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Global Energy and Environmental Impacts of an Expanding China

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Abstract

China accounts for 10 percent of global energy use and will continue to rely on coal for generating approximately 75 percent of its energy over coming decades. The environmental problems associated with coal burning are a concern for China as well as regionally and globally. The present paper summarizes China's energy structure and likely future energy requirements, while exploring the impact of energy use on air quality, black carbon emission, sulphur dioxide (SO_2) emissions, and carbon dioxide emissions. Although China has begun to take action on local environmental problems from energy, there is still much to be done. In particular, the problem of black carbon and carbon dioxide emissions needs to be addressed. The present paper proposes addressing carbon dioxide emissions through a longer-term strategy that acknowledges the need for China to continue to grow without a short-term carbon constraint but with clear pricing of the short-term and long-term cost of carbon dioxide.

Key words: energy, environment, carbon dioxide, long-term strategy
JEL codes: Q53, Q56, Q58

I. Introduction

Rapid economic growth in China and China's economic size have important implications for energy use and environmental outcomes in China, regionally and globally. Although

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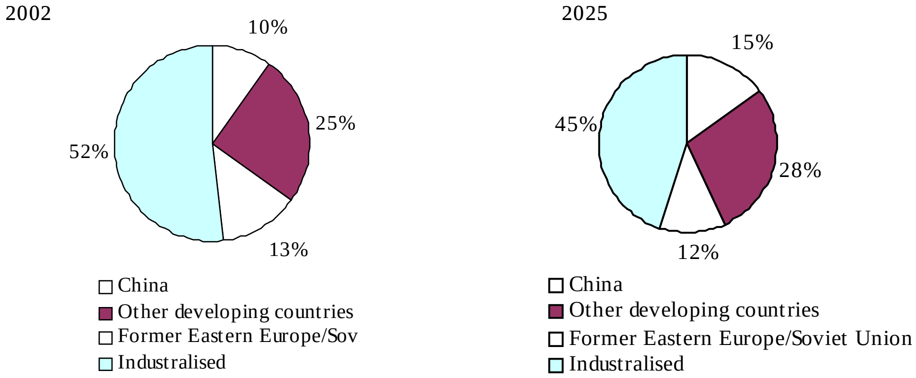
Figure 1. China's Share of Global Primary Energy Consumption

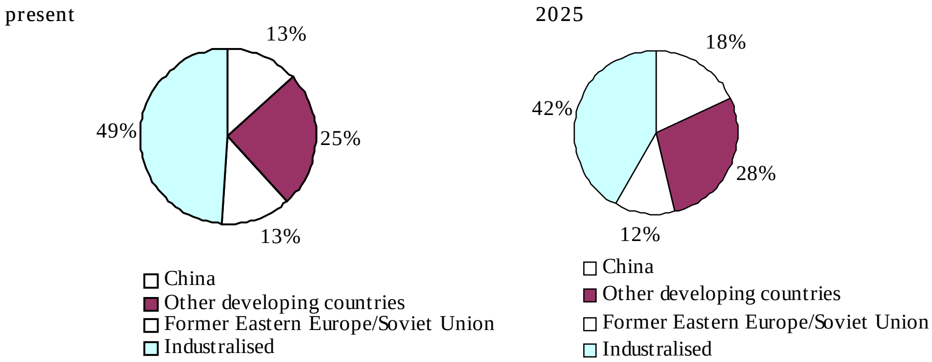


Source: Energy Information Administration (2004).

most statistics related to China are impressive, those related to energy use and environmental problems are startling. China is currently the world's third largest energy producer and the second largest energy consumer.[1] As shown in Figure 1, in 2002, China accounted for 10 percent of world energy use and is projected by 2025 to account for 15 percent of global energy use. China is the world's greatest coal producer, accounting for 28 percent of world coal production and 26 percent of world coal consumption. As the third largest consumer of oil, China is estimated to have the sixth greatest proven reserves of oil. Forecasts of future energy generation predict that China will be responsible for up to 25 percent of the increase in energy generation capacity over the next 3 decades. China has approximately 9.4 percent of the world's installed electricity generation capacity (second only to the USA). As a large energy user, China is estimated to emit 13 percent of global carbon emission from fossil fuels and this share is projected to rise to 18 percent by 2025 (see Figure 2). Despite the reliance on fossil fuels for energy generation, China currently has 9 nuclear reactors with plans for another 30 in the next 2 decades (DOE, 2005). It is estimated that China has the largest hydroelectric capacity in the world (largely in the south west of the country), which is currently generating 20 percent of Chinese electricity. The Three Gorges hydroelectric dam on the Yangtze River will be the world's largest power plant when completed in around 2009. In March 2005, the National Development and Reform Commission approved the largest wind farm in Asia to begin construction in 2006. Despite the emergence of renewable energy, the overall dominance of coal in the foreseeable future means that

[1]All data are sourced from the Energy Information Administration (2004) of the US Department of Energy and are for 2004 unless specifically indicated otherwise.

Figure 2. China's Share of Global Carbon Emissions from Fossil Fuels



Source: Energy Information administration (2004).

China will need to react to the impact of coal on a range of environmental problems, including air quality (including black carbon emissions), acid rain (from SO_2 and nitrogen oxide emissions) and climate change (from carbon dioxide emissions).

The present paper gives an overview of the current position of China in the world economy, with particular focus on energy use and the environmental consequences, at the local, regional and global level. The paper then focuses on the current and medium-term issues currently facing China. The first set of issues relate to how local action to reduce local environmental problems, such as emissions of SO_2 and black carbon, can make an important contribution to regional problems as well as global efforts to tackle greenhouse emissions. Importantly, this action will likely have significant impacts on Chinese economic growth and the well-being of the Chinese people. China is already putting in place policies to tackle local and regional environmental problems.[2] These policies are discussed below. Other issues relate to rising energy use, rising greenhouse emissions and the implications for China of serious global climate change policy. The present paper outlines a response to carbon dioxide emissions that could be implemented in China in coming years but has not yet entered the Chinese debate. This approach focuses on creating long-term property rights and clear incentives in pricing carbon emissions in an effort to reduce greenhouse gas emissions over time. It is in many ways similar to experiments already underway in China with trading sulphur emission permits, but it is important to note that dealing with

[2] China's Environmental Protection Law was promulgated in 1979. A nation-wide levy system on pollution began in 1982. Fees for SO_2 pollution from coal began being collected in 1992. See Jiang (2003) for an overview.

sulphur emissions is very different from dealing with carbon dioxide emissions. This difference is particularly important for China as a large country that has ratified the Kyoto Protocol and would be expected at some stage in the future to take on binding targets for carbon emissions or at least a commitment to some target.[3] China has already shown a commitment to tackle local environmental problems with encouraging outcomes, but there is still much to be done.[4]

II. Historical Experience and Projections of Energy Use

The importance of China in world energy use is clear in Figures 1 and 2. In 2001 China accounted for 10 percent of world energy use (compared to the USA at 23 percent) and 13 percent of global carbon dioxide emissions from fossil fuel use (compared to the USA at 23 percent). Chinese GDP (in 2003) is estimated in purchasing power parity (PPP) terms to be approximately 59 percent of the size of the USA (UNDP, 2004). This implies that although carbon emissions per unit of energy use are higher in China than in the USA, energy use per unit of GDP (in PPP terms) is slightly lower in China than in the USA. Most studies of energy intensity (i.e. energy use per unit of GDP) use market exchange rates for this comparison, which makes China look far more energy intensive. However, GDP measured at market exchange rates is inappropriate as a benchmark given the problems with comparing GDP across countries at different stages of development.[5]

Figure 3 shows the recent history of energy production and consumption in China. Energy demand and supply in China has been rising quickly: more than doubling between 1980 and 1996. In 1998, Chinese energy consumption began to outstrip Chinese energy production. Economic growth and the rising demand for energy in China is now spilling over into global energy prices far more importantly than it did before 2002.

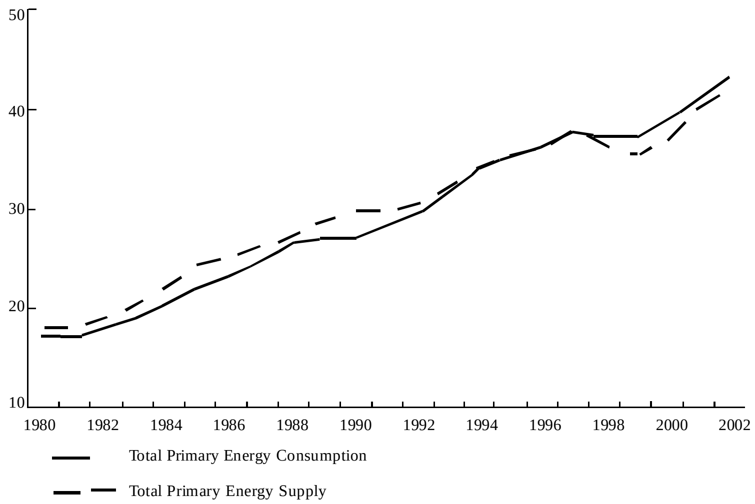
Figure 4 clearly shows that Chinese energy supply has relied predominantly on large supplies of low cost coal (mainly located in the northern part of the country). China produces approximately 28 percent of the global production of coal and consumes 26 percent of the global production. Crude oil is the next largest source of energy supply, followed by

3 Further details on the Kyoto Protocol can be found in section IV.

4 See Jiang (2003) for an overview of China's environmental problems. Jiang and McKibbin (2002) find that Chinese policy has been effective in reducing environmental problems relative to what otherwise would be the case, but other factors related to strong economic growth have offset and masked this improvement.

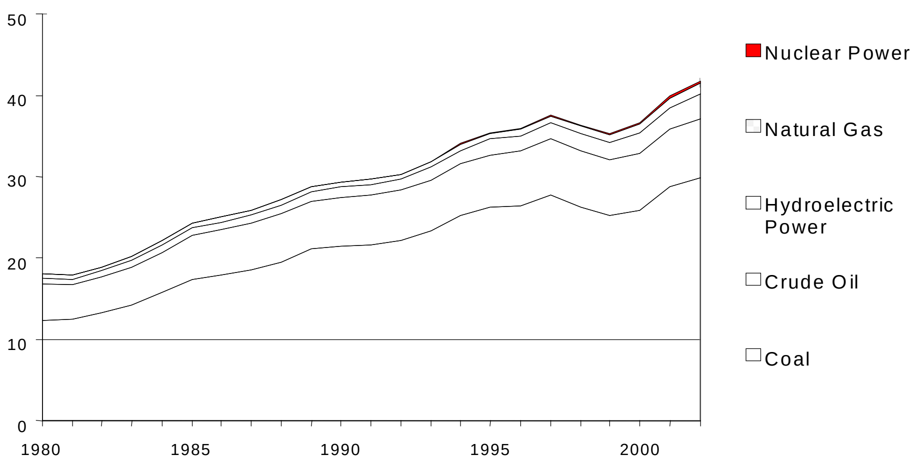
5 A large literature on using PPP for energy inter-country comparisons is summarized in Castles and Henderson (2003).

Figure 3. China's Total Energy Consumption and Supply, 1980–2002 (Quadrillion Btu)



Source: Energy Information Administration.

Figure 4. Energy Production by Fuel Type, China, 1980–2002

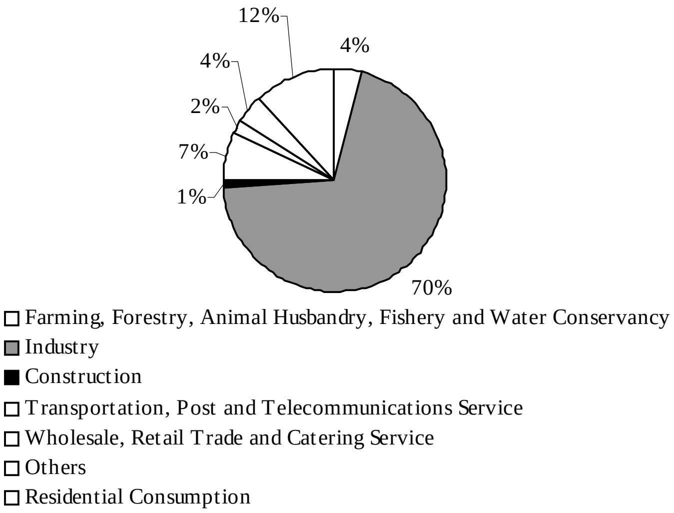


Source: Energy Information Adiministration (2004).

hydroelectricity, natural gas and nuclear energy.

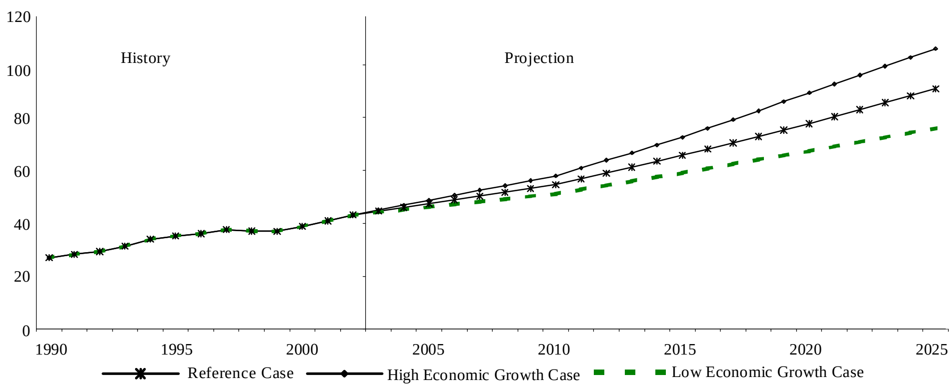
The sources of demand for energy in China (in 2002) are summarized in Figure 5, which shows the decomposition by sector. Industry is overwhelmingly the largest user of energy, amounting to 70 percent of the total. This is followed by the household sector at 12 percent

Figure 5. China's Energy Consumption by Sector, 2002



Source: China State Council Development Research Center (2004).

Figure 6. Total Energy Consumption, China, 1990–2025 (Quadrillion (10^{15})Btu)



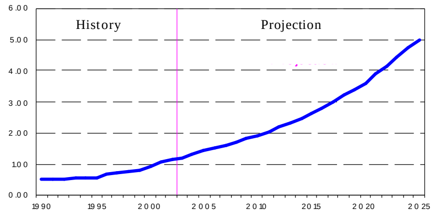
Source: Energy Information Administration/International Energy Outlook 2004.

and transportation at only 7 percent.

Projecting future energy use in China is very difficult. Many forecasters base future projections on recent trends. However, as shown by Bagnoli *et al.* (1996) and McKibbin *et al.* (2004), overall economic growth is not the key determinant of energy use: the sources of economic growth are critical and the assumptions about energy prices are fundamental. Several projections are available. The Energy Information Administration (2004), in their *Annual International Energy Outlook*, provides one source of projections. These are

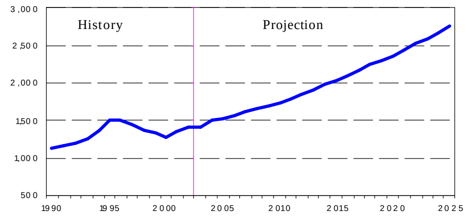
Figure 7. Projections of Energy Use by Sector

Energy Consumption of Natural gas, China,1990–2025 (Trillion Cubic Feet)



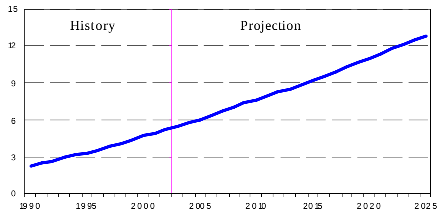
Source: Energy Information Administration(2004).

Energy Consumption of Coal, China, 1990–2025 (Million Short Tons)



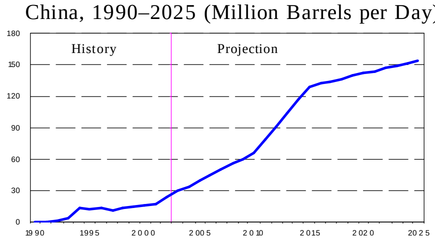
Source: Energy Information Administration(2004).

Energy Consumption of Petroleum,China, 1990–2025 (Million Barrels per Day)



Source: Energy Information Administration(2004).

Energy Consumption of Nuclear Electric Power, China, 1990–2025 (Million Barrels per Day)



Source: Energy Information Administration(2004).

shown in Figure 6 for scenarios of high and low economic growth and a reference case. There is very little change in trend projected in these scenarios for China compared to recent experience. Interestingly, there is also little change in the real price of oil or any fossil fuels throughout the projection period in the *International Energy Outlook*. Figure 7 shows the breakdown of the overall energy projections into energy projections by generation source as predicted by the Energy Information Administration for natural gas, coal, petroleum and nuclear power generation in China from 1990 to 2025. These projections at the aggregate level and the composition of energy generation show a continuation of recent trends at least to 2010.

The emergence of China as a key supplier of energy and producer of energy is one of the most important issues in the debate over global energy use for the foreseeable future. This is also a critical issue for environmental issues in China, regionally and globally.

III. Energy Use and Environmental Issues

Energy use has important implications for the environment. At the local level particulate emissions have important impacts in China. Acid rain has impacts on China as well as in the rest of Asia, particularly Korea and Japan. Carbon dioxide emissions have global implications through potential climate change. Given China's size and potential growth in coming years, carbon dioxide emission from energy use in China is a critical issue for the global environment.

Several studies have explored the local impacts of air pollution caused by energy use in China. The term "air pollution" covers a wide range of problems, including emissions of particulates, SO_2, nitrous oxides and carbon dioxide. The estimated costs of air pollution, largely as a result of the burning of fossil fuels, vary in size. A study by the World Bank (1997) valued health damages from air pollution at 5 percent of GDP in 1995.[6] Other studies, such as Yang and Schreifels (2003), suggest that this is close to 2 percent of GDP. Garbaccio *et al.* (1999) find that a reduction in carbon emissions of 5 percent every year would reduce local health costs by 0.2 percent of GDP annually. A recent report by China's State Environmental Protection Agency (SEPA, 2004) on the environment notes that air quality in cities across China has generally improved but this is from a base of significant problems in most major Chinese cities. A study by the World Health Organization (WHO, 2004) notes that only 31 percent of Chinese cities met the WHO standards for air quality in 2004. A large part of these air quality problems is directly related to energy use.

Whether projections of rising energy use over the coming decade directly lead to projections of increased environmental problems is a critical issue facing policy-makers in China. This is well understood in China. Premier Wen Jiabao in his 5 March 2005 report to the National People's Congress pointed to improved energy conservation as necessary to reconcile rapid economic growth with limited energy resources; he also called for stronger pollution controls. The State Environmental Protection Administration (SEPA) has also been implementing more stringent monitoring and enforcement of environmental legislation.[7]

Particulate emissions cause serious health problems with identifiable economic costs as well as human costs. A study by Ho and Jorgenson (2003) finds that the largest sources of total suspended particulates (TSP) are the largest users of coal: electricity, nonmetal mineral products and metals smelting as well as transportation.

One of the worst pollutants from burning fossil fuels is SO_2 emissions. SO_2 emissions have local (health and acid rain) as well as regional (acid rain) implications. The WHO estimates that more than 600 million people are exposed to SO_2 levels above the WHO standards (WTO, 2001). SO_2 mixing with nitrogen oxides causes acid rain. The WHO (2004)

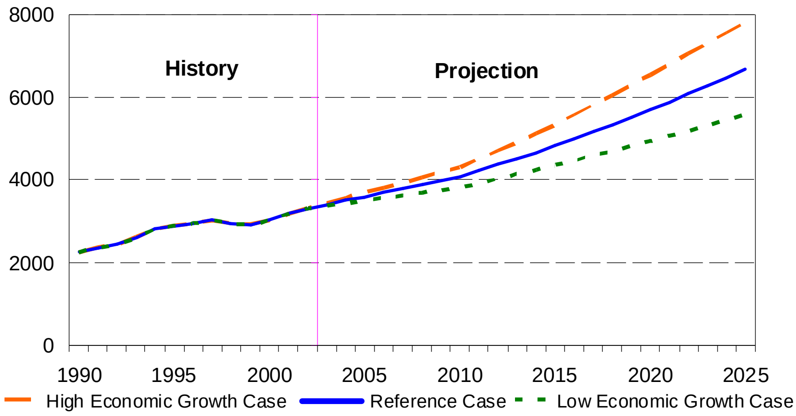
[6] Panayotou and Zheng (2000) estimate that the cost to China from air and water pollution was 14.6 percent of GDP in the late 1990s.

[7] The formerly named National Environmental Protection Agency was set up in 1988 and renamed SEPA in 1998 when it was upgraded to a Ministry.

and SEPA (2004) estimate that acid rain seriously affects 30 percent of China. However, this is not just a problem for China. Streets (1997) estimates that China accounted for 81 percent of SO_2 emissions in north-east Asia in 1990. China is the major source of acid rain across north-east Asia. Without any control policies, Streets estimated in 1997 that this share would change little by 2010 except that the quantity of emissions is expected to grow by 213 percent from 1990 to 2010 and by 273 percent by 2020. Assuming installation of state of the art flue-gas desulphurization systems, Streets estimated that this scenario could be transformed so that SO_2 emissions fall to 31 percent of 1990 emissions by 2020. China has begun to address this problem by closing high sulphur coal mines as well as other direct controls and through developing pilot SO_2 emission trading systems in several control zones. Surprisingly, SO_2 emissions fell gradually from1995 to 2002 but rose again in 2003. Despite some success in dealing with SO2 emissions, acid rain problems have not been reduced because of a substitution of emission towards high stack sources, which spread SO_2 over greater areas (Yang and Schreifels, 2003). Direct policy to deal further with SO_2 emissions would seem to have a significant benefit for China and across the region, and the Chinese authorities are acting on this. Experimentation with price-based charging and emissions trading systems have yielded encouraging results and should be used more extensively to reduce the emission of sulphur from the projected increasing use of coal for generating energy.

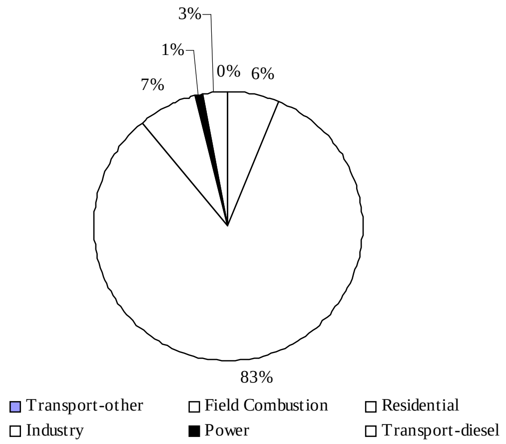
A more recent and potentially more important problem identified by Streets *et al.* (2003) and Streets (2004) is the emission of black carbon. Black carbon is the fine particulates that are released from imperfect combustion of carbonaceous materials. This manifests itself as a thick haze that frequently envelopes many Chinese cities. Current work suggests that

Figure 8. Projuction for Carbon Dioxide Emissions, China, 1990–2025 (Million Metric Tons Carbon Dioxide)



Source: Energy Information Administration (2004).

Figure 9. Sources of Black Carbon in China in 1995



Source: Streets (2004).

direct action to reduce the emissions of black carbon from household energy use and burning of forests and agricultural waste is an important issue that needs urgent attention in China. Studies by Hamilton and Mansfield (1991), Hansen and Sato (2001) and Streets (2004) suggest that reduction in black carbon emissions is a critical issue for China. The consequences of black carbon are wide ranging, from reduced visibility to serious health problems, to damage to buildings. Perhaps most importantly, estimates suggest that agriculture crop productivity might be reduced significantly (by up to 30 percent for rice and wheat) (Streets, 2004). Streets (2004) argues that black carbon is the second most important warming agent behind carbon dioxide. Using circulation models, Menon *et al.* (2002) estimate that black carbon is responsible for local climate problems in China, such as increased drought in northern China and summer floods in southern China. The time lag between reducing black carbon emissions and significant local climate effects is estimated to be approximately 5 years: a far quicker effect on climate than the implications of tackling carbon dioxide emissions, which are measured in many decades.

The estimated sources of black carbon are contained in Figure 9. Surprisingly, a vast majority of emissions are from residential energy use rather than electricity generation or transportation. Residential burning of coal accounted for 83 percent of emissions in 1995. This is a result of the fact that 80 percent of Chinese households use solid/biomass fuels for cooking and heating (WHO, 2004). Therefore, black carbon is likely to be an important issue that authorities are yet to tackle. Part of the reason is that it is a relatively recently understood problem and partly because the solution doesn’t lie in the energy generation sectors but in the use of energy by households.

There are a many environmental problems associated with the expected rise in energy use in China. Some of these are beginning to be tackled and new ones are emerging.

IV. Policies to Deal with Environmental Challenges from Energy Use

Despite the scale of environmental problems evident, China has responded to the local environmental problems associated with rising energy use. Attempts to substitute towards non-fossil fuel energy sources, such as wind, hydro and thermonuclear energy, in energy generation are underway. The Chinese Government has also implemented a range of policies to reduce the emissions of SO_2 from burning fossil fuels. More needs to be done on black carbon emissions. From a global perspective, the one area where China has taken less action is in the emissions of carbon dioxide. This is the focus of this section.

The cumulation of greenhouse gases in the atmosphere is the most important cause of human-induced climate change. Carbon dioxide is the most important greenhouse gas. The United Nations Earth Summit in Rio de Janeiro in 1992 produced a landmark treaty on climate change that undertook to stabilize greenhouse gas concentrations in the atmosphere. The treaty focused on stabilization of emissions, which implied that the risks posed by climate change require that emissions be reduced no matter what the cost. The agreement, signed and ratified by more than 186 countries, including the USA and China (the world's largest carbon dioxide emitters), spawned numerous subsequent rounds of climate negotiations aimed at reducing emissions from industrialized countries to the levels that prevailed in 1990. By early 2006, however, the negotiations have had little effect on actual greenhouse gas emissions.[8] The treaty's implementing protocol, the 1997 Kyoto Protocol, was heavily diluted at subsequent negotiations in Bonn and Marrakech but entered into force on 16 February 2005.[9] There are a still many problems to be faced before it will be evident that the Kyoto Protocol is actually reducing emissions.

At the global level, the problem is actually worse than it appears from the troubled process of Kyoto ratification. The Kyoto Protocol only places restrictions on the industrial economies, excluding the world's largest greenhouse emitter, the USA. Developing countries, including China, have ratified the agreement but have not taken on any responsibilities for

[8] See McKibbin and Wilcoxen (2002a,b) for a summary of the negotiations and critique of the approach.
[9] Earlier estimates of the cost of Kyoto can be found in Weyant (1999). Direct comparisons of the COP3 and COP7 versions of the protocol can be found in Bohringer (2001), Buchner *et al.* (2002), Kemfert (2001), Löschel and Zhang (2002) and McKibbin and Wilcoxen (2004).

reducing emissions except those that emerge from mechanisms such as the Clean Development Mechanism (CDM) and Joint Implementation. The fact that the world's largest emitter, the USA, is not involved in climate policy substantially dilutes global action even further. Because there are no binding commitments by the key developing countries of China, India, Brazil and Indonesia (among others), effective action against possible climate change is still a hypothetical debate.

Developing countries argue that although they are prepared to be part of a regime to tackle climate change, they should not be required to bear a disproportionate part of the costs of taking action. After all, current concentrations of greenhouse gases in the atmosphere are primarily the result of economic activities in the industrial economies since the Industrial Revolution. Why should developing countries not be able to follow the same energy intensive development paths of the currently industrialized economies? One of the biggest dilemmas for developing countries is not just the reality that at some stage they need to make some form of commitment to curbing greenhouse gas emissions but the fact that most estimates of the damages from climate change are borne by developing countries (IPCC,2001).

Other approaches are possible in China and other developing countries despite the common refrain that "Kyoto is the only game in town". This mindset has already hindered effective action for the past decade as countries and industries postpone action until agreements are clarified. Given the uncertainties of climate change and the decisions on energy systems being made in the regions of the developing world that are growing rapidly, this delay in providing clear incentives for moving away from fossil fuel based systems might ultimately prove to be extremely costly.

One of the largest sources of anthropogenic greenhouse gas emissions is the burning of fossil fuels. China is heavily reliant on coal for energy production and at current relative prices for energy, is likely to be for many decades to come. There are huge investments in physical and human capital surrounding existing energy systems, which are costly to change. However, future investments (largely to occur in developing countries) are much cheaper to change before they are undertaken. Technology will ultimately be the source of reductions in emissions whether through the development of alternative sources of energy or through ways of sequestering carbon released from burning fossil fuels. Developing countries have huge potential to avoid the pitfalls in terms of carbon intensities experienced by industrialized economies in their development process. The key issue is how to encourage the emergence of energy systems in developing countries that are less carbon intensive over time. Ultimately, if climate change does emerge as a serious problem, developing countries will have to move towards a less carbon intensive future. It is likely to be significantly cheaper to do this over time than to face a massive restructuring at some future period: the sort of problems being faced within industrialized economies today.

The current state of global policy on climate is that the USA (the largest emitter of greenhouse gases) has rejected the Kyoto Protocol and is arguing for policies that directly or indirectly reduce emissions through technological change; the European Union is committed to emission targets (assuming Russia provides a great deal of those reductions required through selling emission permits) and implemented a Europe-wide emissions trading scheme (that exempts key sectors such as aluminum, motor vehicles and chemicals) on 1 January 2005; Japan is considering what it can do given current emissions are 16 percent above target in an economy recovering from a decade of recession; and developing countries have refused to officially discuss taking on commitments.

Given the current state of global climate policy discussions, China could begin to address carbon emissions and to make a major contribution to a global response. One step would be the removal of energy subsidies or to further raise the price of energy to reflect the true economic and environmental cost of burning fossil fuels.

Economic theory provides guidance about the structure of a possible climate change policy for China.[10] Because greenhouse gases are emitted by a vast number of highly heterogeneous sources, minimizing the cost of abating a given amount of emissions requires that all sources clean up amounts that cause their marginal cost of abatement to be equated. To achieve this, the standard economic policy prescription would be a market-based instrument, such as a tax on emissions or a tradable permit system for emission rights. This type of market-based incentive for environmental pollution is already being undertaken in China through pollution charges and permit trading in SO_2. Richard Cooper (2005) has advocated a carbon tax for China. Garbaccio ***et al***. (1999) and McKibbin and Wilcoxen (2004) find that a price signal would be effective in changing China’s future emissions profiles. In the absence of uncertainty, the efficient level of abatement could be achieved under either a tax or a permit trading system, although the distributional effects of tax and emissions trading policies would be very different.

Under uncertainty, however, the situation becomes more complicated. Weitzman (1974) shows that taxes and permits are not equivalent when marginal benefits and costs are uncertain, and that the relative slopes of the two curves determine which policy will be better.[11] Emission permits are better than taxes when marginal benefit schedules are steep and marginal costs are flat: in that situation, it is important to get the quantity of emissions down to the threshold. A permit policy does exactly that. In the opposite situation, when

[10] See McKibbin and Wilcoxen (2002a) for a survey and Pezzey (2003) for a comparison of taxes and permits.

[11] See also Pizer (1997) for a more recent discussion of the issue.

marginal costs are rising sharply and marginal benefits are flat, a tax would be a better policy. The potential inefficiency of a permit system under uncertainty is not just a theoretical curiosity: it is intuitively understood by many participants in the climate change debate by the expression of the concern about a policy that "caps emissions regardless of cost".

Applying this analysis to climate change, McKibbin and Wilcoxen (2002a,b) show that a tax is likely to be far more efficient than a permit system under the uncertainties surrounding climate change. All evidence to date suggests that the marginal cost curve for reducing greenhouse gas emissions is very steep, at least for developed countries. Although there is considerable disagreement between models on how expensive it would be to achieve a given reduction in emissions, all models show that costs rise rapidly as emissions targets become tighter. At the same time, the nature of climate change indicates that the marginal benefit curve for reducing emissions will be very flat.

Given the advantages and disadvantages of the standard economic instruments, it is possible to combine the attractive features of both systems into a single approach. Second, it is possible to develop a system that is common in philosophy across developed and developing economies but in which developing economies do not incur the short-run costs to the economy in the form of higher energy prices until they have reached a capacity to pay.

There are several goals that should be at the core of any climate change regime. These involve recognizing the trade-off between economic efficiency and equity within and between countries. The policy should also be based around clear property rights over emissions and clear long-run emission targets, but near certainty in the short-run costs to the economy. A sensible climate policy should also create domestic institutions that allow people to self-insure against the uncertainties created by climate change. There should be market mechanisms that give clear signals about the current and expected future costs of carbon. There should be coalitions created within countries with the self interest of keeping climate change policy from collapsing rather than creating a system of international sanctions to sustain the system.

The McKibbin–Wilcoxen Blueprint (see McKibbin and Wilcoxen, 2002a,b) was created to attempt to explicitly deal with these issues. It is a Hybrid system that blends the best features of taxes and emission permit trading.[12] It is a system that can be applied across developed and developing countries but which recognizes that developing countries should not bear the same economic costs as industrial countries in the short run.

Although set out in detail in McKibbin and Wilcoxen (2002a) the approach can be

[12] The intellectual idea actually dates back to Roberts and Spence (1976) for general environmental policy and McKibbin and Wilcoxen (1997) for climate change policy.

briefly outlined here. The basic idea is to impose a requirement that energy producers have an annual emission permit to produce energy each year, based on the carbon content of that energy. A fixed quantity of long-term permits would be created that allow a unit of emission every year for 100 years. These are traded in a market with a flexible price. The government would also be able to create additional annual permits in any year at a guaranteed price. Permits that satisfy the annual constraint for energy production can be either a long-term permit or an annual permit that is provided by the government at a fixed price. The price of emissions in any year would never be higher than the fixed price set by the government and the amount of emissions in any year would be whatever the market delivers. Therefore, we have a long-term target in terms of emissions but an annual target in terms of the maximum cost of carbon to industry. In a developing country like China, the annual price would initially be zero if we allow an allocation of long-term permits well in excess of current emissions. However, the price of long-term permits would reflect the expectation that China would eventually reach the emission levels that caused the carbon emission constraint to be binding. Therefore, the market for long-term permits with positive prices would provide a financial incentive to begin to change Chinese carbon emissions over time even though the annual cost to industry of a carbon permit would initially be zero.

The attractiveness of the blueprint for creating institutions to aid in economic development in a developing country like China should not be underestimated. The ability of investors in energy systems to effectively hedge their investment over a long period of time should be very attractive for the development of energy systems in developing countries. The time frame of the assets we propose to be created (by committing to a global climate regime) is currently unparalleled. China could use this new asset as a way of attracting foreign investment and enhance the development process by creating what is effectively a futures market in energy. This is far more likely to induce foreign investment than the CDM or other similar mechanisms that face very high administrative costs. Critics might argue that the problem with China is the inability to create the sorts of institutions that the above scheme would require. This is a problem in the near term but it is easier for China to create property rights and institutions within China according to the philosophy and characteristics of China, than it would be to impose within China the sorts of institutions and property rights based on developed world approaches that would be required under the Kyoto Protocol for China to be able to sell carbon rights into the global market. The required synchronization of global property rights in a form reflecting the current practices of developed countries is exactly why it is difficult to see how the Kyoto Protocol could be implemented outside the small group of industrialized countries with similar institutional structures that are already involved. Yet including China and other major developing countries in realistic climate policy is exactly what will be required for an effective response to the uncertainties of climate change.

V. Summary and Conclusion

There are many economic and environmental challenges facing an economy that is so large and growing as rapidly as China. No challenges are clearer within China, within Asia or globally than the issue of energy use and the environmental consequences of energy use. The present paper has attempted to summarize a range of these issues. The first thing to note is just how large and important China already is in world energy markets (as well as global markets for most commodities and manufactures). The use of energy and the enormous expected future growth in energy demand and generation has important implications for environmental outcomes. China is already taking action on the local problems of particulate emissions, particularly SO_2 emissions, although much more needs to be done. Policies to substitute to low sulphur coal by closing small, high sulphur coal mines, direct controls on SO_2 emissions, implementation of pilot schemes for SO_2 emission charges and pilot schemes for SO_2 emissions trading are having an impact of emissions of sulphur. This is important for China and well as north-east Asia in terms of acid rain reduction. The problem of black carbon generated by the household sector needs to be addressed. This will require a technology shift in the way households generate heating and cooking. It is feasible to implement a phase in of alternatives at the household level over coming years. The expected payoffs are likely to be large and quickly achieved with benefits for public health, agricultural productivity and local climate outcomes in China.

The emission of carbon dioxide from burning fossil fuels is yet to be effectively addressed in industrialized economies or in China. Even if rapid action was possible, the payoff will not be realized for decades into the future. One option proposed in the present paper is to experiment with Hybrid market/government control schemes, such as the McKibbin–Wilcoxen Blueprint in which important institutions are created to begin a long process of reduced carbonization of the Chinese economy. Such an approach would allow the Chinese economy to continue to grow but would place long-term prices on future carbon emissions as an incentive to gradually shift Chinese energy systems to low carbon emitting technologies. The creation of institutions for environmental management, particularly through market incentives between now and 2010 will be the most important step to be taken in China. The demonstration effect of such an approach could have an even bigger impact of global emissions if it encouraged other developing countries and the USA to begin to price carbon more appropriately given the current state of knowledge about the potential of climate change.

The environmental impacts of energy use over coming decades are varied in nature and require a variety of responses. Potential responses range from technical innovation to incentives for changing behavior by producers and consumers in China. The policy responses also require a mix of market mechanisms and government intervention through regulation. Most importantly, these policies need to be implemented sooner rather than later, especially in a potentially carbon constrained world, as decisions made in the next decade in China will influence the nature of the energy system in China for many decades into the future. As an important developing country, China can play a critical role in demonstrating how effective climate policy can coexist with strong economic growth and environmentally sound development policies.

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