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A Carbon Tax in China?
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Introduction and Summary

Emissions of greenhouse gases (GHGs) are thought to be a serious threat to the well-being of mankind (and other species). The principal culprit is carbon dioxide (CO₂), generated largely by the extensive use of fossil fuels (coal, oil, and natural gas, in that order). CO₂ concentrations in the atmosphere have risen from 285 ppm at the beginning of the industrial revolution to around 370 ppm today, and are still rising. Methane and various industrial gases also contribute to climate change. The concern is that the average surface temperature of the earth will rise, by perhaps 2.5 degrees centigrade, during the 21st century, with a concomitant rise in sea levels by perhaps half a meter due to thermal expansion and glacial melting.

The Framework Convention on Climate Change (FCCC) of 1992 and its Kyoto Protocol of 1997 addressed these issues, in a limited way, by acknowledging the problem, committing all signatory countries to deal with it, and obliging the rich countries (including the former communist countries of central Europe, Russia, and Ukraine) to limit by 2008-2012 their emissions of six specified GHGs to a stipulated fraction of their emissions of 1990, all in agreed CO₂ equivalents.

In 2004 the Kyoto Protocol hangs in suspension, awaiting ratification by Russia, which would be sufficient to bring it into force. Russia is equivocating. Even if Russia ratifies, the Kyoto Protocol will have a limited impact on GHG emissions, since the USA and Australia have withdrawn their support, and the Kyoto Protocol in any case does not and cannot easily be extended to cover developing countries, including such important emitters as China, India, and others whose fossil fuel consumption is growing rapidly.

While forecasts of long-term energy use have been notoriously off the mark (see Abt (2002), Smil(2003)), the subject at hand is inherently quantitative and future-oriented, so a quantitative baseline is necessary to frame serious discussion. The Intergovernmental Panel on Climate Change has put forward six different main scenarios to specify "business as usual" trajectories of GHG emissions over the course of the next century (IPCC, 2001). The

Energy Information Administration of the US Department of Energy and the OECD-based International Energy Agency, among others, do 25-year forecasts of energy use, by region and by major fuel.

The IEA's World Energy Outlook 2004 will not be available until early 2005, so this paper will rely heavily on the International Energy Outlook 2004 published in April 2004 by the US Department of Energy (EIA, 2004). It shows world emissions of CO₂ (on which this paper will focus, largely ignoring other GHGS, which however account for about 30 percent of greenhouse warming potential since 1800) rising from 23.5 million metric tons (mmt) in 2000 (up from 21.6 mmt in 1990, the base year of the Kyoto Protocol) to 37.1 mmt in 2025, an increase of 1.9 percent a year on the basis of an assumed annual average growth in gross world product (GWP) of 3.0 percent. China's CO₂ emissions are assumed to grow by 3.3 percent a year, the highest rate in the world among large countries or regions, with Brazil and India not far behind. China's share of world CO₂ emissions increases from 12 percent in 2000 to 18 percent in 2025, rapidly approaching the US share of 22 percent (underlying data from EIA 2004, Table A9).ⁱ In view of these trends, the problem of GHG emissions cannot be seriously addressed without engaging China, Brazil, India, and other rapidly growing countries.

Worldwide agreement on national GHG emission targets that have enough bite to limit growth in atmospheric CO₂ concentrations is likely to prove impossible, at least for several decades. It is hard to imagine an effective formula for national targets that will be acceptable both to rich countries such as the USA and to poor countries with aspirations for rapid growth, such as China and India (Cooper, 2001). The targets of the Kyoto Protocol are based on a base year, 1990, an approach that is unappealing to countries that desire and expect to grow rapidly.

Another approach is needed if human sources of climate change are to be addressed seriously. A leading alternative approach is to focus on concrete national commitments to action rather than emission targets. One such action, favored by many economists to deal

with negative externalities from human activity, is to tax the offending activity, here atmospheric emissions of CO₂ -- and eventually other significant GHGs. The central idea is to levy a tax on CO₂ emissions from major sources, and in particular on the burning of coal, oil, and natural gas and the making of cement, unless the CO₂ released from such processes is prevented from entering the atmosphere through sequestration. The eventual rate of tax should be calibrated to the desired reduction in CO₂ emissions. This paper will address the imposition of such a tax in China, already second largest CO₂ emitter after the USA, with the most expected rapid growth in emissions, and by far the world's largest producer and user of coal.

China has not evinced major concern about the possibility of global climate change, although it officially accepts that it is a potential problem, and it is a signatory of the FCCC and the Kyoto Protocol.ⁱⁱ It has many higher priorities, among which are to maintain rapid economic growth (the official aspiration is to quadruple its GDP between 2000 and 2020, implying average annual growth of 7.2 percent); to provide employment for large numbers of people leaving agriculture (which still accounts for about sixty percent of the labor force) and those released from over-manned state-owned enterprises (SOEs), to assure political stability; and, under the environmental heading, to reduce floods and water and air pollution, while preserving energy security.

The attraction of a CO₂ tax to China would not, therefore, rest mainly on its contribution to avoiding climate change, but rather its contribution to reducing air pollution, which derives heavily from use of coal and, increasingly, from automotive emissions in the larger cities; and, above all, as a source of revenue, which is badly needed by the central government. China is unlikely to impose a stiff CO₂ tax alone, because of concerns about loss of international competitiveness in energy-intensive industries such as steel-making. But such effect could be neutralized if the tax were imposed as part of a broad international agreement to introduce such taxes, as proposed by Cooper (1998), to limit GHG emissions.

This paper will discuss the current state of China's energy sector and its outlook for

the next few decades; the impact of a CO₂ tax on the volume and composition of China's energy use; the revenue implications of such a tax; and the possible impact of a carbon tax on the growth and structure of China's economy.

China's Energy Consumption and Outlook

Table 1 provides basic information on China's primary energy consumption in 1990 and 2000, and the reference case projection of China's energy use to 2025 by the US Department of Energy.ⁱⁱⁱ It can be seen there that China is heavily dependent (nearly two-thirds in 2000) on coal, the most carbon-intensive fossil fuel, mainly for electricity generation but also for industrial and household use. Oil accounts for just over one quarter of primary energy use. Over the next 25 years the relative importance of coal is expected to decline, while that of oil rises (as more Chinese acquire automobiles, and truck traffic increases). But because of rapid growth, the use of coal is nonetheless expected to double by 2025, from an already large base. China is taking significant steps to increase the use of natural gas in households, industry, and for the generation of electricity, and to increase nuclear power, both of which are expected to grow rapidly, but by 2025 they together still account for only seven percent of China's primary energy consumption.

It is noteworthy that the EIA assumes that China over this period grows at "only" 6.1 percent a year, over a percentage point less than China's 7.2 percent growth aspiration, and that energy growth is not much more than half this expected growth in GDP, implying considerable improvements in efficiency in the use of energy as well as changes in the structure of the Chinese economy toward less energy-intensive activities. Despite lower growth, improvements in efficiency, and the relative decline of coal, China's CO₂ emissions are expected to grow by 3.3 percent a year, the most rapid in the world.

The demand for electricity grows with increases in income, for it is relatively clean and convenient at the point of use. In 1997 China had 263 GW in installed electricity generating capacity, two-thirds coal-fired (74 percent of actual electricity generation), 23

percent hydro-electric, with the remaining ten percent relying on oil, nuclear, gas, and renewables, in that order (IEA, 2000, p.204). The International Energy Agency expected China to add 500 GW of capacity by 2020, raising capacity by nearly a factor of three over existing capacity, two-thirds of which would be coal-fired, despite out-sized increases in gas-fired, nuclear, and hydro-power. This compares with a total of new generating capacity in the USA (Europe) of only 396 GW (477 GW, mostly gas) over the same period.^{iv}

China faces a basic dilemma in framing its future energy policy. It has abundant coal resources, but has so far had difficulty finding abundant oil or gas. Coal accounts for much of the air pollution -- 85 percent of sulfur dioxide (of which only 30 percent comes from power plants), for instance, and much particulate matter. In addition, the mines are mainly located considerable distance from the main sources of demand for energy, requiring extensive transportation. Switching to oil or gas, however, would also involve extensive investments in infrastructure, and will prospectively increase China's dependence on the rest of the world for primary energy, something that makes Chinese leaders uncomfortable. Their attempts to resolve this dilemma leads them to place heavy emphasis on hydro- and nuclear-power; to explore intensively for oil and gas (but not to the point of inviting foreign equity participation in Chinese production); and to diversify their sources of imports, notably by considering (expensive) oil- and gas-pipelines from Kazakhstan and from Siberia, in order to reduce inevitable growing dependence on sea-borne oil (and, in the future, gas) from the Persian Gulf.

China has extensive hydro-electric potential, 290 GW estimated to be economically exploitable, of which only 60 GW was developed in 1997. The controversial Three Gorges Dam will bring on an additional 18 GW by 2009. IEA assumes the total will rise to 171 GW by 2020 (IEA, 2000, p.205).

China's first nuclear power plant came on line in 1991 and by 2000 China had 2.1 GW of capacity. Official plans call optimistically for 40 GW by 2020 (CDF 2003, p.71), but IEA assumes because of cost, long lead times, and other difficulties that China will

reach only 20 GW. (The capital costs of nuclear plants are about three times higher per kW than for new coal-fired plants in China.)

China has discovered the many attractions of gas-fired power plants, in cost, scale, and low pollution. China's problem is insufficient economical gas. It has approved two LNG terminals, both on the south coast, and has several more under consideration; it has contracted for Australian gas. Power plants will however have to compete with high priority residential and industrial uses of gas. The IEA nonetheless projects a 20-fold increase in gas-fired power plants between 1997 and 2020, from a low base (IEA, p.205).

The structure of the Chinese energy market is highly fragmented. While national policy is set in Beijing, actions by each province and municipality reflect local interests. End-use of energy, as in many countries particularly gas and electricity, is subject to local price control. This is partly to prevent exploitation of local monopoly in delivery, but also represents a residual of habits created during central planning days in the energy sector, which is seen as critical to many industrial activities. There are no national or even extensive regional electricity grids in China, so most power plants distribute only within the vicinity of the plants (over 95 percent of China's population has access to electricity). Long-distance gas pipelines are few, although construction is proceeding on the West-East pipeline to bring gas from the Tarim Basin in Xinjiang province to Shanghai and other eastern destinations. Thousands of small coal mines also serve mainly local needs, although vast amounts of coal are also shipped east and south by rail and coastal barge.

Furthermore, with few exceptions, energy is provided by SOEs, many now owned by provinces or municipalities. Oil production and distribution has been concentrated in three large national SOEs, mostly non-competing. Electricity production is typically provided by provincial or municipal enterprises. China is having difficulty placing SOEs under tight budget constraints; they have historically had ready access to bank credit, and while banks (all themselves SOEs) are under instruction to make loans only on a commercial basis, local politics continues to play an important role in credit allocation,

especially (I suspect) to energy firms.

China is notably inefficient in its use of energy. Table 2 provides one indicator, the ratio of GDP per unit of primary energy consumed. It can be seen there that on this measure (which incorporates differences in economic structure as well as energy efficiency per se) China in 2000 produced less than one-third in final output per unit of energy than did the United States, and only 15 percent of Japan (the most energy-efficient among the rich countries). China's energy efficiency is expected to improve over the projection period to 2025, at 2.4 percent a year, compared with 1.5 percent for the United States, but even then will remain under 40 percent of US efficiency (and under one quarter of Japan's).

According to the IEA, China's coal-fired generating plants operated at only 28 percent efficiency, 26 percent below the 38 percent average of the OECD countries in the late 1990s (IEA, p.204), despite more extensive pollution controls on the OECD plants. Generating plants in China were much smaller, coal consistency was uneven, and plants were down more often. New plants in China are typically much larger than average, over 300MW, but remain well behind world best-practice.

China's authorities are well aware of their energy needs, problems, and constraints. They acknowledge that energy should not simply serve the requirements of growth, but should also take into account cost, environmental factors, and security. They also acknowledge the need to separate more sharply policy formulation from regulation and supervision (at all levels of government), and the need to move to price-incentives based competitive markets subject to regulation to protect consumers from natural monopolies, particularly in final distribution, and taking into account environmental externalities (see statements by Qingtai Chen and Jiange Li of the Development Research Center at the China Development Forum on China's Energy Strategy and Reform, Beijing, November 2003). As is often the case in China, the difficult task is in translating coherent principles into actual practice.

One part of China's strategy seems to be to back out coal as rapidly as investment in

gas, nuclear, and hydro permit, and to charge consumers of electricity what is necessary to finance the required investment.

A Carbon Tax

The basic proposal is for China to impose a tax on burning fossil fuels in proportion to CO₂ emission, i.e. in proportion to the carbon content of the fuels. One would also want to include making cement, which in addition to the energy consumed emits CO₂ from the breakdown of carbonates, and in 2000 accounted for emissions of over six percent those arising from the energy sector (Johnson, 2003,p.6). The tax would be heaviest on coal, which is about 75 percent carbon by weight, lighter on oil. The tax would also be levied on natural gas, which is about 75 percent carbon by weight, but much lower than coal in terms of useful energy produced. The tax would thus discourage the use of all fossil fuels, relative to alternatives, with coal being discouraged the most, gas, which emits about half as much CO₂ as efficient coal per unit of power, the least.^v

Administratively, the tax would be most easily levied at the key bottlenecks in the fossil energy system: trunk pipelines for gas, refineries for oil, railroad heads for coal. China has thousands of small coal mines producing mainly for local consumption, and these would be difficult to reach except by local authorities. China supposedly closed down over 30,000 such mines in the late 1990s, as being unsafe, polluting, and inefficient. During the fuel crisis of 2003 many were re-opened, some with approved work-safety improvements, others illegally. Presumably many of these mines will be closed again as the rationalization and efficiency of China's energy system improves.

The idea of imposing a carbon tax is in complete harmony with China's official energy strategy, adopted in 2002, which in the words of one senior Chinese official (Wu Yin, Deputy Director-General of the Energy Department of the National Development and Reform Commission, 4/23/04) "will constantly improve the macro control and power market regulatory system, deepen the power system reform, and try hard to build up *an*

incentive mechanism for resource conservation, efficiency improvement, environmental protection, and development promotion." (Italics added) Creating appropriate incentive systems for efficiency and environmental protection are constantly mentioned by Chinese officials, as is the need to get the price of coal up to reflect its full social costs, including environmental costs (e.g. CDF 2003, p.93). A tax on an environmentally damaging emissions fits perfectly with this objective.

Several important questions arise with respect to a carbon emissions tax:

- 1) At what level should the tax be set?
- 2) How much will introduction of a tax influence behavior of households and firms?
- 3) What will be the impact on government revenue, and how will it be used?
- 4) What will be the macroeconomic impact of such a tax?
- 5) What will be the impact of the tax on long-run growth of the economy?

Each of these questions will be addressed in turn.

The tax rate should be set high enough to reduce CO₂ emissions significantly. But by how much? We do not know the answer to that question, because much controversy surrounds the extent of likely global warming under business as usual; the damages that such warming would actually cause, after human adaptation to climate change; and the costs of such adaptation. Various attempts have been made at a cost-benefit analysis (see Nordhaus-Boyer 2000, IPCC Working Group III, 1996). There is no general consensus on what needs to be done, and how rapidly; indeed there is wide discrepancy among respectable analysts. Thus the process will inevitably involve trial and error, both with respect to the objective of reducing emissions and the impact of any given tax on such reductions. For purposes of analysis, this paper will be calibrated on \$23 per ton of carbon emitted (= \$6.20 per ton of carbon dioxide, 27 percent carbon by weight -- unhappily both measures are used in the literature, carbon by the IPCC, CO₂ by the Kyoto Protocol).

Impact on emissions

Will a rise in the price of fossil fuels brought on by the tax lead to a reduction in carbon emissions by firms and households? It has already been noted that at present China's energy system is highly fragmented and often subject to price control. Furthermore, electricity costs are "rolled in" to a final charge to the ultimate consumer, regardless of the source of the electricity. Price signals do not drive either consumer behavior or investment. For purposes of this paper, however, we assume that the Chinese authorities succeed during the next decade in their stated objective of creating a competitive energy market, albeit one that is regulated to prevent exploitation of natural monopoly; that a national or at least large scale electricity grid will be created; that the prices charged will cover costs; and that the costs will include consideration of environmental damage arising from the energy system, including (but not limited to) CO₂ emissions. Under these circumstances, imposition of a carbon tax will raise the prices of fossil fuels and electricity generated with fossil fuels, and both intermediate and final energy users will thus experience price incentives to reduce their consumption of carbon-emitting fuels.

International experience suggests that higher prices can in the long run have a substantial impact on consumption of energy. While demand may be highly inelastic in the short run, over a period of time people adjust their behavior to higher prices. Following the large world oil price increases of 1974 and 1979-80, for instance, demand for oil dropped steadily in the United States, Japan, and Europe. High prices for gasoline lead people to buy smaller, more fuel-efficient automobiles than they otherwise would do. Household appliances have become much more efficient than they once were, as have jet engines and a host of other energy using equipment. Buildings are now constructed with energy consumption in mind, to a much greater extent than was true before the 1970s. And so on.

Limited experience in China with pollution taxes or fines re-enforce the observation that users respond to financial penalties by reducing the offending activity. Wang and Wheeler (1999) have shown that effluent charges and fines, levied locally within the framework of a national policy, have significantly reduced air and water pollution in China

during since 1987. China is also experimenting with SO₂ emission charges, to cut down on acid rain and air pollution.

The channels by which a carbon tax might reduce carbon emissions are several:

First, households can be expected to reduce their spending on energy directly, and on energy-intensive products, both of which will become more expensive after imposition of the tax. Thus less electricity (than otherwise) will be consumed, less coal or gas for heating, less gasoline. More insulation will be installed. Consumers will pay more attention to the life-time costs of appliances, automobiles, apartments and other long-term purchases as they become conscious of the higher energy costs, and shift their purchases to products with lower energy usage.

Second, firms, sensitive to this shift, will concentrate more on products that are energy efficient. More importantly, they will cut back on their own use of energy in production by looking for ways to improve energy efficiency -- a process that was observed extensively in the United States following the four-fold increase in oil prices in the mid-1970s. Developers will use more energy-efficient building materials, will install more insulation, and will orient their developments to minimize the impact on dwellers of cold winter winds and maximize the impact of winter solar heating in northern latitudes, while maximizing the use of breezes and minimizing solar heating in southern latitudes (for examples of the possibilities, see Glicksman, 2003). Industrial boilers in China are notoriously inefficient; higher energy prices may drive some firms out of business, but most will adapt by improving their efficiency. As noted above, power generation in China, heavily dependent on coal, does not get maximum advantage of the latent heat in coal; big gains in efficiency are possible, although in some cases only by substituting large, modern generating plants for older, small ones -- something that will become possible with the development of extensive grids, a Chinese objective.

Finally, low carbon-emitting fuels may be substituted for high-emitting fuels in energy-using processes, e.g. nuclear, hydro, wind, or gas for oil and coal in electricity

generation. In China this will probably be the least important of the three channels, at least during the next two decades, for two reasons. First, coal is far the cheapest way to produce electricity in China, given the availability of coal relative to oil and gas (both of which have strongly competing demands), and will remain so unless carbon taxes are very high.^{vi}

Second, China plans to build nuclear, hydro, and some gas plants as rapidly as possible in any case, and it is unlikely in the near future that relatively more expensive coal can accelerate those plans. China has ample wind resources, especially in Inner Mongolia, and plans are in the works for developing them; but their quantitative contribution is likely to remain small for the next two decades.^{vii}

One informed but still rough estimate of the impact on CO₂ emissions in China can be constructed from a study by the US Council of Economic Advisers of the costs to the United States of implementing the Kyoto Protocol under different assumptions about the possibility of trading permits (CEA, 1998). If the United States were to implement its Kyoto target alone, CEA estimated, the cost would be about \$200 per ton of carbon. With trading among all the Annex B countries, the trading price (= marginal cost of avoiding another ton of carbon emissions) would drop to \$56, largely because both Russia and Ukraine were given targets that turned out to be generous relative to their circumstances, so were expected to have many used emission rights to sell to others. If somehow China and India could be included within the trading regime (not envisioned in the Kyoto Protocol), the trading price of implementing the Kyoto targets would drop further to \$23 a ton, reflecting the great possibilities in those two countries for improving energy efficiency. If we assume that the IEA's World Energy Outlook 2000 reflected a plausible trajectory for Annex B countries to 2010, the mid-point of the target period, then to meet their Kyoto targets Annex B countries would have to cut their CO₂ emissions by 11.4 percent from the 2010 projection (which we now believe was too high for Europe, too low for the USA), or by 1526 million metric tons (calculated from IEA 2000, Table 10.1), and that China accounted for half of this if allowed access to the Annex B trading market, China would

have achieved a 19 percent reduction from its 2010 carbon emissions as estimated by the EIA in 2004. Thus on the basis of this estimate a tax of roughly 100 percent on coal (assuming a coal price of \$32 a ton with 75 percent carbon content), and correspondingly less on oil and gas per available btu (oil emits about three-quarters, and gas half that of an efficient coal power plant per unit of electricity), would lead to roughly a 20 percent reduction in China's carbon emissions.

Johnson (2003, p.7) reckons that by 2020 GHGs from China's energy sector could be reduced by 16 percent through greater efficiency, and an additional 12 percent through development of alternative energies, but he does not indicate the actions that would be required to achieve these results.

Ho and Jorgenson (2004) examine the impact of fuel taxes in China for the purpose of reducing health-damaging pollution. Their analysis is applicable to CO₂ emissions. They produce a multi-sectoral model of the Chinese economy, with exogenous technical change and savings rates, calibrated to Chinese data for 1997. They then notionally impose fuel taxes in relationship to the damage to health from pollutants caused by use of coal, oil, and gas, gas being negligible and oil being about 45 percent of coal, per ton (H&J, Table 7.9, implying about 22 percent of coal per useful btu). A 35 percent tax on coal (1.2 percent on oil) would reduce coal production by 30 percent after 20 years, compared with a baseline (no tax) projection; carbon dioxide emissions would be reduced by 19 percent (H&J, Table 8.6, and communication from author). (The impact of a fuel tax is non-linear, in that a 23 percent tax would reduce coal production by 22 percent.)

Revenues

The impact of a carbon tax on tax revenues obviously depend on the tax rate, the enforcement of collection, and the behavioral responses discussed in the preceding paragraphs. There is of course a trade-off between revenue collection and social success of the tax in reducing emissions: the more successful the tax is in reducing carbon emissions,

the less revenue will be raised. Thus a carbon tax does not necessarily represent a permanent source of revenue; eventually carbon emissions from the energy system may be greatly reduced. However, such a tax is likely to raise revenues for many, many years, measured in decades. This aspect will appeal to ministers of finance.

We can use the calculation above, combined with EIA projections for 2010, to calculate the revenue available in that year if such a tax had been put in place in, say, 2000, to provide time for the many adjustments discussed in the preceding section to take place. If at \$23 a ton China would have reduced its carbon emissions by 19 percent from a projected level of 4063 mmt CO₂, China's emissions after imposition of the tax would be 2537 mmt. As noted above, the implied tax per ton of CO₂ is \$6.20. Thus the revenue collected in 2010 would be \$15.7 billion. EIA (2004) projects China's GDP in 2010 to be \$2228 billion in dollars of 1997, or \$3272 billion in 2010 dollars if the Chinese deflator, measured in dollars, rises by three percent a year. Thus carbon tax revenues on this calculation would be 0.5 percent of GDP, or about 2.5 percent of government revenues if the latter are 20 percent of GDP.

Demands for government expenditures are heavy in China, as is rivalry between municipalities, provinces, and the central government for new revenues. In 1998 the central government had available for central government use only 5.9 percent of GDP [WDR 2000/2001], extraordinarily low. Yet it has responsibility for national projects such as the long-distance highway system and the long-distance pipelines, re-capitalizing the banking system, developing the western part of the country (requiring large infrastructure expenditures), modernizing the military forces, and probably, in the final analysis, nationalizing parts of the social security and pension system. If the carbon tax were a central government tax (as it should be), it would augment significantly available central government revenues.

Macroeconomic Impact

Significant new taxes can have macroeconomic effects. However, in this case the macroeconomic effects would be negligible, for two reasons.

First, the tax could be introduced gradually. CO2 emissions and climate change is a long-term problem, not an urgent one. It is important to address it soon, but it is not necessary to create great short-run economic damage in doing so. Since many of the behavioral changes such a tax might bring about can take place only over a period of time, often involving different forms of investment (e.g. in energy efficient housing), what is important is to put economic agents on notice that the tax is coming, and perhaps drive the point home by introducing the tax, but at a rate lower than the target rate. The tax rate can then be raised every year to two until it reaches the target rate.

Second, of course, the revenues will not be withdrawn from the income stream. They will somehow be dispersed. They could be dispersed either as reductions in other taxes, a point taken up below, or more likely in the case of China would be used to cover central government expenditures, also to be discussed further below. As the taxes will be introduced gradually, the use of the revenues can also be planned ahead, so no macroeconomic shock need occur. Fuel taxes will of course reduce temporarily the real income of households, hence their consumption of goods and services. But the impact on aggregate demand can be neutralized by slow phase-in combined with parallel increases in government expenditures.

Impact on Growth

Some will be concerned that raising prices on energy will discourage economic growth, since energy is a critical input to all modern economies. The impact of a carbon tax on long-term growth is likely to be negligible, at least with the right complementary policies. The issue can be discussed under four headings; energy as a direct input to production; use of the carbon tax revenue; impact on the cost of capital and hence potentially on the rate of investment; and impact on international competitiveness and hence

potentially on export growth.

Energy is a key input to most aspects of modern economies, including agriculture. Surely raising the price of energy will discourage production? Recall, however, that in China for a variety of reasons energy is used very inefficiently, relative to actual practice in other countries. Thus the possibility often exists to produce the same output with a lower input of energy. Sometimes this change simply requires an adequate incentive (i.e. higher energy price); sometimes it requires the incentive plus new knowledge about better practice; sometimes it requires an incentive plus new investment in more energy-efficient structures or equipment. And of course investment requires funding. On the other hand, many energy-saving investments would yield handsome rates of return, particularly if energy prices were higher. So investment may be diverted from other destinations to energy saving, and on that account could lower growth. On the other hand, China must make huge investments in power generation -- \$67 billion a year 2001-2030 on one estimate (IEA 2003, p.353), over two percent of GDP -- to support its growth aspirations, and to the extent energy efficiency can be improved further, such investment could be reduced. The energy sector itself need not grow so rapidly, thus releasing both capital and labor to be used elsewhere in the economy, thus contributing to growth.

As noted above, the carbon tax will raise revenues. How those revenues are used can influence the rate of growth. If they are used to reduce growth-inhibiting taxes on capital, as Jorgenson suggests, the net impact might even be to accelerate growth. If, as is more likely, they are used to finance expenditures, the impact on growth will depend on the magnitude and growth-efficiency of the expenditures. Expenditures on transport infrastructure will presumably contribute to growth, as would expenditures on under-funded agricultural research and dissemination, or on education. Modernizing the PLA, in contrast, would not contribute much to growth. Thus the Chinese government would have substantial discretion over how much the carbon tax could be directed toward enhancement of growth.

A third channel of influence on growth would be through the cost of capital goods,

hence the real investment that could be undertaken for any given nominal level of investment spending. Raising the cost of capital goods, other things being equal, will reduce growth. Raising the price of energy would increase the cost of those capital goods that are high in direct energy content, such as construction steel and cement. The impact on capital goods prices would of course be mitigated to the extent, per the first point above, that as a result of the tax producers increased significantly the efficiency with which they used energy. It is even conceivable that capital goods prices fell, as efficiency improvements outweighed increased energy prices. Furthermore, in a sufficiently long run technical change can be expected to reduce prices again. There has been no secular decline in the real return to capital in rich countries, those on the technological frontier, as capital-saving technical change has compensated on average for the declining returns that might be expected to flow from the tremendous accumulation of capital that has occurred during the past half century.

Finally, higher energy prices, other things being equal, will increase the relative price of energy-intensive products, hence reduce competitiveness of such products on world markets. A serious loss of competitiveness could, through a variety of channels, reduce economic growth.

Here the international environment in which China imposes a carbon tax comes into play. Climate change is a global issue. While the impact may be uneven (and at this stage highly uncertain) across regions of the world, the concern is a global one. It is difficult to imagine China acting alone to limit GHG emissions. On at least one calculation, China may not expect much net damage from at least modest climate change, indeed might even be a small net beneficiary (Nordhaus and Boyer, 2000, p.160).

Thus, China is likely to introduce a carbon tax (as opposed to other pollution taxes) only in the context of an international agreement of some type that calls on all China's competitors to introduce similar taxes or comparable restrictions on carbon emissions that will have the effect, like a carbon tax, of raising the relative price of fossil fuels, especially

coal, and indirectly of all energy-intensive products. In such a setting, concerns about international competitiveness arising from the carbon tax should be minimal.

Table 1
China's Primary Energy Consumption
(quadrillion Btu)

	1990	2000	2010	2020	2025	2001-25 Growth (%)
Total	27.0	37.0	54.6	77.7	91.0	3.5
Coal	20.7	23.6	32.0	43.6	50.7	2.9
Oil	4.7	9.7	15.4	22.3	26.0	4.0
Nat. Gas	0.5	1.0	2.0	3.7	5.2	6.9
Nuclear	0	0.2	0.7	1.5	1.6	9.7
Hydro	1.3	2.3	4.2	5.9	6.8	3.8

Source: calculated from EIA (2004), Appendix A

Table 2
Energy Intensity
(\$ 1997 trillion per quad)

	1990	2000	2010	2020	2025	Change per year 2000-2025
China	15.9	30.3	40.8	49.9	54.7	2.4
USA	80.8	94.4	111.2	129.0	138.3	1.5
Japan	212.7	201.6	212.8	238.0	249.5	0.9

Source: calculated from EIA (2004), Tables A1, A3

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Endnotes:

i. The EIA also produces high and low trajectories for world energy use, and emissions, in addition to its reference case. On the high variant, China's primary energy consumption increases by 4.2 percent a year 2001-2025, on the low variant, by 2.7 percent. China's share of world energy consumption rises from 14.0 percent on the low variant to 14.9 percent on the high variant.

ii. Some Chinese are concerned with climate change, however, and the official Energy Research Institute has a Center for Energy, Environment, and Climate Change Research which seeks ways to reduce GHG emissions without compromising China's development objectives. See CDF 2003, pp.116-125.

iii. Normal units of measurement have been converted into quadrillion British thermal units (quads) at the following rates:

petroleum: 1 million barrels a day = 2.03 quads per year

coal: 1 million short tons = 0.0184 quads

gas: 1 trillion cubic feet = 1.034 quads

nuclear power: 1 billion kwh = 0.0105 quads

iv. China is expected to invest over 2001-2030 a total of \$795 billion in new power generation, compared with \$654 billion in the USA and Canada, \$525 billion in the European Union, and \$274 billion in Japan. IEA, 2003, p.353

v. For electricity generation conventional coal fired produces 962 metric tons of CO₂ emissions per GWh, fluidized bed production produces 961 tons, integrated gasification combined cycle produces 748, oil-fired produces 726 tons, and gas-fired produces 484 tons. From Owen 2003, drawing on IEA 1989.

vi. China's average incremental busbar costs per kwh are as follows: \$.038 for pulverized coal, .045 for natural gas combined cycle, .048 for clean coal, .053 for nuclear, .068 for hydro, all assuming that coal costs \$32 a ton and gas costs \$4 per GJ. Allowance is made for capital costs: \$700 per kwh for coal, \$550 for gas, \$1800 for nuclear, \$1500 for hydro. (Logan 2004)

vii. CDF 2003, p. 81, reports that 3-5 GW of wind capacity might be installed by 2010, and 10-30 GW by 2020, up from .46 GW in 2002.