2006

Effects of Economic and Environmental Reform on the Diffusion of Cleaner Coal Technology in China

Stephanie Ohshita

University of San Francisco, sbhshita@usfca.edu

L Ortolano

Follow this and additional works at: <http://repository.usfca.edu/envs>

Part of the [Environmental Health and Protection Commons](#)

Recommended Citation

Ohshita, S. B. and Ortolano, L. (2006). Effects of Economic and Environmental Reform on the Diffusion of Cleaner Coal Technology in China. In P. Ho and E. Vermeer (Eds.), *China's Limits to Growth: Greening State and Society* (73-95). Oxford: Blackwell [Wiley].

This Book Chapter is brought to you for free and open access by the College of Arts and Sciences at USF Scholarship: a digital repository @ Gleeson Library | Geschke Center. It has been accepted for inclusion in Environmental Science by an authorized administrator of USF Scholarship: a digital repository @ Gleeson Library | Geschke Center. For more information, please contact repository@usfca.edu.

Part 2. The ‘Technological Fix’: Greening Industry and Business

Chapter 4

Effects of Economic and Environmental Reform on the Diffusion of Cleaner Coal Technology in China

Stephanie B. Ohshita and Leonard Ortolano

INTRODUCTION

Coal is both the major fuel for China’s economic development and the major source of its severe air pollution. China’s reliance on coal for nearly three-quarters of its primary energy has contributed to local air pollution, regional acid rain and global climate change. At the same time, the country’s coal consumption has electrified its growing cities and helped Chinese steel and chemical industries to become international powerhouses.

This contribution considers how the intertwined issues of environmental reform and economic reform have affected efforts to reduce coal-related air pollution in China. Our analysis focuses on government efforts to promote the diffusion of cleaner coal technologies (CCTs) among industrial state-owned enterprises (SOEs). We utilize a framework of ‘fragmented authoritarianism’ (Lieberthal and Oksenberg, 1988) for our investigation of CCT-related policies, examining the changing relationships among central and local government actors and enterprises during the past decade of economic reforms. We also examine how economic reforms have influenced environmental policy development at the centre, environmental policy implementation at the local level, and the response of enterprises to these changing policies. Fragmented authoritarianism helps explain why, despite government efforts to promote technologies that reduce coal-related air pollution in China, the diffusion of CCT has been slow.

We argue that the poor diffusion of CCT has been due to: (1) conflicting interests in policy development among central government agencies; (2) tensions between central and local governments in policy implementation; and (3) a lack of strong incentives for enterprises to adopt CCT. Although solutions to China’s coal-related pollution problems require integrated planning of environmental, energy and economic policies, central government

decision making on CCT is fragmented. Promoting the diffusion of CCT requires active involvement of local governments, but policies do not yet address the shifting balance of power from central to local governments which has been spurred by economic reform. In addition, central government policies for CCT have not sufficiently considered the growing autonomy of SOEs nor the financial pressures they face from economic reforms.

Cleaner Coal Technology in China

The terms 'clean coal technology' and 'cleaner coal technology' encompass a wide range of equipment and methods aimed at reducing pollution from coal preparation and utilization.¹ Given the dominance of coal in China's domestic energy mix, CCT represents a pragmatic strategy for pollution reduction. Broadly speaking, CCTs can be divided into four categories according to the stage of coal flow at which they are applied: pre-combustion, conversion, combustion and post-combustion. Table 1 summarizes the technologies in each category, along with their environmental and energy objectives.

The pre-combustion technologies in Table 1 include coal washing, briquetting and coal-water mixture (CWM) technologies. Coal washing is the most widespread form of CCT in China; briquettes for residential use are also common. Among conversion technologies, coal gasification for the production of town gas has been on the increase in China and helps to reduce local air pollution in cities. With nearly 500,000 industrial boilers in China, improvements in combustion efficiency could produce significant environmental benefits. Flue gas desulphurization (FGD) technology, often referred to as a 'scrubber', is the main type of post-combustion CCT.

For illustrative purposes, we focus on two types of CCT in this contribution: coal washing, a pre-combustion technology; and FGD, a post-combustion technology. Coal washing has relatively low costs and yields multiple environmental and energy conservation benefits by reducing the sulfur and ash content of coal. However, waste water and sludge from coal washing must be managed properly to avoid serious water and land pollution problems. Compared to coal washing, FGD technology has high sulfur removal efficiency, but it is an end-of-pipe pollution control technology focused solely on the removal of sulphur dioxide (SO₂). Advanced FGD units can remove as much as 99 per cent of SO₂ but units are costly and consume large amounts of energy and materials. Capital costs of FGD technology may be ten times higher than coal washing technology, and operating costs are two to three times higher (CCPUA and EPRI, 2000).

1. We use the term *cleaner* coal technology to emphasize that coal-related pollution is reduced, not eliminated. Other options for addressing China's coal-related environmental problems include renewable energy and energy efficiency.

Table 1. Coal Flow and Cleaner Coal Technologies

COAL FLOW	TYPE OF CCT	EXAMPLES	OBJECTIVES
<i>Pre-Combustion</i>			
Preparation	Coal Preparation	Coal washing , process control technology	Remove debris, ash (20–50%), sulphur (40–50%); improve coal quality and combustion efficiency; conserve water
	Briquetting	Bio-briquetting, conventional carbonization briquetting	Shape coal for more efficient combustion; incorporate sulphur removal agent
Processing	Handling	CWM with sulphur removal	Improve ease of handling; incorporate sulphur removal agent; CWM as oil alternative in industrial boilers
<i>Conversion</i>			
Conversion	Liquefaction	Bituminous and brown coal liquefaction technology	Liquefied coal as an alternative to oil
	Gasification	Coal gas for towns and cities, integrated gasification combined cycle power generation (IGCC)	Gasified coal as an alternative to natural gas; reduce residential pollution (by using coal gas rather than direct coal combustion); improve efficiency and reduce pollution from electric power generation
	Coking	Improved coking technology, advanced pyrolysis technology, organic chemical production	Improve efficiency and reduce emissions of SO ₂ , NO _x , particulates, volatile organics, etc. from metallurgical and chemical industries
<i>Combustion</i>			
Combustion	High-efficiency Combustion	Circulating fluidized bed boiler (CFB), CFB with sulphur removal, pressurized fluidized bed combustion (PFBC)	Improve efficiency; reduce CO ₂ emissions; reduce emissions of SO ₂ , NO _x , particulates, and other pollutants
<i>Post-Combustion</i>			
Pollutant Control	Exhaust Gas Treatment	Flue gas desulphurization (FGD) , electrostatic precipitation (ESP)	Reduce emissions of SO ₂ (75–99%) and particulates
	Ash Utilization	Use of ash in fertilizer and bricks	Reduce solid waste

Note: Technologies examined in this paper are noted in **bold**.

Source: Ohshita (2003: 36).

The Fragmented Authoritarianism Model

For decades, Chinese scholars have used the 'fragmented authoritarianism' model to help explain policy design and implementation within China during post-Mao economic reforms (see, for example, Lieberthal, 1992; Lieberthal and Oksenberg, 1988; Wang, 1995). This model argues that, despite views of China as a strong, centrally-dominated developmental state, decision-making power in much of the Chinese bureaucracy is disjointed and fragmented. The model also holds that the fragmentation is structurally based and has increased during the reform period. Consequently, bargaining has become increasingly important in efforts to attain policy consensus. The following elements contribute to the fragmentation of authority within the Chinese administrative system:

- Organization of bureaucracies into hierarchical, functional systems (*xitong*) with vertical reporting relationships known as *tiao*. This structure allows authority in a particular policy arena, such as environmental protection, to flow vertically from the ministerial level (such as the State Environmental Protection Administration or SEPA) down through counterpart organizations (in this case, environmental protection bureaus or EPBs) at lower levels.
- Territorial or *kuai* reporting relationships in which a governmental organization at the sub-national level reports to the local governmental leadership at that level (for example, the reporting relationship of a municipal EPB to the mayor of the municipality).
- The bureaucratic ranking system, under which an agency with a particular rank is unable to exert authority over other governmental organizations having the same or higher rank.
- Fiscal decentralization, in which budgetary authority has devolved to local levels thereby enabling many local bureaucratic units to acquire 'extra-budgetary funds.'
- Decentralized decision-making authority, in which the central government has delegated increased responsibilities for decision making to local governments and enterprises in an effort to improve the economy.

The fragmented authoritarianism model has been most successfully used to explain decision making in economic bureaucracies, particularly at the central level government (Naughton, 1992). Bargaining behaviour resulting from the fragmented structure of public administration is most often observed when tangible resources are involved (such as large investment projects) and there is leeway in how a policy can be implemented (Lieberthal, 1992: 18). Scholars examining agencies at local levels of government and in non-economic policy arenas have provided further nuance and highlighted the model's limitations. For example, Walder (1992) emphasizes that bargaining between municipal governments and enterprises over financial flows stems not so much from

fragmentation of authority, but from efforts to reduce risks and provide equitable resource distribution during the transition from central planning to a socialist market economy. Manion (1992), in a study of personnel policy, finds that if a policy is vague or inconsistent with other directives faced by local government, it is unlikely to be implemented. This finding is supported by research on environmental policy implementation in China (Ma and Ortolano, 2000; Sinkule and Ortolano, 1995).

The fragmented authoritarianism model, along with some of its extensions and critiques, has explanatory power for the case of CCT-related policy design and implementation by China's environmental administration. Two aspects of the model are particularly useful in analysing the diffusion of CCT: the structure of bureaucratic authority; and changes in incentives that have accompanied fiscal decentralization and enterprise deregulation. As we will show, the outcomes of bargaining processes on a particular issue sometimes yield policy inconsistencies with significant consequences for the ability to diffuse CCT. We will also show that fiscal decentralization and enterprise deregulation have given industrial SOEs incentives to prioritize profit maximization, which sometimes comes at the expense of investments in environmental protection. Moreover, because of their ability to extract greater extra-budgetary funds from enterprises, local governments have financial incentives to prioritize economic development over environmental protection.

Subsequent sections of this contribution examine fragmented authoritarianism in the behaviour of three sets of actors pertinent to the diffusion of CCT: central agencies, local governments and industrial state-owned enterprises. The fragmentation of authority for energy and environmental policy among national ministries is discussed in detail in the next section. The analysis then considers central–local government tensions in policy implementation, which relate directly to the decentralization of authority for decision making in the fragmented authoritarianism model. The remaining sections examine changing incentives for SOEs to adopt two types of CCT: coal washing and flue gas desulphurization.

FRAGMENTED DECISION-MAKING AT THE CENTRE

Chinese central government decision making related to CCT is fragmented and dispersed among several ministries and commissions. In the absence of a single energy agency, the State Development and Planning Commission (SDPC) led broad policies on energy pricing and the structure of energy supply in the 1990s.² The Commission's policy is informed by the work of

2. In 2003, SDPC was transformed into the National Development and Reform Commission (NDRC). SETC was disbanded and its functions distributed among NDRC and other ministries. Supervision of industrial bureaus also shifted. We use SDPC and SETC in this contribution to reflect the names of the organizations during our period of analysis.

the Energy Research Institute (ERI), which is under SDPC control. Decisions on industrial structure and technology policy for energy-intensive enterprises were led by the State Economic and Trade Commission (SETC) and by industry-specific state bureaus (sometimes referred to as administrations) under SETC supervision, such as the State Bureau of the Coal Industry and the State Bureau of the Chemical Industry. Technology policy was also under the purview of the Ministry of Science and Technology (MOST), which promotes the acquisition, development, and dissemination of technology in China. Policies affecting the price of coal or commodities produced by coal-consuming enterprises must gain the approval of the State Price Bureau and the Ministry of Finance (MOF). Environmental policy that could drive the adoption of CCT is the responsibility of the State Environmental Protection Administration (SEPA).

Jurisdiction over CCT-related policies shifted during the 1990s, with the most significant changes occurring in 1998. The 1998 reforms sought to address some long-standing problems of China's central government administration: the overlap of responsibilities and competition among agencies, conflicts of interest caused by the mixing of government and business functions, and inefficiency due to overstaffing and excessively large government offices (CESTT, 1998). The number of ministries and commissions was reduced from forty to twenty-nine, and the number of staff was cut by half within the following three-year period. The 1998 restructuring gave prominence to environmental protection by elevating the former National Environmental Protection Agency (NEPA) to just half a rank below ministerial level. The former Environmental Protection Committee of the State Council, which had often advocated different priorities than SEPA, was disbanded (ERM China, 1998). While these were hopeful signs for strengthening of environmental administration, economic commissions, planning commissions, and industrial bureaus continued to have stronger connections to enterprises and greater influence over enterprise technology adoption.

Administrative restructuring has reduced, but not eliminated, fragmentation of central government policy making on energy and environment. This outcome is particularly evident in the efforts of SEPA to implement a programme of SO₂ fees that would give coal-consuming industries strong incentives to reduce air pollution, through the adoption of production process changes and end-of-pipe controls.

Tensions in Policy Development: The SO₂ Fee Programme

Since the beginning of the post-Mao period, China's environmental administration has advocated the collection of emission fees from enterprises discharging SO₂ and other pollutants in excess of national standards. If emission fees are set high enough, they can motivate pollution reduction in two ways. First, high fees can encourage enterprises to cut their emissions

Table 2. Key Chinese Policies Promoting FGD and SO₂ Fees

Year	Policy	Provisions Related to FGD and SO ₂ Fees
1982	Provisional Regulation on Collecting Fees for Pollutant Discharge	Set SO ₂ fees at 0.04 yuan per kg SO ₂ emitted in excess of standards.
1987	Air Pollution Control Law (original)	Established SO ₂ concentration standards; no specific FGD requirements.
1988	Provisional Regulation on Loans from Pollutant Fees	Allowed EPBs to loan pollutant fee money to enterprises for pollution control investments.
1992	Circular on Trial Collection of SO ₂ Fees	Launched trial collection of higher SO ₂ fees (0.2 yuan per kg SO ₂) in Guangdong and Guizhou provinces and in nine cities including Qingdao and Hangzhou.
1995	Air Pollution Control Law (revised)	Revised requirements, with a focus on SO ₂ control at power plants and large industrial enterprises; called for FGD if low-sulphur coal was not used, but did not contain strict requirements for FGD.
1996	Total Emissions Control Policy	Authorized NEPA to determine emission allocations for the provinces and to direct local governments to use permits to establish emission limits for enterprises under their jurisdiction. Stricter limits increased the need for FGD.
1997	China Trans-Century Green Project (Phase I, 1996–2000)*	Planned twenty-seven FGD projects at power plants in acid rain regions and cities with severe SO ₂ pollution.
1998	Two Control Zones Policy and Regulation on Thermal Power Plant Emissions	Formally established acid rain and air pollution control zones. Called for FGD at new power plants burning coal with S>1% and raised fees to 0.2 yuan per kg SO ₂ for all non-compliant enterprises in the two control zones.
2000	Air Pollution Control Law (revised)	Strengthened requirements for FGD at power plants.
2002	Tenth Five Year Plan for Environmental Protection	Reinforced requirements for SO ₂ control, including FGD.

Note: *In the Ninth Five Year Plan for Environmental Protection and Long-Term Targets for the Year 2010.

and meet national standards because doing so eliminates the need to pay fees. Second, revenues generated from emission fees can be used to subsidize enterprise adoption of pollution control equipment through grants or low-interest loans. The evolution of the SO₂ fees policy and the promotion of FGD is shown in Table 2.

After some early trials, fees on SO₂ and other pollutants in China were the subject of a 1982 regulation (State Council, 1982). The fee programme was expanded in 1988, when EPBs began to make loans of pollution fee money to support enterprises in installing pollution control equipment (State Council, 1988). Notwithstanding these regulations, the effects of the SO₂ fee programme were modest because the fees — 0.04 yuan (0.5 US cents)³ per kg of SO₂ — were much lower than the cost of installing and

3. Conversion based on a typical 1998 exchange rate of 8.32 yuan/US\$ 1.

operating control equipment. Enterprises found it cheaper to pay the fees and keep polluting rather than control pollution.

During the 1990s, NEPA urged that SO₂ fees be increased, but the State Council and other central government agencies resisted because of concerns about economic development. Although the State Council's Environmental Protection Commission supported the increase, it was opposed by both the State Price Bureau and the Ministry of Finance.⁴ NEPA made a small advance in 1992 when a fee of 0.2 yuan (2.4 US cents) per kg SO₂ was approved on a trial basis in two provinces and nine cities with severe air pollution (NEPA et al., 1992; State Price Bureau and Ministry of Finance; 2002).

NEPA's efforts to promote higher SO₂ fees and otherwise strengthen air pollution control requirements were given a significant boost in 1997 and 1998 when Premier Zhu Rongji and the State Council were briefed on the negative effects of air pollution on the economy. As one example of the economic costs of outdoor air pollution, Chinese researchers estimated that emissions of SO₂ and particulate matter caused an annual loss of 95 billion yuan (US\$ 11.4 billion) in terms of human health damages, a loss of 1.6 per cent of GDP (Gao and Li, 1999: 145). A widely cited World Bank study (1997) gave similar estimates. As a result of these and other economic studies, China's top leadership became increasingly interested in attempting to curb air pollution because of its adverse economic effects.⁵

Action came in January 1998, when the State Council approved NEPA's plan on the 'Two Control Zones' for acid rain and air pollution control (State Council, 1998; SEPA, SDPC, et al., 1998). The State Council's approval authorized the collection of SO₂ fees of 0.2 yuan per kg SO₂ beyond the 1992 trial areas. These fees were to be collected from enterprises exceeding emission limits within the acid rain and air pollution control zones (Minchener et al., 1999: 561; State Council, 1998). The higher fees have still not been widely implemented, however, even though they are below the cost of installing and operating pollution control equipment, because local officials are concerned about possible adverse effects on the economy.⁶ Local government resistance to collection of SO₂ fees led SEPA to issue another notice in 2000, emphasizing that the State Council had approved the higher fees of 0.2 yuan per kg SO₂ and that local governments must collect them (SEPA, 2000).

4. The fact that the Environmental Protection Commission supported SEPA's position is noteworthy because the Commission (disbanded in 1998) and SEPA (then NEPA) had frequently disagreed on environmental priorities and projects. See Vermeer (1998: 977).

5. Based on interviews by S. B. Ohshita with two researchers advising the State Council's National Resource and Environmental Protection Committee (headed by Qu Geping), Beijing, November 1998 and 1999.

6. Based on interviews by S. B. Ohshita with a senior SEPA official and three environmental researchers advising SEPA, Beijing, November 1998 and 1999; and with the manager of a chemical plant operating FGD equipment, Shandong, October 1998.

The struggle to implement the SO₂ fee programme illustrates how policy negotiations among central government agencies with different priorities resulted in weak policy signals and poor CCT diffusion. Without the higher SO₂ fees advocated by SEPA, industrial enterprises had little incentive to invest in CCT. Even after fees were raised, CCT diffusion was slowed because of local government resistance to implementing centrally-issued pollution control policies that were inconsistent with local development goals.

CENTRAL-LOCAL TENSIONS IN POLICY IMPLEMENTATION

Local implementation of central government policy — especially environmental policy — is crucial for the promotion of CCT. Local governments are obliged to carry out central government environmental directives, but they also have strong incentives to promote local economic development (Oi, 1999). This central-local tension is rooted in the organizational structure of China's environmental bureaucracy. Figure 1 illustrates the relationships among central and local government agencies relevant to CCT policy.

Local EPBs report vertically to SEPA (*tiao* relationship), but must also report horizontally to local industrial bureaus and planning commissions (*kuai* relationship). The necessity of working with pro-development agencies of local government can make it difficult for EPBs to achieve environmental goals. Often local agencies promoting economic development have larger budgets, more staff and greater political strength than local EPBs. Mayors or other high-ranking local officials can also strongly influence EPB activity. As a result, local agencies and leaders may win out over the EPB if central environmental directives appear to conflict with local economic objectives.⁷

Economic reforms of the 1990s intensified central-local government tensions linked to CCT. Policies promoting CCT call for investment in new technology by enterprises, especially SOEs. However, SOEs must have approval of their supervising government agency to invest in CCT. As more and more SOEs shifted from central government control to supervision by local governments, their financial performance became increasingly important to local governments. China's major tax reform in 1994, which redistributed tax revenues between the central and local government, made local officials especially keen on enhancing their budgets.⁸ Because they were allowed to keep a major portion of taxes from the enterprises they controlled, local governments had incentives to increase enterprise profits.

7. For further discussion, see Jahiel (1998); Ma (1997); Ma and Ortolano (2000); Sinkule and Ortolano (1995).

8. For details on the 1994 tax reform, see Cao et al. (1999). For local government response to tax reforms, see Oi (1999).

Figure 1. Central–Local Chinese Government Relations Pertinent to CCT Policy in the 1990s

Source: Authors, based on Ma and Ortolano (2000); Sinkule and Ortolano (1995). Names in parentheses reflect post-2000 changes in administrative structure.

The 1995 budget law gave local governments a further incentive to improve the financial performance of enterprises under their supervision. This law prohibited the central government from deficit financing its current account and it required all levels of local government to have balanced budgets (Cao et al., 1999). The 1994 tax reform coupled with the 1995 budget law made local officials scrutinize enterprise investments more carefully, especially investments in technology like CCT that might not generate a return during the local officials' terms of office.⁹

In general, the 1990s economic reforms aimed at industrial SOEs significantly reduced the ability of unprofitable enterprises to rely on government bailouts, and the reforms forced enterprises (and the local governments overseeing them) to face hard budget constraints (Cao et al., 1999; Lardy, 1998). Because the reforms also made it more difficult for SOEs to access credit, they discouraged many SOEs from engaging in pollution control activities that might reduce net revenues or require large loans.¹⁰ The implication for CCT

9. Because top-level local officials are typically assigned to a particular location for only a few years before being transferred, they tend to prefer investments with paybacks during their terms of office. See also BECon and PNL (1996).

10. Tightened monetary policy in 1993 decreased the rate of new loans to SOEs and subsequent banking reforms also made loan criteria more stringent.

adoption was that industrial enterprises only had incentives to adopt technologies that would enhance profits or improve their competitive advantage, such as coal washing technology. Technologies with extremely high capital costs — such as FGD — were not appealing, as they required hard-to-get loans.

The fragmentation of central government decision making pertaining to environment and development thus makes it difficult for the central government to send consistent policy signals encouraging enterprises to adopt CCT. Moreover, the impacts of reforms related to local budgets and supervision of state-owned enterprises have made both SOEs and the local governments that supervise them reluctant to invest in CCTs unless those technologies yield short-term profits.

CONFLICTING PRIORITIES, WEAK INCENTIVES: THE CASE OF FGD

This section examines how fragmented authoritarianism affected the diffusion of FGD, as dispersed decision making and agencies with rival objectives restricted the promotion of FGD. This case also shows that expensive, end-of-pipe pollution control technology is generally at odds with the economic interests of enterprises and local governments.

During most of the 1990s, China's central government did not have a consistent policy position on FGD. By 1998, when SDPC and the State Coal Bureau finally backed SEPA's push for FGD, economic reforms had diminished the ability of the central agencies to control local decision making, and local governments were not inclined to encourage investments that decreased enterprise profits. Consequently, FGD technology experienced limited adoption by Chinese power plants and almost no adoption by industrial enterprises.

With SO₂ emission levels rising and air quality worsening, NEPA (and later SEPA) determined that its goals for emission reduction and ambient air quality could not be met without strong controls such as FGD. NEPA's FGD requirements focused on power plants because they are the largest individual sources of SO₂.¹¹ Moreover, the contribution of electric power plants to total emissions of SO₂ in China has been growing. Between 1990 and 2000, SO₂ emissions from thermal power plants grew from 25 to nearly 50 per cent of the national total.¹²

Policies promoting FGD began with the 1995 revisions to the Air Pollution Control Law and subsequent SO₂ concentration standards (see Table 2 above). The push for FGD became stronger with NEPA's 1996 'Total Emissions Control Policy', which called for provinces and lower

11. SEPA's emphasis on FGD for power plants is similar to the approach for SO₂ control in other countries.

12. Emissions statistics from SEPA (1998b). For details on this estimate, see Ohshita (2003: Ch 9).

levels of government to control the total amount of SO₂ and other pollutants by issuing emission limits on individual sources. Control of total emissions heightened the need for FGD at large emission sources like power plants, but because of weak implementation of the total emissions control requirements, only a few FGD units were adopted.

The China Trans-Century Green Project (Phase I, 1996–2000), part of the Ninth Five Year Plan for Environmental Protection and Long-term Targets for the Year 2010, identified twenty-seven FGD projects to be undertaken in areas affected by acid rain and urban areas with severe air pollution (NEPA et al., 1997). Although the Trans-Century Green Project also called for FGD at large industrial enterprises, no specific projects were listed. With the approval of NEPA's 'Two Control Zones' policy by the State Council and the issuance of new thermal power plant SO₂ standards in 1998, the regulatory push for FGD at power plants was strengthened. The 1998 regulations required FGD at *new* power plants burning coal with sulphur content above 1 per cent. However, the regulations did not explicitly require FGD at *existing* power plants or large industrial enterprises. Local governments were given discretion to decide whether existing enterprises should install FGD.

NEPA's promotion of FGD was resisted by both industry and government, beginning with other central government agencies during the policy-making process. The Ministry of Finance, SDPC, SETC and the former Ministry of Electric Power wielded greater bureaucratic power than NEPA; when differences emerged, the other ministries usually got their way in policy decisions. In the case of high-cost FGD, there was tension between NEPA's pollution control goals and SDPC's economic development objectives. NEPA's desire to cut power plant SO₂ emissions with FGD also conflicted with efforts of SETC and the former Ministry of Electric Power to rapidly expand electric power production during the 1990s (Vermeer, 1998). Unlike some other cleaner coal technologies, FGD lowers profits by raising capital and operating costs. Flue gas desulphurization was also at odds with SDPC and SETC energy efficiency goals, as FGD operation consumes large quantities of energy.

The limited support for FGD that eventually emerged during the 1990s can be attributed to the small area of overlap between NEPA's goals and those of other central government agencies. Estimates of the costs of pollution damage indicated that SDPC objectives for macro-economic development would be served by some level of SO₂ control, including FGD. Flue gas desulphurization would also enable new power plants to fire readily available domestic coal rather than expensive and less-abundant natural gas; the coal option was favoured by SDPC, SETC and the former Ministry of Electric Power.¹³ But SDPC estimates of FGD cost led it to plan for FGD at only one-quarter of new power plants in the Ninth Five Year Plan, not for all new plants as NEPA had suggested (US Embassy Beijing, 2000).

From the perspective of Chinese state-owned enterprises, FGD is unappealing in terms of economics, operations and management. FGD can increase capital costs of a new power plant by 15 to 20 per cent, and it has high operating costs (Ohshita and Lu, 1996: 41). For industrial enterprises outside of the power sector, cost increases can be even more dramatic. Because it is an end-of-pipe pollution control device, FGD offers no process benefits. Operation is complex, maintenance is demanding and re-use or disposal of waste sludge is problematic. Furthermore, FGD technology is not available domestically and must be imported, which requires identifying foreign vendors, obtaining foreign credit, completing tedious customs procedures, and working around language barriers during training. Economic reform pressures on SOEs to improve financial performance have only intensified enterprise resistance to FGD. In short, enterprises are not likely to adopt FGD if they can avoid it (Ohshita and Ortolano, 1999, 2002).

Even when forced to adopt FGD by regulation, Chinese SOEs have had difficulty obtaining the necessary funds to purchase and operate the equipment. During the 1990s, little financing was available domestically. Government investment in FGD was small and banks were generally unwilling to provide loans for pollution control equipment as expensive as FGD. The SO₂ fee programme did not generate NEPA's desired level of funds for investment in air pollution control equipment, because the fee level was low and (as described above) fees were not collected regularly by EPBs.

The limited diffusion of FGD that did occur in China during the 1990s was accomplished primarily with concessional financing. The World Bank, the Asian Development Bank and the Japanese government have been the main sources of capital funds for FGD at Chinese power plants (Evans, 1999). Japan's Green Aid Plan appears to be the only source of foreign financing for FGD at Chinese enterprises outside the power sector (Ohshita, 2003; Watson, 2002). With FGD requirements in the 2000 revisions to the Air Pollution Control Law, and another surge in power plant construction in 2004, conditions for wider diffusion of FGD equipment in China are beginning to emerge. Today, most equipment is made domestically and costs have dropped to 400 yuan/kg.

CHALLENGES IN CO-ORDINATING ENVIRONMENTAL AND ECONOMIC REFORM: THE CASE OF COAL WASHING

Despite government efforts to promote coal washing, the production of washed coal in China experienced ups and downs during the 1990s. This was the result, in part, of dispersed bureaucratic decision-making structures

13. Chinese energy policy began to promote use of natural gas in the late 1990s, but coal-fired power plants are still seen as a short-term necessity.

and difficulties in co-ordinating economic and environmental reforms. Our examination of coal washing technology highlights the difficulties of creating timely incentives for technology adopters during periods of dynamic reform, such as coal pricing liberalization and coal industry restructuring. The incentives for Chinese coal mines to adopt and utilize coal washing technology were strongly influenced by these economic reforms.

Coal Industry Restructuring and Coal Pricing Reforms

China's coal mining industry has been characterized by four main ownership types: large state-owned mines (managed by the central government until 1998); small- and medium-sized state-owned mines managed by local governments; small, rural collective mines (mines that are township and village enterprises, or TVEs); and private mines (IEA, 1999b; Thomson, 1996). The latter two types are often referred to as non-state mines. Figure 2 presents trends in coal production by these four types of mine ownership. In the early 1980s, more than half of China's coal was produced by the large, centrally-managed state-owned mines. Poor performance of the coal industry in the 1980s, accompanied by coal and electricity shortages, prompted the central government to relax ownership restrictions and encourage TVEs and other types of owners to expand production (IEA, 1999b). As a result,

Figure 2. Chinese Coal Production by Ownership Type

Source: Based on LBNL (2004: Table 2B.1); *AsiaPulse News* (2002, 2004); Xinhua News Agency (2002).

growth in Chinese coal production from the mid-1980s to the mid-1990s came primarily from non-state mines.

Energy, particularly coal, was one of the last factors of production to be released from strict central planning by the Chinese government. Until the early 1990s, coal prices were controlled by the government and kept low in order to spur economic growth and prevent hardships for residents using coal for heating and cooking. While this policy benefited coal consumers, it caused the coal mining industry to become the largest loss-generating industrial sector of the Chinese economy (Rawski, 1994).

As a first step in coal pricing reform, in 1993 the central government established a dual pricing system, whereby state-owned mines sold at a low, government-controlled price, and township and village mines sold at a market-determined price (IEA, 1999a: 104). As market prices rose to nearly twice the artificially low state price, state-owned mines continued to experience heavy losses; nearly 90 per cent of state-owned mines reported losses in 1993 (IEA, 1999b). The dual-pricing system also generated a great deal of corruption as low-priced state coal was illegally sold at higher market rates (Thomson, 1996).

In 1994, state-owned mines were allowed to sell a portion of their coal on the market. Despite this change, 72 per cent of state-owned coal mines still lost money in 1996, prompting the central government to liberalize all coal prices. With coal in high demand domestically and international oil prices boosting coal prices, many large state-owned mines began to move into the black in 1997 (IEA, 1999b).

The 1997 rise in coal prices was short-lived, however. The Asian financial crisis, coupled with Chinese domestic economic changes, led to an unexpected downturn in coal demand. After decades of demand exceeding supply, China experienced a coal glut. The small collective mines were most immediately affected, and their production fell the same year. The decline in demand was accompanied by a drop in coal prices in early 1998. As losses began to mount, the government announced an overhaul of the coal industry. The ninety-four large state-owned coal mines were transferred from central to local management, mostly to the provincial level. The 2,500 smaller mines owned by local governments were directed to improve efficiency. Of the 75,000 small mines run as TVEs, 25,800 were slated for closure in an effort to balance supply and demand, improve the overall efficiency of the industry, and reverse the drop in coal prices (IEA, 1999b).¹⁴

At the end of 2001, coal prices finally began to rise and the state-owned mining sector as a whole began to generate profits again (Xinhua News Agency, 2002). Increased demand for Chinese coal exports and an upturn in

14. The central government's efforts to close small mines, for both economic and environmental reasons, have met with local resistance, as the mining industry is one of the largest employers in China. Closed mines continue to be re-opened illegally, a problem SEPA (1998a) refers to as 'glowing embers re-kindling'.

domestic demand helped the industry. Continuing efforts to restrict small non-state mines reduced excessive supply and generated some improvements in coal quality and mining safety. However, a 2004 surge in domestic and international demand has again raised safety and quality challenges for China's coal industry (*AsiaPulse News*, 2004).

Policies Promoting Coal Washing

Table 3 summarizes key Chinese policies promoting coal washing technology during the 1990s. In 1994, the former Ministry of the Coal Industry announced its goals for expanding the use of CCT, including coal washing technology (Zhu and Yu, 1999). Promotion of coal washing in 1994 coincided with the second year of the dual pricing system for coal and the Ministry's efforts to improve coal quality and the profitability of large state-owned mines. In 1995, revisions to the Air Pollution Control Law also encouraged adoption of coal washing technology and the use of washed coal by industrial enterprises (Hao, 1996). In 1996, NEPA, with approval by the State Council, began a drive to decrease production of low quality coal

Table 3. Key Chinese Policies Promoting Coal Washing

Year	Policy	Provisions Related to Coal Washing
1994	CCT Plan	Ministry of Coal Industry announced its CCT Plan, including coal washing.
1995	Air Pollution Control Law (revised)	Encouraged coal washing and use of washed coal by industrial enterprises.
1996	'15 Smalls' Policy	Called for the closure of small mines, many with high-sulphur coal; reduced competition can help improve adoption of coal washing technology by medium and large mines.
1997	Ninth Five Year Plan for Chinese Clean Coal Technologies and Development Programme to the Year 2010	Coal washing identified as one of fourteen technologies; viewed as fundamental CCT for China.
1997	Ninth Five Year Plan for Environmental Protection and Long-term Targets for the Year 2010	Called for coal washing as one of several measures to control SO ₂ and particulate matter air pollution.
1997	China Trans-Century Green Project (Phase I, 1996–2000)	Contained a few coal washing projects, representing a small subset of the national CCT plan.
1998	Two Control Zones Policy for Acid Rain and Sulphur Dioxide Control (including SO ₂ fees)	Banned the opening of new mines with coal having >3% sulphur; restricted existing mines with >3% S; called for new or expanding mines with >1.5% S to install coal washing technology; called for existing mines with >1.5% S to adopt coal washing in stages.
2000	Air Pollution Control Law (revised)	Reinforced requirements for SO ₂ control, including coal sulphur restrictions.
2002	Tenth Five Year Plan for Environmental Protection	Further promoted coal washing, as well as fuel switching.

by closing small non-state mines (State Council, 1996). Targets for growth in coal washing appeared in 1997, as part of the Ninth Five Year Plan (Du and Liu, 1999). From a coal washing rate of roughly 25 per cent in 1995, the central government planned to increase the rate to 30 per cent by 2000 and to reach 40–50 per cent by 2010 (JCOAL, 1998).

The strongest policy push for coal washing came in 1998, when the State Council approved SEPA's Two Control Zones policy (State Council, 1998; SEPA, 1998b). The policy required new and existing mines in the acid rain control zone and the air pollution control zones to adopt coal washing technology based on the sulphur content of mined coal. Local governments were forbidden to issue permits to proposed new mines whose coal sulphur content would be above 3 per cent. Existing mines with a coal sulphur content greater than 3 per cent were to be closed or have their production restricted. As detailed in Table 3, requirements for mines with lower coal sulphur content were less strict.

Policies promoting coal washing reflect increased co-ordination by central government agencies in response to their overlapping economic, energy and environmental interests and objectives in the late 1990s. When coal pricing liberalization and coal industry restructuring encountered an unexpected downturn in coal demand, the economic and industry ministries gave priority to the promotion of coal washing and closure of small non-state mines, which was consistent with SEPA's efforts to curb coal-related air pollution. As shown below, coal washing increased as the different priorities of central government agencies became more closely aligned and bureaucratic co-ordination improved. The trend in coal washing during the 1990s points to the benefits of co-ordinating economic and environmental reforms, so as to create consistent policy signals and incentives to which enterprises can respond.

Incentives and Barriers to Coal Washing

China met some of its goals for coal washing during the 1990s: in percentage terms, it achieved its target of 30 per cent by 2000. But the production of washed coal in absolute terms (Mt/year) did not reach levels hoped for by Chinese officials. Figure 3 illustrates trends in the production of washed coal, based on data from China's large state-owned mines (LBNL, 2004). Coking coal is the dominant form of washed coal, and is used by the iron and steel sector. A smaller share of washed steam coal is used mostly by electric power plants (CCPUA and EPRI, 2000: 3–10). Between 1980 and 1990, the production of washed coal at large state-owned mines rose slowly, encouraged mainly by government subsidies and directed by central planning. After a slight dip in 1991 and 1992, production rose in 1993, coinciding with the liberalization of coal prices. In 1997, washed coal production by the large mines reached an all-time high. In 1998 and 1999, production of washed coal fell sharply, following declines in export and domestic demand,

Figure 3. Production of Washed Coal By Large State-Owned Mines

Source: LBNL (2004: Table 2B.10); *AsiaPulse News* (2002, 2004); Xinhua News Agency (2002).

as well as the drop in coal prices. By 2000, the production of washed coal was on the rise again, and by 2002 production had surpassed the 1997 peak.

The price that mines are able to charge for washed coal is a key determinant in their decision to adopt and operate coal washing technology. While coal prices vary substantially in China depending on the destination of the coal, with transportation costs accounting for as much as 70 per cent of the delivered price (World Bank, 1997), we can make a few generalizations. When coal prices were depressed, as they were before the 1996 price liberalization and during the 1997–99 glut, the price differential between washed and unwashed coal was substantial. For example, when the run-of-mine price for *unwashed* coal (that is, the price of coal at the mine, before transport and delivery) was around 100 yuan (US\$ 12)¹⁵ per ton, the price of *washed* coal was an additional 50 yuan (US\$ 6) per ton (CCPUA and EPRI, 2000). Thus the run-of-mine price for washed coal was 50 per cent higher than the price for unwashed coal. In terms of the price of delivered coal, which is the price most directly experienced by the coal consumer, the difference is smaller but still notable: prices for delivered washed coal were 10 to 20 per cent higher than those for unwashed coal.

15. Conversion based on a typical 1998 exchange rate of 8.32 yuan/US\$ 1.

Demand for washed coal — another determinant in a mine's decision to adopt and operate coal washing technology — has been strong in the steel and electric power sectors, but generally weak in other industrial sectors. Many industrial enterprises were unable to use washed coal because they had out-moded boiler technology (CCPUA and EPRI, 2000; Fang et al., 1999). In addition, enterprises that were not pressed to meet SO₂ standards may not have felt the need to pay 10 to 20 per cent more for washed coal. As a result, demand for washed coal was generally low outside the steel and electric utility sectors, and many mines were not able to charge enough to cover the additional production costs for washed coal, especially washed steam coal (JCOAL, 1998).

Mines that did have incentives to operate coal washing facilities during the 1990s were primarily large state-owned mines producing relatively high quality coal for export or for sale to domestic steel plants and electric utilities. In contrast to these large mines, the many small and medium-size coal mines in China had weaker incentives: small Chinese mines operate at a low technological level and cannot take advantage of economies of scale.¹⁶ In general, small mines produce low quality coal and sell it locally; they do not compete in higher-priced export markets. Because of their size, small mines tend to sell to small enterprises that are less likely to purchase washed coal. With limited technical resources, modest finances and limited demand for washed coal, small mines generally did not adopt coal washing technology during the 1990s. Recognizing the weak incentives and capabilities at small mines, some researchers have suggested that local governments should support the construction of centralized coal washing facilities that use simple technology (Ohshita, 2003).

The promotion of coal washing was thus affected by fragmented decision making in the Chinese bureaucracy. While there was a trend toward greater co-ordination among central government agencies, and although the interests of economic, industrial and environmental ministries were increasingly overlapping at the end of the 1990s, decentralization made it more difficult for the centre to push its agenda at the local level. Data on coal washing show that production of washed coal became more closely linked with the market as the reforms progressed. As coal pricing reform and coal industry restructuring changed incentives for state-owned mines, the decisions of mines and local government to produce washed coal became more heavily influenced by economic signals. Coal washing is likely to increase as industrial modernization enables more enterprises to improve their combustion technology and realize the benefits of washed coal. However, as long as small mines and small industrial coal consumers continue to exist in large numbers, technologies and implementation efforts targeted at small-scale enterprises will be needed to realize widespread air quality benefits.

16. This was emphasized in author interviews with officials at the China Coal Research Institute, Beijing, November 1998 and 1999. See also Smil (1989, 1998).

CONCLUSIONS

China's experience with CCT demonstrates some degree of greening of the Chinese state, whilst highlighting that significant effort is still needed to reconcile environmental protection with economic development. Policies on the closure of small coalmines and limits on coal sulphur content are positive examples of co-ordination of central government plans for energy, environment and economic development — consistent with a 'win-win' ecological modernization paradigm. In contrast, fragmented authority of central government agencies during policy formulation on SO₂ fees contributed to the poor diffusion of FGD. Improved co-ordination among central government agencies can provide clear and consistent signals to both local officials and enterprises. Linking economic policies with environmental goals can promote adoption of cleaner technology by emphasizing economically-favourable approaches (for example, improved fuel quality and energy efficiency) that simultaneously reduce energy-related pollution and promote economic development.

The CCT experience also shows that central agencies have encountered difficulties with policy implementation and enforcement by local governments. As a consequence of economic reforms during the 1990s, especially the imposition of hard budget constraints and increased market liberalization, local governments prioritized improving the economic performance of the enterprises in their jurisdiction. Enforcement of environmental policies generally received lower priority. This difficulty with enforcement has two implications. First, local government leaders need incentives that reward them for implementing national environmental policies. Such incentives could be provided, for example, by changing the tax treatment of investments in cleaner technology, or by increasing the emphasis on environmental achievements within China's formal system for evaluating the performance of government officials. Second, central government intervention is still needed to counter market signals that lead to actions with negative environmental impacts.

Finally, the greening process is only beginning to extend to Chinese industry. To improve the diffusion of CCT, regulatory incentives for enterprises need to be augmented. During the 1990s, low emission fees and weak implementation of some air pollution control requirements provided little motivation for enterprises to invest in CCT. This could change by increasing SO₂ fees to levels that are comparable to the costs of installing and operating equipment with lower emissions. In addition, domestic financing packages (such as tax breaks and low-interest loans) could spur investments in pollution control by enterprises, and encourage further development of enterprises that manufacture low-cost CCT equipment within China. Wider dissemination of information on the economic benefits of cleaner coal technologies could also promote technology diffusion and ecological modernization among Chinese enterprises.

Acknowledgements

The research on which this contribution is based was supported financially by the US National Science Foundation, the UPS Foundation, the John D. and Katherine T. MacArthur Foundation and Stanford University's Institute for International Studies. The authors are grateful for field research assistance from the Environmental Engineering Department of Tsinghua University and the Beijing Environment and Development Institute of the People's University in China, as well as assistance from the Japanese Ministry of Economy, Trade and Industry, and the New Energy and Industrial Technology Development Organization. We also wish to acknowledge invaluable assistance from Mara Warwick in sorting through Chinese regulations and government restructuring.

REFERENCES

- AsiaPulse News* (2002) 'Profile: China's Coal Industry', *AsiaPulse News* 16 October.
- AsiaPulse News* (2004) 'Profile: China's Coal Industry', *AsiaPulse News* 6 October.
- BECon and PNL (1996) 'Energy Efficiency Opportunities in China: Industrial Equipment and Small Co-Generation'. A report by the Beijing Energy Efficiency Center (BECon) and Pacific Northwest Labs (PNL), PNL-10252. Available online: <http://www.pnl.gov/china/opportun.pdf> (accessed September 2002).
- Cao, Y., Y. Qian, and B. R. Weingast (1999) 'From Federalism, Chinese Style, to Privatization, Chinese Style', *Economics of Transition* 7(1): 103–31.
- CCPUA and EPRI (2000) 'Technology Assessment of Clean Coal Technologies for China: Volume 2 — Environmental and Energy Efficiency Improvements for Non-power Uses of Coal'. Report prepared by the China Coal Processing and Utilization Association (CCPUA) with the assistance of the US Electric Power Research Institute (EPRI), February.
- CESTT (1998) 'Environmentally Sound Technology in China', *CESTT Newsletter*. Beijing: Centre for Environmentally Sustainable Technology Transfer (February).
- Du, M., and C. Liu (1999) 'The Commercialization of Clean Coal Technology and Policy Support', in B. Zhang and W. Fan (eds) *2nd Int'l Symposium on CCT*, pp. 98–104. Beijing: China Coal Industry Publishing House.
- ERM China (1998) *The State Environmental Protection Administration: A New Environment in Government?* Beijing: ERM China.
- Evans, P. C. (1999) *Cleaner Coal Combustion in China: The Role of International Aid and Export Credits for Energy Development & Environmental Protection, 1998–1997*. Cambridge, MA: Center for International Studies, MIT.
- Fang, J., T. Zeng, L. I. S. Yang, K. A. Oye, A. F. Sarofim and J. M. Beer (1999) 'Coal Utilization in Industrial Boilers in China: A Prospect for Mitigating CO₂ Emissions', *Applied Energy* 63(1): 35–53.
- Gao, Y. and W. Li (1999) 'Coal Demand and Supply and the Environmental Impact from Coal Utilization in China', in B. Zhang and W. Fan (eds) *2nd Int'l Symposium on CCT*, pp. 143–57. Beijing: China Coal Industry Publishing House.
- Hao, J. (1996) 'Environmental Policies and Energy Use', in S. B. Ohshita and Y. Lu (eds) *Economic Growth, Energy Use and Environmental Issues*, pp. 34–35. Beijing: China Environmental Science Press.
- IEA (1999a) *World Energy Outlook 1999 (Looking at Energy Subsidies: Getting the Prices Right)*. Paris: International Energy Agency.

- IEA (1999b) 'Coal in the Energy Supply of China'. A report of the Coal Industry Advisory Board, Asia Committee. Paris: International Energy Agency.
- Jahiel, A. (1998) 'The Organization of Environmental Protection in China', in R. Edmonds (ed.) *Managing the Chinese Environment*, pp. 33–63. Oxford: Oxford University Press.
- JCOAL (1998) *Chugoku ni Okeru Kondo no Sentan Gijutsu no Doukou Chosa* (Future Trends in Coal Preparation Technology in China). Tokyo: New Energy and Industrial Technology Development Organization.
- Lardy, N. (1998) *China's Unfinished Economic Revolution*. Washington, DC: The Brookings Institution.
- LBLN (2004) *China Energy Databook (version 6.0)*. Berkeley, CA: Lawrence Berkeley National Laboratory, University of California.
- Lieberthal, K. (1992) 'Introduction: The "Fragmented Authoritarianism" Model and Its Limitations', in K. Lieberthal and D. Lampton (eds) *Bureaucracy, Politics, and Decision Making Post-Mao China*, pp. 1–32. Berkeley, CA: University of California Press.
- Lieberthal, K. and M. Oksenberg (1988) *Policy Making in China: Leaders, Structures, and Processes*. Princeton, NJ: Princeton University Press.
- Ma, X. (1997) 'Controlling Industrial Water Pollution in China: Compliance in the Context of Economic Transition'. PhD dissertation, Stanford University.
- Ma, X. and L. Ortolano (2000) *Environmental Regulation in China*. Lanham, MD: Rowman & Littlefield Publishers, Inc.
- Manion, M. (1992) 'The Behaviour of Middlemen in the Cadre Retirement Policy Process', in K. Lieberthal and D. Lampton (eds) *Bureaucracy, Politics, and Decision Making Post-Mao China*, pp. 216–44. Berkeley, CA: University of California Press.
- Minchener, A. J. (1999) 'Low Cost Routes for Improving Coal-Based Energy Efficiency and Environmental Performance', in B. Zhang and W. Fan (eds) *2nd Int'l Symposium on CCT*, pp. 129–42. Beijing: China Coal Industry Publishing House.
- Minchener, A. J., J. Gale, M. Neimann et al. (1999) 'Evaluation of Flue Gas Desulphurisation Technology For Chinese Coal-Fired Power Plants', in B. Zhang and W. Fan (eds) *2nd Int'l Symposium on CCT*, pp. 557–70. Beijing: China Coal Industry Publishing House.
- Naughton, B. (1992) 'Hierarchy and the Bargaining Economy: Government and Enterprise in the Reform Process', in K. Lieberthal and D. Lampton (eds) *Bureaucracy, Politics, and Decision Making Post-Mao China*, pp. 245–82. Berkeley, CA: University of California Press.
- Naughton, B. (1995) *Growing Out of the Plan: Chinese Economic Reform, 1978–1993*. New York: Cambridge University Press.
- NEPA, SDPC and SETC (1997) *China Trans-Century Green Project: Phase I (1996–2000)*. Beijing: China Environmental Science Press.
- NEPA, State Price Bureau, Ministry of Finance and Economic and Trade Office of the State Council (1992) 'Notice on Collecting Pollution Charges on Sulphur Dioxide from Industrial Fuel Coal on a Trial Basis'. Beijing: NEPA (14 September).
- Ohshita, S. B. (2003) 'Japan's Cleaner Coal Technology Transfer to China: The Implementation of MITI's Green Aid Plan'. PhD dissertation, Stanford University.
- Ohshita, S. B. and Y. Lu (eds) (1996) *Economic Growth, Energy Use and Environmental Issues*. Beijing: China Environmental Science Press.
- Ohshita, S. B. and L. Ortolano (1999) 'Incentives and Barriers to Clean Coal Technology Diffusion in Chinese Enterprises', in B. Zhang and W. Fan (eds) *2nd Int'l Symposium on CCT*, pp. 105–116. Beijing: China Coal Industry Publishing House.
- Ohshita, S. B. and L. Ortolano (2002) 'The Promise and Pitfalls of Japanese Cleaner Coal Technology Transfer to China', *International Journal of Technology Transfer and Commercialisation* 1(1/2): 56–81.
- Oi, J. (1999) *Rural China Takes Off: Institutional Foundations of Economic Reform*. Berkeley, CA: University of California Press.
- Rawski, T. (1994) 'Progress Without Privatization: The Reform of China's State Industries', in V. Milor (ed.) *Changing Political Economies*, pp. 27–52. Boulder, CO: Lynne Rienner Publishers.

- SEPA (1998a) 'Notice Concerning the Work of Closing, Banning and Stopping Production at the 15 Types of Seriously Pollution Enterprises in 1998'. Beijing: SEPA (20 May).
- SEPA (1998b) 'Division on the Controlled Regions of Acid Precipitation and SO₂ Pollution', *Huanjing Baohu* 3: 7–10.
- SEPA (2000) 'Notice Concerning Implementation of the Expanded Pilot SO₂ Discharge Fee Collection.' SEPA [2000] 75 (30 March). Beijing: SEPA.
- SEPA, SDPC, Ministry of Finance and SETC (1998) 'Notice Concerning Expansion of Pilot Locations for SO₂ Discharge Fee Collection in the Acid Rain Control Zones and the SO₂ Control Zones'. SEPA [1998] 6 (6 April). Beijing: SEPA.
- Sinkule, B. and L. Ortolano (1995) *Implementing Environmental Policy in China*. Westport, CT: Praeger.
- Sinton, J. and D. Fridley (2000) 'What Goes Up: Recent Trends in China's Energy Consumption', *Energy Policy* 28(10): 671–87.
- Smil, V. (1989) *Energy in China's Modernization: Advances and Limitations*. New York: M. E. Sharpe.
- Smil, V. (1998) 'China's Energy and Resource Uses: Continuity and Change', in R. Edmonds (ed.) *Managing the Chinese Environment*, pp. 211–27. Oxford: Oxford University Press.
- State Council (1982) 'Method of Levying Pollution Discharge Fees'. Beijing: State Council (5 February).
- State Council (1988) 'Provisional Method for Issuing Loans from Pollution Sources Treatment Fund'. Beijing: State Council (28 July).
- State Council (1996) 'Decisions of the State Council on Certain Environmental Protection Problems'. Beijing: State Council (3 August).
- State Council (1998) 'State Council Approval of Matters Concerning the Acid Rain and SO₂ Control Zones'. Beijing: State Council (12 January).
- State Price Bureau and Ministry of Finance (1992) 'Notice Concerning Environmental Administration's Administrative Fee Collection Programme and Standards'. Beijing: SPB and Ministry of Finance (20 April).
- Thomson, E. (1996) 'Reforming China's Coal Industry', *China Quarterly* 147: 726–51.
- US Embassy Beijing (2000) 'PRC Planners' New Energy Strategy: Oil Not Coal'. (February). Available online: <http://www.usembassy-china.org.cn/sandt/sdpcenergy.html>.
- Vermeer, E. B. (1998) 'Industrial Pollution in China and Remedial Policies', *China Quarterly* 156: 952–85.
- Walder, A. (1992) 'Local Bargaining Relationships and Urban Industrial Finance', in K. Lieberthal and D. Lampton (eds) *Bureaucracy, Politics, and Decision Making Post-Mao China*, pp. 308–33. Berkeley, CA: University of California Press.
- Wang, S. (1995) 'Fiscal Reform and the Decline of Central State Capacity in China', in A. Walder (ed.) *The Waning of the Communist State: Origins of Political Decline in China and Hungary*, pp. 87–113. Berkeley, CA: University of California Press.
- Watson, J. (2002) 'Cleaner Coal Technology Transfer to China: A "Win-Win" Opportunity for Sustainable Development?', *International Journal of Technology Transfer and Commercialisation* 1(4): 347–72.
- World Bank (1997) *Clear Water, Blue Skies: China's Environment in the New Century*. Washington, DC: The World Bank.
- Xinhua News Agency (2002) 'China's Coal Industry on Way to Recovery'. Xinhua News Agency (24 January).
- Zhu, D. and Z. Yu (1999) 'Market Analysis of Clean Coal Technologies in China', in B. Zhang and W. Fan (eds) *2nd Int'l Symposium on CCT*, pp. 10–25. Beijing: China Coal Industry Publishing House.