.earth-policy.org/Alerts/Alert13.htm>

⁹ The following reasons have been offered as explanations to the industrial decline in coal consumption (Kang Wu of East West Center and Jeff Brown of FACS, personal communication). First, more advanced equipment associated with growing industrialization has called for increased use of electric power. The direct use of coal in the industrial sector has to a great extent been replaced by coal-fired power, which is more energy efficient. Second, diesel is often favored over coal for its cleanness and efficiency. Finally, high hauling charges discourage the transportation of coal and encourage substitution to electricity and diesel. Moreover, imported equipment may run on diesel only, or electric power. As a result, between 1995 and 2002, China's use of electric power in the industrial sector increased notably, the use of diesel was higher, while the use of coal declined. Other possibilities for this trend include the relatively longer time it takes to install coal-using capital equipment, increased oil demand in response to increase demands for cars, and the possible difficulty of rapid increases in coal production or even coal imports.

¹⁰ Notably, the Ministry of Electrical Power was also abolished in 1998.

¹¹ Source: Geoff Hiscock, CNN Asia Business Editor. Monday, March 10, 2003, at CNN.com.

¹² China became a net importer of oil in 1993. In 2003, the net import was 973.5 million tons. The oil dependence by 2020 is expected to reach 60% (www.cei.gov.cn)

¹³ Source: http://www.mlr.gov.cn/GuotuPortal/appmanager/guotu/index?nfpb=true&pageLabel=desktop_index_page_zygk

¹⁴ There are 17 rare earth elements: Scandium, Yttrium, Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, and Lutetium.

¹⁵ Source: National Oceanic and Atmospheric Administration’s China-U.S. Fishery Project, <http://www.lib.noaa.gov/china/chinafp.htm>

¹⁶ Forest, energy, and mineral depletion data was obtained from the World Bank's "Adjusted Net Savings: Results" spreadsheet, downloaded from www.worldbank.org/environmentaleconomics, December 1, 2004. GNI data from World Bank's World Development Indicators, 2004.

¹⁷ According to World Bank (1995), the price elasticities of industrial water demand in developing countries are generally in a range of -0.45 to -1.37.

¹⁸ Figures 1-3 adjusted for population. Ambient concentration data source: World Bank's Development Research Group (DRG), population data source: <http://www.citypopulation.de/China.html>