

China's Energy and Environmental Problems and Policies

by

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Abstract: This paper describes China's energy and environmental degradation problems in terms of air pollution, water pollution, CO₂ emission and shortage of energy. It discusses the laws, agencies established and policies introduced to solve the energy-environment problems as well as the practical difficulties in the implementation of government environmental policies. Finally it presents three major issues to be resolved. Contact: fax 609-258-7315; gchow@princeton.edu.

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1. Introduction

The economic activities of production and consumption require the use of energy, and the use of energy affects the environment in the forms of water pollution, air pollution and emission of CO₂ that causes global warming. Furthermore the use of energy from exhaustible resources can create energy shortage in the future. The solutions to the problems of energy and environmental degradation include (1) reducing the use of energy in production and consumption, (2) increasing the use of energy-saving and environmentally friendly methods in production and consumption and (3) promoting technological innovations that will reduce the use of energy per unit of output (reduce energy intensity or increase energy efficiency) or reduce pollution per unit of output to achieve (1) and (2) in the future. To achieve (1) and (2) given the state of technology we can regulate the use of energy by law or by economic incentives to limit the emission of pollutants.

The last is an example in solving the problem of “externalities” in economics - the undesirable external effects of production or consumption, the cost of which is not born by the producer or consumer responsible. An economic solution to the problem of externalities is to charge the cost to the producer or consumer who is responsible.

In section 2, we describe the energy-environment problems during China’s recent economic development. In section 3, we discuss the laws, government agencies established and the policies introduced by the Chinese government to protect the environment and reduce energy consumption. Section 4 deals with difficulties in implementing China’s environmental policies. Section 5 discusses three most important issues related to the attempts to solve the energy-environment problem. Section 6 concludes.

2. Environmental Problems in China

As pointed out in the Introduction, there are four aspects of the energy-environment problem, namely (1) air pollution, (2) water pollution, (3) the emission of CO₂ in the atmosphere that causes global warming, mainly from the burning of coal, and (4) shortage of future energy supply that relies on exhaustible resources. Environmental pollution from coal combustion is damaging human health, air and water quality, agriculture and ultimately the economy. China is facing all four problems.

2.1 Air Pollution

The air and water in China, especially in the urban areas, are among the most polluted in the world. According to a report of the World Health Organization (WHO) in 1998, of the ten most polluted cities in the world, seven can be found in China. Sulfur dioxide and soot caused by coal combustion are two major air pollutants, resulting in the formation of acid rain, which now falls on about 30% of China's total land area. Industrial boilers and furnaces consume almost half of China's coal and are the largest sources of urban air pollution. The burning of coal for cooking and heating in many cities accounts for the rest. Mercury released into the air by coal-fired power plants is captured by raindrops, and transferred to the soil and groundwater. Groundwater is polluted by runoff from factories, smelters and mining operations, and then used by farmers downstream to irrigate their crops. Heavy use of fertilizers has contributed to contamination also. Fertilizers in China often contain high levels of metals, especially cadmium, which is harmful.

As the country becomes industrialized, pollution from both industrial and consumer sources will increase because of higher levels of output and consumption, the latter including the increase in the use of automobiles, unless pollution per unit of output or consumption can be reduced.

2.2 Water Pollution

China's water is polluted also by the disposal of waste. Water beds of several important cities including Beijing and Shanghai are low, causing shortage of supply of well water.

Supply of waters from rivers including the Yellow River and the Yangtze River are running short because of diversion to agriculture production and electricity generation along the sources. Deforestation has caused the flow of mud along the rivers and affects water supply and quality. *People's Daily*, June 12, 2007 reports that Lake Taihu was covered with a foul-smelling algae and freshwater was shut off for more than 2 million people in Wuxi due to the blue-algae infestation of the lake. Sewage treatment plants had to be established for chemical factories to meet a new water emission standard by the end of June 2008. Chemical factories that fail to meet the new water emission standard risk suspension. They will be shut down permanently if they still fail to meet the standard by the end of next June. The new Chinese water emission standard for the Taihu valley will raise the bar for sulfur dioxide emissions.

2.3 Energy Consumption

According to “China country analysis brief” published by the US Department of Energy (2001) China accounted for 9.8% of world energy consumption. By 2025, projections indicate that China will be responsible for approximately 14.2% of world energy consumption. Of the 40 quadrillion Btu of total primary energy consumed in China in 2001, 63% was coal, 26% was oil, 7% hydroelectricity, and 3% natural gas. While residential consumption has increased its share of China’s energy demand over the last decade, the largest absolute gains in consumption were from the industrial sector. In 2001, China’s energy intensity as measured by thousand Btu per 1990 dollars of output was as high as 36 thousand, as compared with 21 thousand for Indonesia, 13 thousand for South Korea, 4 thousand for Japan and 11 thousand for the United States, because of differences in output mix among these countries and in energy intensities in producing the same products.

While China ranks second in the world behind the United States in **total** energy consumption and carbon emissions, its **per capita** energy consumption and carbon emissions are much lower than the world average. In 2001, the United States had a per

capita energy consumption of 341.8 million Btu, greater than 5.2 times the world's per capita energy consumption and slightly over 11 times China's per capita consumption. Per capita carbon emissions are similar to energy consumption patterns, with the United States emitting 5.5 metric tons of carbon per person, the world on average 1.1 metric tons, and China 0.6 metric tons of carbon per person. With a growing economy and increasing living standards, however, per capita energy use and carbon emissions are expected to rise. Although per capita energy use is relatively low, China's total consumption of energy and the resultant carbon emissions are substantial, due to the country's large population and heavy use of coal.

Concerning the possible shortage of future energy source, China imported 162.81 million tons of oil in 2006 as the world's second largest energy user. Its dependence on imported oil reached 47 percent, having increased by 4.1 percentage points from 2005. China's rapid increase in oil consumption will contribute to future shortage of this exhaustible resource.

2.4 CO₂ Emission

CO₂ emissions result in climate changes which are affecting the world's physical and biological systems. As of 2001 China accounted for 13 percent, Western European 16 percent and the US 24 percent of the world's energy related carbon emission. By 2007 China has taken over the US for the first time as the world's top producer of greenhouse gases. China is a non-Annex I country under the United Nations Framework Convention on Climate Change. This means that it has not agreed to binding emissions reductions in the Kyoto Protocol, which it ratified in August 2002. China's policies aim at cutting energy costs and reducing local pollution, rather than reducing carbon emissions for the benefit of the world.

People's Daily Online June 4, 2007 reports the following facts:

“According to the Initial National Communication on Climate Change of the People's Republic of China, the country's total greenhouse gas (GHG) emissions in 1994 are 4,060 million tons of carbon dioxide equivalent... Its total GHG emissions in 2004 is

about 6,100 carbon dioxide equivalent, of which 5,050 million tons is carbon dioxide, 720 million is carbon dioxide equivalent of methane and 330 million is carbon dioxide equivalent of nitrous oxide. From 1994 to 2004, the average annual growth rate of GHG emissions is around 4 percent, and the share of carbon dioxide in total GHG emissions increased from 76 percent to 83 percent.

“China’s cumulative emissions of carbon dioxide from fossil fuel combustion accounted for only 9.33 percent of the world total during the period of 1959-2002, and the cumulative carbon dioxide emissions per capita are 61.7 tons over the same period, ranking the 92nd in the world.

“Statistics from the International Energy Agency (IEA) indicate that per capita carbon dioxide emissions from fossil fuel combustion were 3.65 tons in 2004 in China, equivalent to only 87 percent of the world average and 33 percent of the level of the Organization for Economic Co-operation and development (OECD) countries.

“Along with steady social and economic development, the emission intensity defined as the carbon dioxide emission per unit of GDP declined generally. According to the IEA, China’s emission intensity fell to 2.76 kg carbon dioxide per U.S. dollar (at 1999 prices) in 2004, as compared to 5.47 kg carbon dioxide per U.S. dollar in 1990, a 49.5 percent decrease. For the same period, emission intensity of the world average dropped only 12.6 percent and of the OECD countries dropped 16.1 percent.”

Since China is a developing country, it is not surprising that its per capita CO₂ emission was only 87 percent of the world average and 33 percent of the level of the OECD countries. The concern is the rate of increase in China’s per capita CO₂ emission.

There is a consensus in the scientific community that the level of total CO₂ in the atmosphere should not exceed a level equal to twice the level existing before the Industrial Revolution (see Pacala and Socolow, 2004). Exceeding that level would cause violently unstable weather, melting glaciers and prolonged draughts. If the rate of increase in emission in the future continues as it did in the last thirty years, this critical level will be reached in fifty years time. Therefore CO₂ emission is a critical and urgent

problem. To obtain a global agreement on this issue is difficult, as shown by a week-long meeting of the Intergovernmental Panel on Climate Change in Bangkok, reported in an article in *San Francisco Chronicle* May 7, 2007.

For China to be willing to reduce its use of coal-fired power plants that cause CO₂ emission alternative energy source must be priced not higher than the price of power generated by coal. This will be possible if there shall be sufficient technological innovations in the production of clean energy at such low prices. Market incentives for such innovations have a good chance of success, according to Friedman (2007, p.50).

Without the benefit of new technology, the world community can reduce the rate of carbon emission by (1) using alternative energy to coal such as gas, nuclear, ethanol and solar, (2) reducing the consumption of electricity at homes, offices and factories, and (3) controlling the amount of CO₂ emission by reducing the burning of forests and capturing the amount of carbon from coal burning.

3. Laws, Agencies and Policies for Protecting the Environment

3.1 Laws and Agencies for environmental protection

The Chinese central government has been aware of the environmental problems and has made serious attempts to protect and improve China's environment. In 1979, China passed the Environmental Protection Law for Trial Implementation. The 1982 Constitution included important environmental protection provisions. Article 26 of the Constitution requires that "the state protects and improves the environment in which people live and the ecological environment. It prevents and controls pollution and other public hazards." There are also provisions on the state's duty to conserve natural resources and wildlife. Based on these provisions a number of special laws have been enacted. These include the Water Pollution Prevention and Control Law of 1984, the Air Pollution Prevention and Control Law of 1987, the Water and Soil Conservation Law of 1991, the Solid Waste Law of 1995, the Energy Conservation Law of 1997 and several important international agreements including the Kyoto and Montreal Protocols.

Beginning in the late 1980s, Premier Li Peng, a nuclear engineer by training, issued statements underscoring the government's commitment to giving attention to environmental protection in its formulation and implementation of economic development policy. China's national legislature, through its promotion of "Cleaner Production" and other attempts to reduce air pollution, has significantly revised the Law on the Prevention and Control of Air Pollution in 2002.

New laws establishing comprehensive regulations have begun to curb the environmental damage. On the national level, policies are formulated by the State Environmental Protection Administration (SEPA) and approved by the State Council. The role of SEPA, which was established in 1998, is to disseminate national environmental policy and regulations, collect data and provide technological advice on both national and international environmental issues. . In June 2002, China enacted the Cleaner Production Promotion Law, which established demonstration programs for pollution regulation in ten major Chinese cities, and designated several river valleys as priority areas.

3.2 Policies for energy saving

On Friday, May 8 2007, Premier Wen Jiabao made a speech stating that the current macro-control policy must focus on energy conservation and emission reduction in order to develop the economy while protecting the environment. The Chinese government has set a target of reducing energy consumption for every 10,000 yuan (1,298 U.S. dollars) of GDP by 20 percent by 2010 [or 4 percent per year], while pollutant discharge should drop by 10 percent.

"To curb excessive growth of the sectors that consume too much energy and cause serious pollution, China must tighten land use and credit supply and set stricter market access and environmental standards for new projects amid efforts to rein in the rapid expansion of energy-gorging industries including power, steel, oil refinery, chemicals, construction materials, and metals.

"Restrictions should be imposed on exports in these sectors as soon as possible...We will continue to curb the energy-guzzlers by further adjusting exports rebates, levying more

exports tariff, and reducing exports quotas... China will cancel preferential policies on the industries like lower tax, electricity and land costs.

“Outmoded production methods must be eliminated at a faster pace and how this policy is implemented by local governments and enterprises will be open to the public and subject to social supervision... The ten nationwide energy saving programs, such as developing oil alternatives, upgrading coal-fired boilers and saving energy indoors, will save China 240 million tons of coal equivalent during the 2006-10 period, including 50 million tons this year...”

Note that Premier Wen’s policy statements for environmental protection include (1) restricting the quantities of outputs, especially those that are environmentally polluting and high-energy consuming, by tightening land use and credit supply, (2) setting environmental standards for production, especially in new projects, and (3) improving method of production to make it environmentally friendly. Category (1) includes the restriction of export production that affects the environment by means of “adjusting exports rebates, levying more exports tariff, and reducing exports quotas.”

3.3. Policies for environment protection by regulation and economic incentives.

To reduce the amount of sulfur dioxide emitted from the burning of coal in the factories, the Chinese government has imposed heavy penalties to such emissions and encouraged the building of equipment to capture sulfur dioxide. However the use of such equipment is costly even after it is built and many factories do not use it except when they are being inspected. More recently the government is trying to introduce the use of monitoring device to measure the amount of sulfur dioxide emission coming out of each plant, but such a monitoring system has not yet been put into practice effectively.

China is also using economic incentives to solve the problem of externalities resulting from the use of energy. To reduce the use of coal and encourage a switch to cleaner burning fuels, the government has introduced a tax on high-sulfur coals. A system of emissions trading for sulfur dioxide, similar to that used in the United States, is being tested in some cities with pilot projects, and may eventually be applied nationwide.

The Chinese government will advance reforms in the pricing of natural gas, water and other resources, raise the tax levied on pollutant discharge, establish a “polluter pays” system and severely punish those who violate the environmental protection laws. To insure that fees charged on pollutants are higher than abatement costs and to strengthen existing laws, the government is considering the imposition of large fines on pollutant emissions. Future Chinese environmental initiatives also may include formulating a tax structure beneficial to environmental protection, and granting preferential loans and subsidies to enterprises that construct and operate pollution treatment facilities. The government will also provide incentives to companies that use more energy efficient production facilities and techniques.

Besides economic incentives, efforts are made to introduce technologies that will treat wastewater, prevent air pollution and improve environmental monitoring systems. Because of the above mentioned government policies state and non-state enterprises have tried to find cleaner technology to generate power than from coal. Governments of cities like Shanghai have tried to adopt urban planning strategies that are friendly to the environment. Space within a city is reserved for planting trees in order to improve air quality. Travelers to Beijing, Shanghai and Guangzhou in years 1998 to 2000 could witness that these cities became cleaner and the air quality was improved during this period.

3.4 Policies on CO₂ emission

Policies for reducing the emission of CO₂ per se are still under negotiation among nations. China appears to be more concerned with the problems of air and water pollution since the CO₂ emission problem is less urgent for China. A recent expression of China’s policy of limited involvement in the prevention of global warming is a statement of President Hu Jintao on Thursday June 7, 2007, during the G8 meetings in Germany that calls for upholding the principle of “common but differentiated responsibilities” for developing countries in tackling climate change. “We should work together to make sure the international community upholds the goals and framework established in the United Nations Framework Convention on Climate Change and its Kyoto Protocol [in 1997] and

the principle of common but differentiated responsibilities” while developing countries should also carry out “active, practical and effective cooperation...Considering both historical responsibility and current capability, developed countries should take the lead in reducing carbon emission and help developing countries ease and adapt to climate change... For developing countries, achieving economic growth and improving the lives of our people are top priorities. At the same time, we also need to make every effort to pursue sustainable development in accordance with our national conditions.”

Climate change, which could cause swelling sea levels and climate swings, was a major issue at the G8 summit from June 6 to June 8, 2007. Kyoto Protocol which requires industrialized countries to cut greenhouse gas emission by 5 percent from 1990 levels will expire in 2012. Parties concerned hope to launch negotiations for its replacement at an early date. Skepticism, however, was evident at the summit for reaching fixed, quantifiable targets for reducing the greenhouse gas emission. (See *People's Daily Online*, June 8, 2007).

3.5 Development of clean and renewable energy

China regards the creation of clean and renewable energy as an important national policy, and is developing hydropower, solar power, wind power, natural gas, biomass fuel and methane under its 11th Five-Year Plan. Current efforts to offset coal consumption include the development of natural gas and coal-bed methane infrastructure, increasing the number of combined heat and power plants, adding approximately 3,000 megawatts (MW) of hydropower annually, and developing renewable energy resources such as wind and photovoltaics for electricity generation.

For China's electricity generation, renewable sources of energy (including hydroelectricity) accounted for 18.6% in 2001, second to coal. With assistance from the United Nations and the United States, China hopes to embark on a multi-million dollar renewable energy strategy to combat pollution. Wind resources are concentrated in the northern and western regions of China, as well as along the coast, and are suitable for both rural village electrification and large-scale, grid-connected electricity production.

The highest wind potential in China lies along the coast and the offshore islands, in or near many of the major population centers. The next highest wind potential region covers Inner Mongolia and the northern Gansu Province, both of which are home to numerous villages with no access at present to grid-based electricity.

Current utilization of solar energy includes small-scale uses, such as household consumption, television relays and communications, but it is increasing steadily, especially in the number of solar kitchen ranges to substitute for the use of coal.

While solar and wind power provide significant renewable energy potential, China's growth in renewable energy in the next decade will be dominated by hydropower, particularly with completion of the 18.2-gigawatt Three Gorges Dam project in 2009. Although the Three Gorges Dam is seen as both an important source of energy for China's growing electricity consumption needs and a means of taming the Yangtze River, notorious for its disastrous floods, the controversial dam also could prove to be an environmental disaster. Thus far, few attempts have been made to address concerns regarding the accumulation of toxic materials and other pollutants from industrial sites that will be inundated after construction of the dam.

By 2025, the share of nuclear power used for China's electricity generation is expected to increase to 4% from the little over than 1% currently.

4. Problems of Policy Implementation and Law Enforcement

As examples of failure to implementing government environmental policies, consider the policies stated by Premier Wen Jiabao in April 2007 as reported in section 3.2. The quoted speech of Premier Wen states:

“The challenge of reducing energy consumption and greenhouse gas emissions has proved arduous as China's economy grew 11.1 percent in the first quarter [of 2007] but power consumption surged 14.9 percent... Energy consumption as a fraction of GDP fell only 1.23 percent in 2006, well short of the annual goal of four percent [as stated in the 11th Five-Year Plan of 2006-2010].”

The positive aspect of the above story is that, unlike other developing countries such as India, South Korea and Brazil, China was able to reduce both the amount of energy and carbon consumed per dollar of GDP over the past two decades. The reduction of energy intensity was made possible by its very high level to begin with, the efforts by the Chinese government to conserve energy, and the adoption of more modern industrial plant and equipment. China's Energy Conservation Law came into effect on January 1, 1998. Further efforts by the government to increase overall energy efficiency have included the reduction of coal and petroleum subsidies. Coal consumption is again rising, however, after declining in the late 1990s, and China's energy intensity increased slightly in 2001. At the same time, the government has promoted a shift towards less energy intensive services and higher value-added products, as well as encouraged the import of energy intensive products.

The failures in meeting policy targets such as reducing energy intensity by 4 percent per year are the results partly of the unrealistic nature of the targets and partly of the failure to implement laws and policies by the Chinese government in general, including those to protect the environment. Besides the reduction of the use of energy per unit of output, a more important way to protect the environment is to control the emission of pollutants in production that uses the same amount of energy or to use clean energy. Laws to control such emission are not effectively enforced. Chinese producers violate environmental protection laws to reduce cost of production. More importantly local government officials do not cooperate in enforcing such laws. It is often to the advantage of local governments to allow pollution to take place illegally in order to promote a higher rate of economic growth and the central government cannot control them. Local government officials benefit from higher levels of output in their region as they receive credits for economic development and sometimes bribes from polluting producers. These factors will continue to hinder the enforcement of environmental laws for some time to come.

However, there are also factors contributing to successful implementation of laws and policies to protect the environment. One is the strong resolve of the central government.

The second is that, if it wishes, the central or local government has the power to enforce such laws because the operation of an industrial enterprise requires its approval and sometimes even its assistance in the provision of land or credit. In order to protect and improve the environment the government not only can punish the offender but can provide economic incentives for people to act for the economic welfare of the society. There are a number of incentive schemes adopted by the Chinese government for industrial producers as we have described in section 3.3. For example, Wheeler, Dasgupta and Wang (2003) has provided econometric evidence to show that pollution levy does have a negative effect on the quantity of water and air pollution per unit of output. Third, there is a positive income effect on the demand for a clean environment. As the Chinese economy gets more developed the demand for cleaner water and air will increase, and the Chinese people can afford to pay for it. In the long run, though not necessarily in the near future, this favorable income effect should more than offset the unfavorable effect of producing a large quantity of output as the experience of the developed economies has demonstrated.

Since the control of pollution resulting from production using existing technology is difficult, one way for environment protection is to promote the use of clean energy by reducing its price relative to the price of existing energy. This can be achieved by imposing a cost to using polluting energy (which is hard to enforce) or by promoting technological innovations for the development of clean energy, especially to replace the use of coal. There are incentives in the free market for such innovations to take place. In addition the government can promote such innovations by subsidy and tax policies if it can identify them correctly.

One cannot depend entirely on a market solution to the problem of environmental degradation. Economy and Lieberthal (2007) appeal to multinationals doing business in China to play a positive role in protecting China's environment by setting an example for practicing environmentally friendly production while impressing the Chinese government of such conduct in their pursuit of profits. If it is to the self-interest of the multinationals to do so, one wonders why this would not be to the self interest of domestic Chinese

firms also. If such an undertaking is to their self interest why have the multinationals and Chinese domestic enterprises failed to do so? Accepting the authors' recommendation implies that self-interests on the part of market participants will solve the environment degradation problem. Evidence that environmental degradation has occurred while private enterprises are pursuing their own economic interests suffices to place the authors' recommendation in doubt. After all the problem of environmental degradation is one which the market cannot solve entirely and requires intervention by the government.

5. Three important current issues

In solving China's energy-environment problems three areas require our special attention. First, although the central government understands the use of economic penalties and incentives for promoting the use of clean energy, such as fines, taxes and subsidies, specific laws to deal with different environmental problems are yet to be enacted and a set of consistent policies is yet to be formulated. The work involves listing all polluting activities in production and consumption, estimating their costs to society as externalities and specifying a set of most suitable penalties for violation and economic inducements for the adoption of clean energy alternatives. The Chinese government has made much progress in this work. However, a set of comprehensive laws and regulations have yet to be established. As suggested in our previous discussion in section 3, some suggested solutions to the energy-environment problems are phrased in future sense and some, like the imposition of high tax and severe penalties, are not stated in specific quantitative terms.

Second, after the enactment of a comprehensive set of laws and the announcement appropriate policies, implementation will pose serious problems, as in the case of protection of intellectual property rights. Laws are not obeyed and policies are not followed. When there are economic benefits by violating the laws for environment protection, penalties for violation have to be strictly enforced and inducements to abide by the laws have to be provided. A major hindrance to environmental law enforcement is the lack of cooperation on the part of local government officials who are interested in

increasing output of their own regions. The central government needs to establish and monitor a clear set of environmental standards and severely punish the governor of the violating province even by relieving him of his position. When Zhu Rongji was President of the People's Bank in the 1990s, he succeeded in restricting the quantity of money supply by enforcing the policy that the President of a provincial People's Bank would be replaced if the extension of credit in his province were to exceed the quota set by the Central Bank. The same method for the enforcement of environmental policy can be applied. Given the risk of such a severe punishment a provincial governor would apply the same policy to enforce environmental standards in cities and counties in his province by similarly punishing the mayors and county officials. It would be difficult to decentralize the enforcement of environmental protection to provincial governments because they may be more interested in regional development at the expense of the environment; if regional governments were concerned with the environment they would be enforcing the policy of the central government already. It is doubtful, however, whether the central government would have the strong resolve to enforce environmental protection policies as suggested above.

Third, a multinational effort needs to be made to limit the emission of CO₂. As pointed out previously if the level of carbon dioxide reaches twice the level existing before the Industrial Revolution great climate instability will occur. How to achieve an international political consensus to reduce the rate of increase with each country sharing its fair share so as not to exceed the above critical level is a most pressing problem today, but the solution to this problem is beyond the scope of this paper and the wisdom of its author.

6. Conclusions

Environmental problems created by the use of energy are world-wide problems. The solution rests on the control of emission of pollutants, the reduction of energy use per unit of output (or energy intensity), the substitution of clean energy, and the promotion of technological innovations to achieve the last two objectives.

China's central government has paid a great deal of attention to the environment problem in its strategy for sustainable development. However the emphasis is on reducing air and water pollution rather in controlling the emission of CO₂ that can cause global warming. The problem of CO₂ emission is not felt immediately and China would rely on the developed countries to take a greater share of the burden since the latter have caused the high level of CO₂ accumulated up to this point. In China, even the control of air and water pollution requires improvement in both legislation and law enforcement.

Much work needs to be done for China to enforce existing laws for protecting the environment and to formulate a systematic set of laws and policies for environmental protection as suggested in section 5. The successful enforcement of these laws and implementation of such policies are difficult mainly because of the lack of cooperation of local government officials. As China has become richer in recent years many government officials have become more complacent. Strong resolve on the part of top Communist Party leadership would be required to change the behavior of these officials by severe punishment but such resolve may not be forthcoming. A likely prospect is that environmental laws will not be strictly enforced for some time to come.

In the mean time the central government can try to protect the environment by reducing energy intensity in production and increasing the use of clean energy through the provision of economic incentives for energy saving and the reduction of the relative price of clean energy. How to design a set of incentives to achieve this in practice remains a very challenging problem for research.

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