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The Prospects for Coal:
Global Experience and Implications for Energy Policy[*]

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Abstract: This paper argues that coal and its industry is promising. It is found that the Western European (including the British) case has been misunderstood and the US case shows a developing coal industry under increasing levels of environmental pressure. The demonstration of the declining emissions intensity of coal provides an additional mean of reconciling the development of the coal industry with the environment. In the long term the enforcement of environmental regulations can benefit the coal industry in several ways, and the alternatives to coal are not yet available in a sufficiently large scale. Based on the positive prospects of coal, issues related to climate change, clean coal technology and energy policy are discussed.

Keywords: Coal; Environment; Regulation; Energy Policy

JEL Classification: Q32; Q48; Q56

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1. Introduction

Since the 1972 Stockholm Conference, environmental issues have become more prominent worldwide. The number of international conventions for protecting the environment has increased considerably (UN, 2002). With the emergence of more environmental regulations, many observers think that the future for coal is unpromising (Coal Enterprise Management, 2001; Keay, 2003). This paper demonstrates the reconciliation of coal development and the environment by examining the global case and several typical regional cases. The paper argues that there are promising prospects for coal in the near future. One significant contribution is the demonstration of declining emission intensity.

Coal plays an important role in social and economic development worldwide. It triggered the industrial revolution and has driven industrialisation in the past several centuries. Coal currently supplies over 41 per cent of the world's electricity and 26 per cent of global primary energy needs; 70 per cent of global steel production is dependent on coal (WCI, 2008). Coal is also the only affordable energy available in large parts of the developing world, such as China and India.

Coal, however, is one of the primary environmental polluters. Its production and consumption have negative impacts on the local, regional and international environment. Local environmental impacts are predominantly those caused by mining activities and include land subsidence, water pollution and pollution arising from mine waste. Regional and international environmental impacts come from emissions from coal combustion, such as particulate pollution and the emission of nitrogen oxides, soot, dust, carbon dioxide and sulphur dioxide. China's air pollution is mostly caused by the use of coal[1] (Wang and Feng, 2003). The correlation between increased sulphur dioxide levels and coal consumption is above 95 per cent (He *et al.*, 2002).

To mitigate the environmental impacts of rapid economic growth, proposals to reduce waste-gas emissions (WGEs) usually include changing the economic structure, reducing energy intensity and enforcing waste-gas treatment (Liang and Zhou, 2008). These measures often lead to reductions in the use of fossil-fuel energy in general and coal in particular. Emerging concerns about climate change add further pressure on the use of coal. It is worried that environmental regulations will limit coal's ability to compete with other fuels (McGinley, 1992). Many people, however, disagree with this pessimistic view and argue that coal is promising, at least in the foreseeable future (Coal Enterprise Management, 2001; Huang, 2001; Li, 2003; Shi, 2003; 2006; Wang, 1999).

The prospect for coal is an important issue in countries that rely heavily on coal, such as China, India and Australia in terms of energy supply and security, jobs, and economic development. It is also very important to the global community in terms of environment and climate change. The key question related to the prospect for coal is: Can the coal industry really be reconciled with the environment? There are three issues related to this question. How should the decline of the coal industry in Western Europe be interpreted? How can the coal industry overcome the adverse impacts of environmental regulations? And is there a low-emissions prospect for coal? No empirical evidence has yet been provided with which to examine these issues.

This paper examines the regional and global issues raised by emissions from coal

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[1] Coal provides 70 per cent of China's primary energy. It has been reported that 85 per cent of the sulphur dioxide, 70 per cent of the soot and 60 per cent of the nitrogen oxides emitted into the atmosphere in China come from the burning of coal.

use. It examines the coal industry in the cases of the whole world, the EU, the UK and the US. It also analyses empirically the evolving pattern of coal emissions intensity using China's industry WGE data for the period 1996–2007. The paper also advances reasons as to why there might be a way to reconcile coal production and use with protection of the environment. The prospect for coal in an uncertain carbon constrained future and the role of technologies and implications for energy policy are also explored.

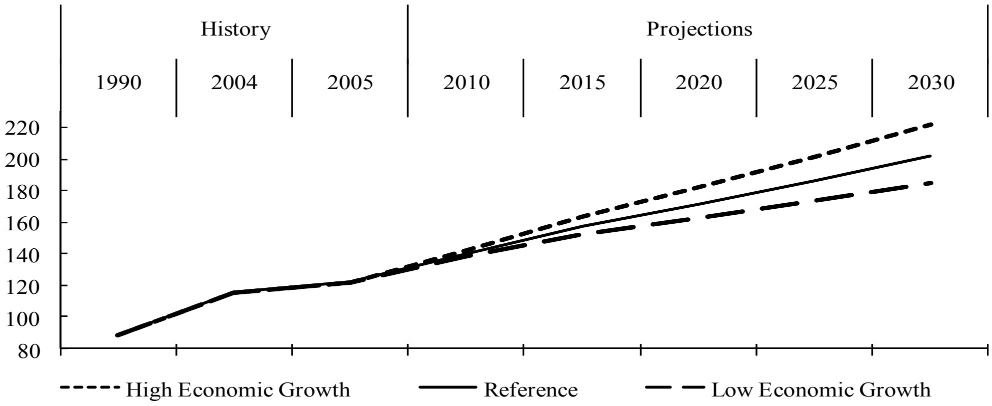
The rest of the paper is organised as follows. The next section introduces several cases which have demonstrated that the coal industry was able to continue its development in parallel with stricter environmental regulations. The third section outlines the reconciliation of coal and the environment and presents the empirical evidence for declining emissions intensity in China. The fourth section explains why there might be a way to reconcile coal with the environment. The fifth section discusses prospects and strategies for coal under a carbon-constrained scenario, the role of technologies, and policy implications. The last section concludes the paper.

2. The Coal Industry and the Environment: A Historical Experience

2.1. Coal Industry Grew Despite Increasing Environmental Regulations

Globally, the development of coal has not been hindered by environmental regulations. Despite the increasing number of environmental regulations relating to coal in the past three decades, global demand for coal has increased steadily since 1970 and it is expected to continue to increase in the next two decades (Figure 1). Total world consumption of coal is projected to increase 73 per cent and its share of energy will increase from 25 per cent to 28 per cent during the period 2005-2030[2] (IEA, 2007).

Figure 1. World Coal Consumption (Quadrillion Btu), 1990-2030.



Source: EIA (2008b).

With growing demand in the past twenty years, coal prices have been stable most of time over the past two decades (Figure 2). It is projected that the world average price of imported steam coal will fall slightly in the long run (IEA, 2007). Thus historic coal prices have not increased, despite higher user costs imposed by environmental regulations. Hence, there is no global evidence that environmental regulations will damage coal's competitive ability against other energy forms.

It is possible that the coal industry will not only overcome the adverse impacts of environmental regulations, but will continue to grow. Coal has the advantage of there being huge reserves which can last for more than one hundred years and that they are evenly distributed (BP, 2008). Coal is the most abundant fossil fuel. At the end of 2007, the world's total recoverable coal reserves were predicted to last for 133 years at current

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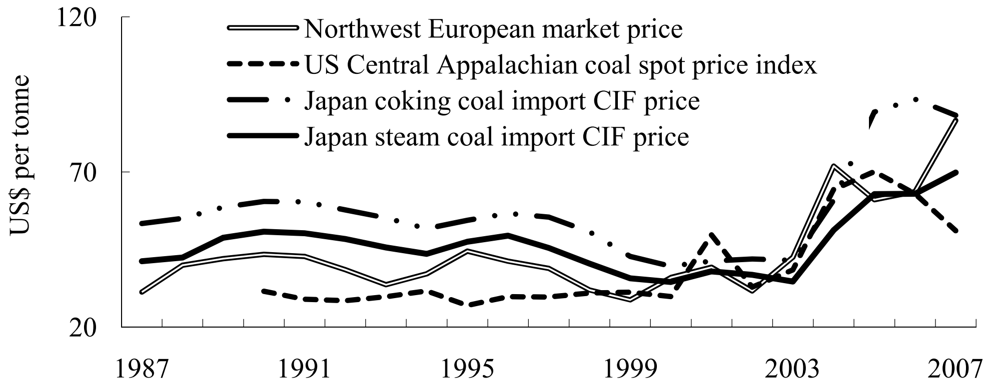
[2] This forecast, however, does not consider the effects of environmental regulations such as the Kyoto Protocol and thus implies that carbon dioxide emission will parallel the increased pace of coal consumption.

exploitation levels, while oil and gas could be depleted in 41.6 years and 60.3 years, respectively (BP, 2008). Coal reserves are more widely spread than oil and gas, which means that coal is a more reliable and perhaps more affordable energy source than oil and gas in many countries[3] (WCI, 2008).

Figure 2. Coal Prices in Four Representative Markets.



Source: BP (2008).

Until recently, rising oil and gas prices, combined with concerns about energy security and the demand for affordable sources of energy, have highlighted the special status of coal, and thus coal has attracted growing interest. The EU Commission projects that coal will still dominate electricity generation for the near future (EurActiv, 2006). Coal-fired power generation is projected to increase its share in total generation to 45 per cent in 2030 (IEA, 2007). Deutsche Bank argues promising prospects of coal by highlighting coal's ability to fill the energy gap in the immediate future and the possibility of making it clean by utilising new technologies (Auer, 2007). McFarland *et al.* (2004) studied the future of coal consumption under different scenarios of changing

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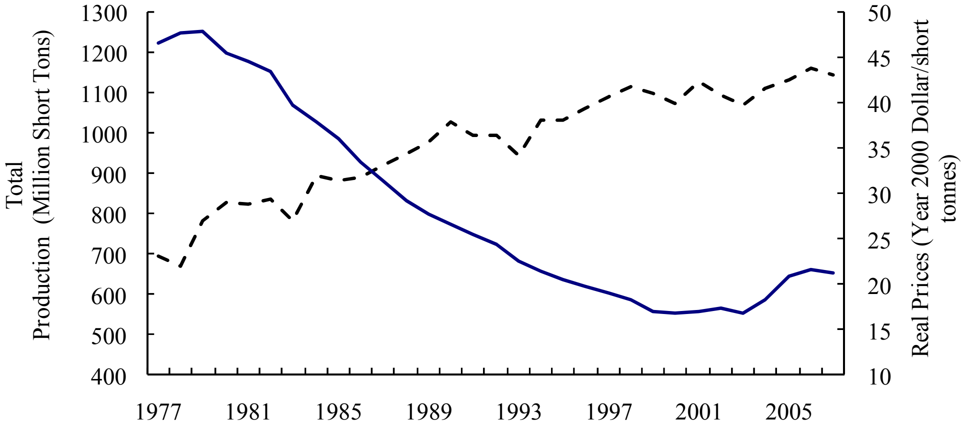
[3] Coal reserves are available in more than 70 countries, while over 67 per cent of oil and 66 per cent of gas reserves are concentrated in the Middle East and Russia.

carbon prices, gas prices and clean coal technological costs and concluded that in the US and among the EU countries, coal would continue to be viable.

This continuous growth of coal despite the emergence of environmental regulations has also been demonstrated by the US case. The US has a unique combination of a large coal industry and strict environmental regulations. The US environmental regulations over coal use emerged in the early 1970s. A detailed review of the legislation can be found in Shi (2006). Although experiencing continuous environmental pressures, US coal production continued to increase, and its price continued to decline (Figure 3).

Figure 3. US Coal Production and Real Prices, 1977-2007.



Source: EIA (2007).

The EIA forecasts that coal production in the US will continue to grow through 2030, and that the US average mine-mouth price of coal would decline slightly between 2006 and 2020, from $1.21 per million Btu in 2006 to $1.14 per million Btu in 2020 (in 2006 dollars) (EIA, 2008a).

2.2. Misleading Relationship in Western Europe

The dramatic decline of the coal industry in Western Europe may be cited as evidence of the negative impacts that tightening environmental regulations will have on coal. The argument is that if coal in Western Europe dwindled due to the introduction of environmental regulations, then coal in other parts of the world will shrink as more environmental regulations are put in place.

However, the a synchronisation between the decline of the western coal industry and the introduction of environment regulations suggests that the decline of the coal industry in Western Europe has not resulted significantly from environmental regulations. The first European Commission-wide air-quality standard was the 1980 Air Quality Directive (Soot and Sulphur Dioxide). Further standards encompassing nitrogen oxides were established in 1985 (Haigh, 1990). But the European coal industry has been declining since the 1950s. If environmental regulations were the main reason for the decline, coal consumption should have begun decreasing much earlier and to an extent not less than production, because environmental regulations affected coal use first.

Contrarily, production has decreased more than consumption. The annual coal output in Western Europe declined from approximately 600 million tonnes in the early 1960s to 86 Mt in 2000. After France closed its last coal mine in 2004, Western European coal is only being produced in Germany, the UK and Spain, which experienced another significant decline in coal production and employment the period 1995-2005.

The true likely reason for the decline of the coal industry in Western Europe is that the indigenous coal production lost market competitiveness, largely due to cheap imported coal, higher local extraction costs and increased labour costs (Commission EC, 2007). For example, in Germany, Spain and France, domestic production costs are three to five times more than imported coal prices (EIA, 2002). The average price for imported coal was €60 per tonne of coal equivalent in the second half of 2005, which is less than half of the average production cost in Spain, Germany and Hungary (Commission EC, 2007). This is also evident from the fact that the increased gap between consumption and production of coal was filled by increased imports (Table 1).

Another piece of evidence for the weak competitive ability of indigenous coal in Western Europe is the existence of huge subsidies which are vital to the survival of Europe’s coal mining industries. The EU currently, and up to 2010, allows member states to grant subsidies to their coal industry[4] (Commission EC, 2007). The annual cost of saving or preserving one job in the UK is estimated to be from €6,125 to €12,245; in Germany, it is estimated to between €75,000 to over €112,000; in Spain it is estimated between €35,000 to over €130,000 (Europe Economics, 2006). When these countries liberalise their coal trade, domestic coal production will inevitably lose markets to cheap imported coal. The share of imported coal increased in Germany from 20 per cent in 1995 to nearly 60 per cent in 2005 (Table 1).

Table 1 . Coal Production and Employment for Selected Countries

	Germany		Spain		UK	
	1995	2005	1995	2005	1995	2005
Number of pits	19	9	133	38	31	8
Production (Mt)	53.1	24.7	17.6	11.9	35.1	9.6
Employment	93,000	38,528	26,000	8,200	9,500	4,400
Imports (%)*	20.3	58.2	43.2	65	20.9	59.5

Note: The data of imports were in 2004 instead of in 2005.
Source: Europe Economics (2006).

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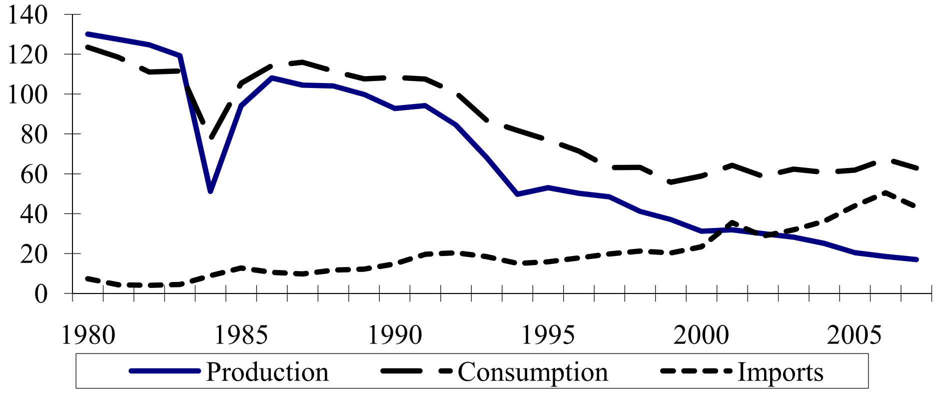
[4] Germany intends not to end operating aid before 2018.

2.3. The British Case: Production Costs and Import Prices are Responsible

As the largest coal producer in the EU, the UK case further supports the argument that the decline of coal production was due to high domestic production costs rather than environment regulations. The environmental regulations that potentially affect the UK coal industry have been in place since 1956. However, it was not until the early 1980s that coal production fell sharply (Shi, 2006). Furthermore, like Germany, Spain and France, coal consumption in the UK declined less than production, while imports increased significantly (Figure 4).

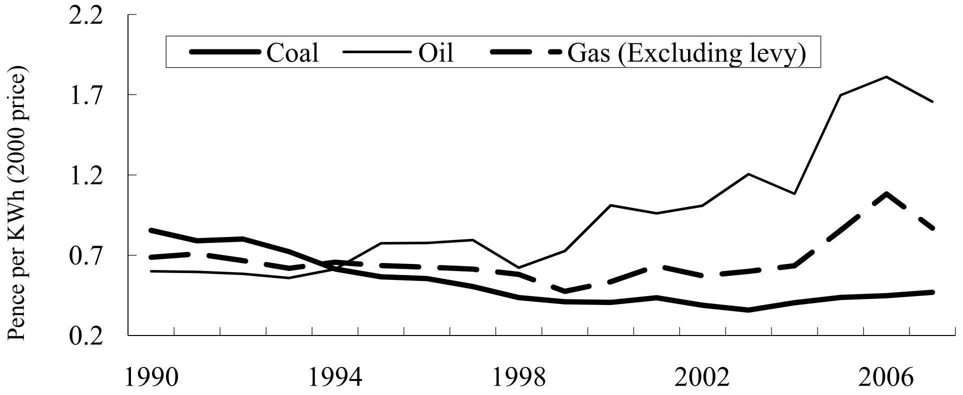
Figure 4. Coal Production, Consumption and Imports in the UK, 1980-2007.



Source: UK BERR (2008).

Similar to the circumstance in other Western European countries, the decline of the British indigenous coal industry was likely due to cheap imports. During the period 1994-2005, the total amount of aid to the British coal industry authorised by the EU Commission amounted to €5.2 billion, which corresponded to €6,125 to €95,000 per annum per job still existing at the end of the period (Europe Economics, 2006). With the increased importation of cheaper coal from other countries, the UK prices for coal purchased by major power producers decreased by 33 per cent when compared with the price in 1994 (Figure 5). Compared with oil and gas prices, the price of coal has remained stable, which may help coal to become more competitive.

Figure 5. Average Prices of Fuels Purchased by the Major UK Power Producers.



Note: Prices of gas are at delivery points.
Source: UK BERR (2008).

A further decline of British coal consumption is unlikely. In June 2006, the UK Prime Minister was advised to keep up the current capacity of coal-fired power plants, but gradually replace them with clean coal technology, and finally zero emissions (EurActiv, 2006).

In summary, global and US history shows that the coal industry continues to grow despite the continual enforcement of environmental regulations, and that these regulations were not the main cause of the decline of the coal industry in Western Europe and UK. Those claiming that the Western European cases indicate a trend are assuming a spurious relationship between changed environmental regulations and the decline of the coal industry.

3. The Coal Industry and the Environment in China: Empirical Evidence of Declining Emissions Intensity

3.1. Hypothesis of Declining Emissions Intensity

The Chinese coal industry has managed to develop despite increased environmental protection. Since environmental protection was entrenched as one of China's basic national policies in the 1980s, a considerable degree of control of air pollution has been achieved. Shi (2008) provides a review of China's environmental policy and its control of air pollution related to coal. The amount of industrial sulphur dioxide, industrial soot and dust discharged in the generation of one unit of GDP in China in 2004 dropped by 42 per cent, 55 per cent and 39 per cent, respectively, from levels recorded in 1995 (State News Office, 2006). As shown in Figure 6, although coal consumption has been soaring in recent years, dust and soot emissions are declining. There has been a slight increase in sulphur dioxide emissions, but the speed of the increase is far slower than that of coal consumption.[5]

One argument to explain this phenomenon is that there is a decreasing trend in pollution emissions per unit of coal, or emissions intensity (Shi, 2003; 2006). The argument suggests that environmental pressure will induce innovations in clean-coal technologies. The ultimate level of cleanliness will depend on technical progress and socioeconomic conditions.

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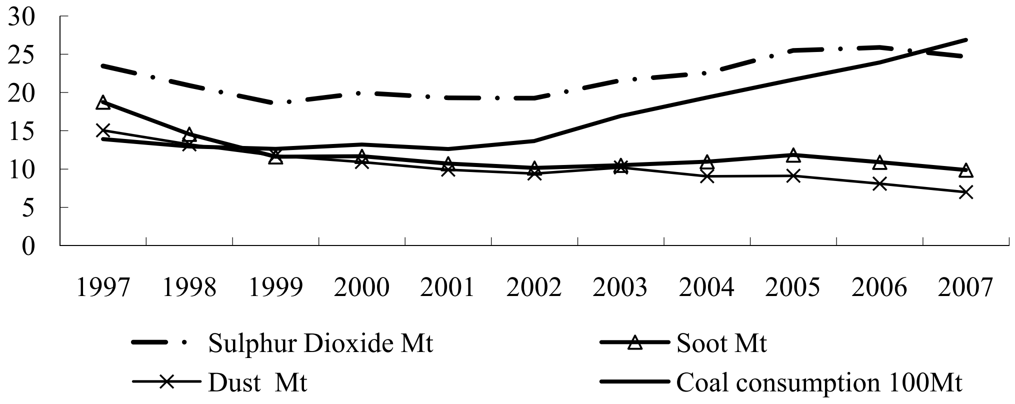
[5] Coal consumption increased nearly 92 per cent between 1997 and 2006, yet emissions of sulphur dioxide increased only slightly, by 10.35 per cent, during the same period.

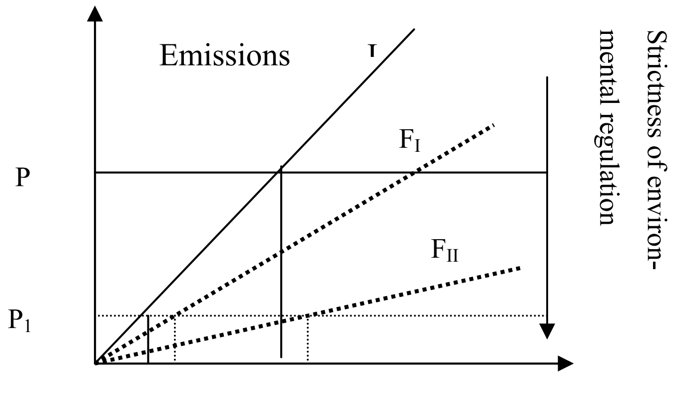
Figure 6. Coal Consumption and Air Pollution Emissions in China, 1997–2007.



Note: To avoid the underreporting of production due to the mine closure policy, production data were extracted from BP (2008).
Sources: State Environmental Protection Administration (1996-2007), NBS (various years) .

This hypothesis implies that capping the amount of pollution emissions does not necessarily lead to a decline in coal production and consumption. For example, if new technologies change the emissions intensity from F_I to F_{II}, even under stricter regulation that reduces total emissions from P to P_1, coal consumption may increase, rather than decline (Figure 7). This hypothesis presents an additional way for coal to be reconciled with the environment.

Figure 7. The Impact of Different Emissions Intensity.



Source: Shi (2003; 2006).

3.2. The Data

This hypothesis is tested using empirical data from China's industrial sector. The focus on industrial waste gas emissions (WGEs) only is appropriate because industrial pollution plays a dominant role in total emissions[6] (CEYP, 2006). The empirical study will focus on three air pollutants: sulphur dioxide emissions (SO_2), industrial soot emissions (Soot) and dust emissions (Dust).

Data for these three kinds of air pollutants, consumption of two kinds of coal and various environmental variables were drawn from the relevant issues of the *China Environmental Yearbook* (CEYP, various years). The data for national total coal production (in physical quantity and in standard coal equivalent), energy consumption and its mix, GDP and population which are used in the index decomposition method are drawn from the relevant issues of the *China Statistical Yearbook* (NBS, various years). Total consumption of coal (TC), fossil-fuel energy (FE) and energy consumption (TE) are evaluated at 10,000 tonnes of standard coal equivalent (SCE), which will avoid heterogeneity of different coal qualities. The national GDP data are deflated to 1996 constant prices by GDP deflator. When there is more than one set of data, the most up-to-date one is preferred because China's State Statistical Bureau significantly adjusted energy-use data in 2006.

Carbon dioxide emissions, although a common and significant emission in the future, are not included here. The literature (Ang and Pandiyan, 1997; Ang *et al.*, 1998; Wang *et al.*, 2005; Wu *et al.*, 2006) often infers carbon dioxide emissions by assuming constant emissions intensity for each fuel, including coal. This practice is reasonable

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[6] In 2005, 86 per cent of total sulphur dioxide emissions and 79 per cent of total soot emissions came from industrial sources.

because carbon dioxide emissions have been free from any regulation until now and thus emissions intensity is decided by the chemical and physical characteristics of coal, not by the regulatory environment. This study tries to show the changing pattern of emissions intensity. Therefore, the published carbon dioxide data, although available, are inappropriate for this analysis. In addition, although carbon dioxide emissions are a major and emerging concern, the historic, long-existing and immediate environmental phenomenon is local ambient air pollution, which is predicted to cause health damage worth 13 per cent of China's gross domestic product (GDP) by 2020 ((OECD, 2007a), cited in IEA (2007)).

3.3. Two Alternative Empirical Models

To test the hypothesis of declining emissions intensity over time, two alternative methods are employed. An econometric technique is used to test the emissions intensity of coal with focus on long-term dynamic aspects of this intensity. An index decomposition (ID) approach is used to qualify the individual contributions of various factors that determinate the final emissions.

The first method to be used is a fixed-effects panel data model, which will test the general trend of emissions intensity—that is, at time *t*, in province *i*, the *jth* WGE, is:

$$WGE_{itj} = \beta_0 + (\beta_1 + \beta_2 T)FuelC_{it} + (\beta_3 + \beta_4 T)MatC_{it} + \beta_5 X_{it} + \alpha_{ij} + u_{itj} \quad (1)$$

in which *WGE* denotes pollutant emissions; *FuelC* and *MatC* denote consumption of fuel coal and material coal, respectively; *T* is a general time trend; α_{ij} is the province-specific effect in the case of the *jth* pollutant in the *ith* province ; u_{itj} is a normally distributed error term; $j = 1,2,3$ is sulphur dioxide, soot and dust, respectively. Of particular interest are the signs of β_2 and β_4. If β_2 or β_4 are significantly negative, evidence of decreasing emissions intensity is found. Due to differences in characteristics between fuel and material coal in different cases of air pollution, β_2 and β_4 may be different in the case of different pollutants.

X is a vector of exogenous variables representing factors such as population (POP), average GDP and environmental regulations and enforcement, and is used to investigate the impacts of various exogenous variables on the emissions function.

The more stringent the environmental regulation and enforcement, the lower are the WGEs because polluters are more likely to be punished or charged. Several variables have been used to approximate legislation and enforcement, such as cumulative environmental standards (Bao and Peng, 2006) or the number and amount of penalties (fines) (Gray, 1987). In this study, the cumulative number of environmental standards (*Standard*) is used to approximate the effect of legislation; the operating cost of waste-gas treatment equipment (*Cost*) is used to approximate the stringency of enforcement.

Environmentally related research and development expenditure (*R&D*) is included to measure the technology progress effect, as in Bao and Peng (2006). The GDP deflator is used on all monetary value terms to deflate them into the 1996 constant price of 10,000 Chinese yuan.

The second model is index decomposition, which has been a popular tool used in the past 40 years for the quantitative assessment of various factors affecting WGEs and energy demand. In terms of the decomposition method, the Laspeyres index and the Divisia index are the most frequently used and preferred decomposition methods in energy-induced gas emission studies (Ang and Zhang, 2000). A detailed survey of this literature can be found in Shi (2008). In this study, the Logarithmic Mean Divisia Index (LMDI) approach is applied because it has the time-reversal property of an ideal index and can perform a perfect decomposition and accommodate zero values in the data set, which is preferable to the refined Laspeyres method (Ang and Zhang, 2000).

Similar to Wang *et al*. (2005), the total WGE is expressed as an extended Kaya Identity (IPCC, 2001; Kaya, 1990)—that is:

$$WGE_j = \frac{WGE}{TC}\frac{TC}{FE}\frac{FE}{TE}\frac{TE}{Y}\frac{Y}{P}P = ECFIGP \qquad (2)$$

in which *j* is the type of emissions, including sulphur dioxide, soot and dust; *Y* is GDP ; *E* is the mean WGE emissions intensity of coal (which is the core interest of this study); *C* is the share of coal in total fossil-fuel energy, or the fossil-fuel composition; *F* is the share of fossil-fuel energy in total energy consumption, or the energy composition; *I* is energy intensity; *G* is GDP per capita and *P* is population. The explicit introduction of coal into the emissions function is an extension of the current study.

As shown by Wang *et al*. (2005), using the LMDI (Ang *et al*., 1998), the difference in WGEs between two periods, *t* and *T*, can be expressed as:

$$\begin{aligned}\Delta WGE_{tT} &= WGE_{iT} - WGE_{it} = E_{iT}C_{iT}F_{iT}I_{iT}G_{iT}P_{iT} - E_{it}C_{it}F_{it}I_{it}G_{it}P_{it} \\ &= \sum\nolimits_{K} \Delta WGE_{K-effect}, K = E, C, F, I, G, P\end{aligned} \qquad (3)$$

In which, the K*th*-effect on emission reduction is:

$$\Delta WGE_{K-effect} = L(WGE_{it}, WGE_{iT})\ln(K_T / K_t) \qquad (4)$$

in which:

$$L(x, y) = (x - y) / \ln(x / y) . \qquad (5)$$

The case of no change in emissions intensity (*Non–CEI*) is also defined as the basis for comparison with the current status. The *Non–CEI* of WGEs can be derived by dropping the emissions intensity effect as:

$$Non-CEI = \sum_K \Delta WGE_{K-effect}, K = C, F, I, G, P \qquad (6)$$

3.4. Econometric Results

The time trend of emissions intensity and determinants of WGEs from coal consumption are studied using China's provincial panel data from 1996–2006. This period was chosen because data for coal consumption broken down to combusting and material inputs were available only from 1996 onwards.

As in the literature (Bao and Peng, 2006; Shadbegian and Gray, 2006), the Seemingly Unrelated Regressions (SUR) model is employed to allow for correlations in the residuals across equations for the three air pollutants. SUR is used because factors such as environmental legislation, environmental policy and changes in enforcement will affect the outcomes for all air pollutants simultaneously. To accompany both the fixed effects, or unobserved provincial heterogeneity, and SUR, a dummy variable version of the SUR model is used—that is, one dummy variable is created for each province and all but one of them are included in the regression functions to accompany the fixed effects. Estimation results of the SUR model are shown in Table 2.

The results demonstrate that there is a significant decline in emissions intensity in the case of material coal. For fuel coal, there is also a significant decline in emissions intensity, except in the case of dust. To test the robustness of this conclusion, in the second specification regulatory and economic variables are removed—and the conclusion is unchanged.

Table 2. Estimated Results of the Fixed-effects SUR Model.

	SO2		Soot		Dust	
	Coeff.	t ratio	Coeff.	t ratio	Coeff.	t ratio
Specification 1						
Fuel coal	117.41***	6.31	53.43***	4.12	-24.23	-1.17
T*Fuel Coal	-3.29**	-2.39	-2.07**	-2.16	2.10	1.38
Material coal	45.29***	2.74	130***	11.30	142***	7.75
T*Material Coal	-2.91*	-1.94	-8.74***	-8.37	-8.94***	-5.38
Time trend (T)	11146**	2.35	9245***	2.79	16482***	3.13
Legislation	-4872**	-2.33	199.27	0.14	1915.57	0.82
Enforcement	-0.28*	-1.76	-0.35***	-3.08	-0.49***	-2.74
R&D	-20.39**	-2.25	-9.55	-1.51	-14.91	-1.48
Average GDP	9.57	1.13	-9.93*	-1.69	-17.46*	-1.87
aveGDP square	-0.0002*	-1.66	0.00	1.59	0.00	1.50
Population	36.38	1.53	-32.89**	-1.99	-10.91	-0.41
Constant	-114673	-1.02	101771.	1.30	219257*	1.76
Specification 2						
Fuel coal	123.63***	6.63	43.36***	2.83	-30.44	-1.50
T*Fuel Coal	-4.74***	-3.56	-2.63**	-2.41	0.68	0.47
Material coal	56.79***	3.38	148***	10.76	166***	9.10
T*Material Coal	-3.19**	-2.10	-9.89***	-7.92	-10.38***	-6.26
Time trend (T)	14188***	5.29	3694*	1.68	7702***	2.64
Constant	-90396**	-2.45	-73420**	-2.43	-31147	-0.77

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Legislation, approximated by cumulative environmental standards, has a significant impact on reducing sulphur dioxide emissions. The insignificant effect of legislation in the case of soot and industrial dust could be due to the fact that much environmental legislation is not related to air pollution and this variable is therefore not a good proxy in this study; an alternative reason could be that environmental standards focus more on sulphur dioxide emissions than on the other two kinds of emission.

Enforcement, approximated by the operating costs of WGE-treatment machines, is significant for all three emissions. The significance of the enforcement of regulations on the removal of sulphur dioxide may be due to the fact that environmental regulations have spurred a demand for low-sulphur coal, as noted by Darmstadter (1999) in the US case. Whatever the reason, it can be concluded that enforcement is as important as legislation.

The technological effect, approximated by environmentally related research inputs (R&D), is, however, negative and significant in the case of sulphur dioxide. This imbalance of research on emissions could be because sulphur dioxide was regulated at an earlier time and in a stricter manner than soot and dust. Therefore, most R&D money has been spent on the development of desulphurisation equipment and technologies. R&D research also spills over provincial boundaries and thus is not a good proxy variable for technical progress. This spill over, however, cannot be tested in this data.

The variable *POP* is estimated to have different signs among the three cases of emission, but is only significant in the case of soot. The reason for this could be that population is not itself a decisive factor in air pollution emissions when the use of coal is controlled.

The findings about the pollution–income relationship are not consistent with the literature. Bao and Peng (2006) found that all three air pollutants—sulphur dioxide, soot and dust—show an inverted-U shaped relationship with economic growth. In contrast, Shen (2006) finds SO_2 has a U-shaped relationship with per capita income while dust shows no significant relationship. In this study, an inverted-U shaped relationship was found only between economic growth and sulphur dioxide—a finding reported also by Kaufmann *et al*. (1998) and Markandya *et al*. (2006). The reason for this could be that this study has controlled the consumption of coal, which captures the major effect of economic growth on air pollution emissions.

In terms of regional diversity, several provinces achieve the same results as Beijing in all three emissions cases: Tianjin, Shanxi, Shanghai, Anhui, Fujian, Yunnan, Gansu, Qinghai, Ningxia and Xinjiang. Two provinces, Shandong and Guangxi are significantly worse than Beijing in all three emissions. Detailed results concerning the regional heterogeneity are presented in Shi (2008).

3.5. Index Decomposition Results

These decomposed results show that economic growth has the biggest impact on emissions change among all six factors tested for, during the period 1996–2007; this is following by emission intensity, which has an opposite effect to the economic growth (Table 3).

Table 3. Factors that Affect the Changes in Emissions (ΔWGE), 1997–2007.

	ΔWGE	E-effect	C-effect	F-effect	I-effect	G-effect	P-effect
SO2	202.10	-1276.35	-45.82	-27.91	-588.49	1977.53	157.36
Soot	-484.20	-1372.24	-24.34	-14.83	-312.68	1050.71	83.61
Dust	-806.30	-1463.02	-20.35	-12.40	-261.41	878.41	69.90

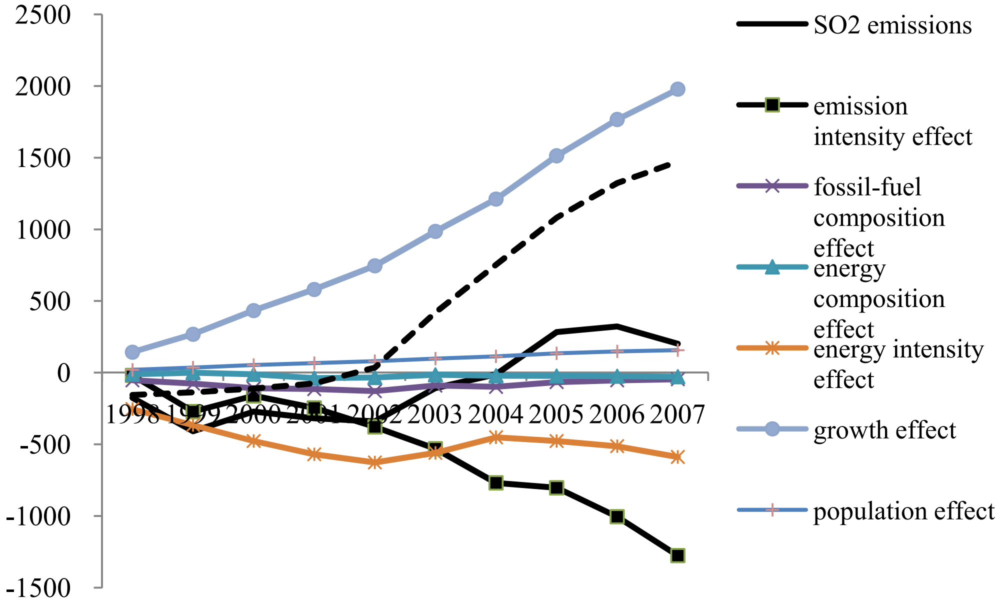
The decrease in soot and dust emissions was due primarily to the decrease in emission intensities. The impact of energy intensity is next to that of emissions intensity in terms of scale. In the case of sulphur dioxide emissions, even though overall emissions have been increasing recently, emissions intensity and energy intensity have negative overall effects.

Compared with industrialized countries, where decreases in the aggregate energy intensity and aggregate carbon dioxide intensity are explained mainly by declines in energy intensity (Ang and Zhang, 2000; Torvanger, 1991), China's changes in industrial WGEs are to a large extent the result of the decline in emissions intensity of coal.

The changing structure of coal among fossil-fuel energy sources and the change of energy mix also contribute to the decrease in emissions. However, the small value reveals a relatively weak impact on WGE changes from the change of fossil fuel composition and the use of renewable energy, mainly because the composition of energy consumption is stable.

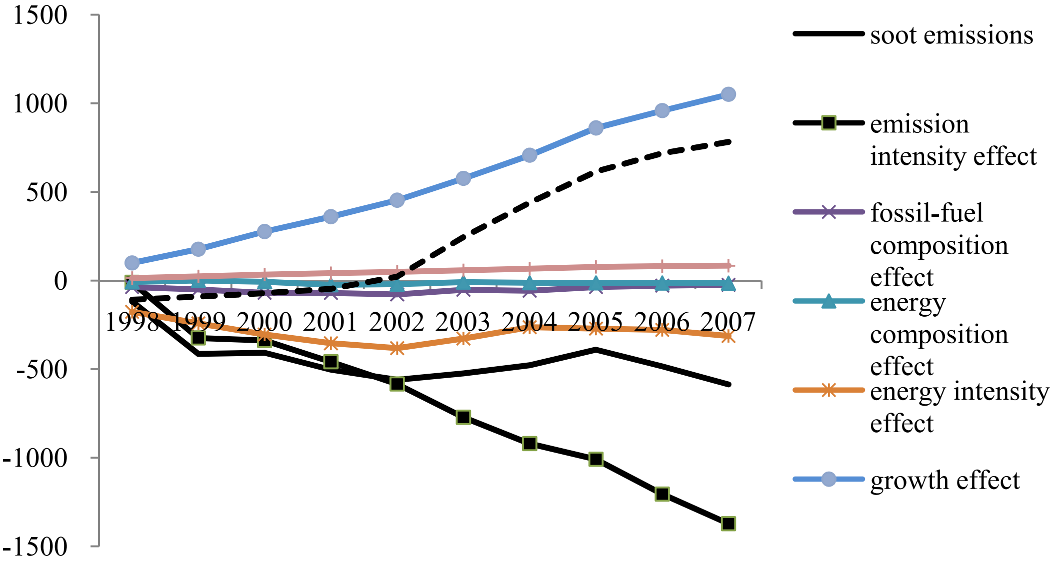
To simplify the discussion, the results for the three WGEs are normalised to the year 1997. The cumulative changes of emissions between 1997 and 2007 are decomposed to changes of each factor (Figure 8, Figure 9 and Figure 10).

Figure 8. Decomposition of Sulphur Dioxide Emissions Changes, 1997–2007.



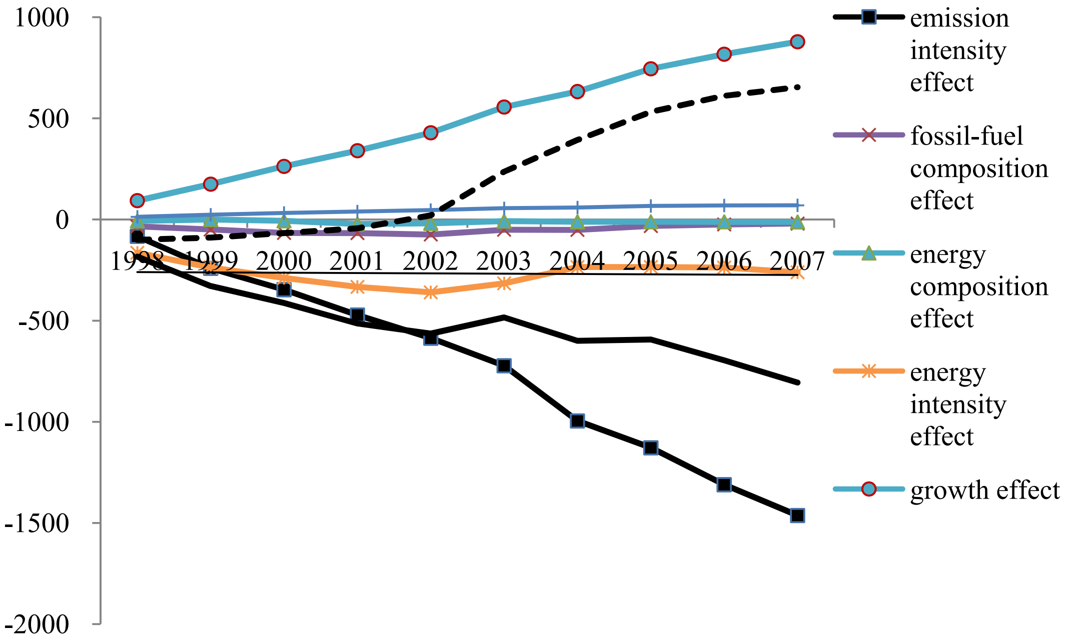
Note: Increased sulphur dioxide emissions compared with 1997.

Figure 9. Decomposition of Soot Emissions Changes, 1997–2007.



Note: Increased soot emissions compared with 1997.

Figure 10. Decomposition of Dust Emissions Changes, 1997–2007.



Note: Increased industry dust emissions compared with 1997.

As in the literature (Lin and Chang, 1996; Shalizi, 2007), economic growth is the major driver of increased emissions. In the literature, a decline in emissions is often attributed to a decline of energy intensity (Lin and Chang, 1996; Shalizi, 2007). However, this study shows that energy intensity has played a less important role than the emission intensity of coal.

In all three cases, it is clear that without considering the change of emissions intensity (non-CEI), the increase of emissions is much higher than actual emissions. This demonstrates that the decreasing emissions intensity is the most significant contributor to emissions reduction.

With the potential to be clean, coal and fossil energy in general, should not necessarily, therefore, be thought of as unpromising. The decrease in emissions intensity of coal will not occur automatically. Technologies play an important role in the reconciliation of coal and the environment

4. Factors Harmonising Coal and the Environment

4.1. Coal Will Become More Valuable Over Time

From a dynamic perspective, the scarcity value of coal will rise so that the current non-economically viable coal will become economically viable in the future. There are two elements in this argument. One element depends on the marginal productivity of coal, which is likely to increase over time due to technical progress and capital accumulation. Another element is an increasing marginal benefit generated from the declining stock of coal, which is a basic economic principle.

A typical Cobb-Douglas production function with natural resources input and technical change is:

$$Q = AK^{\alpha}L^{\beta}R^{\gamma} \qquad (7)$$

where Q is output, K, L are capital and labour inputs, A is technological change and R is resources input; α, β, γ are all positive (Dasgupta and Heal, 1974; Solow, 1974; Stiglitz, 1974). Here the marginal productivity of resources (MPR) is:

$$MPR = \partial Q / \partial R = \gamma AK^{\alpha}L^{\beta}R^{\gamma-1} \qquad (8)$$

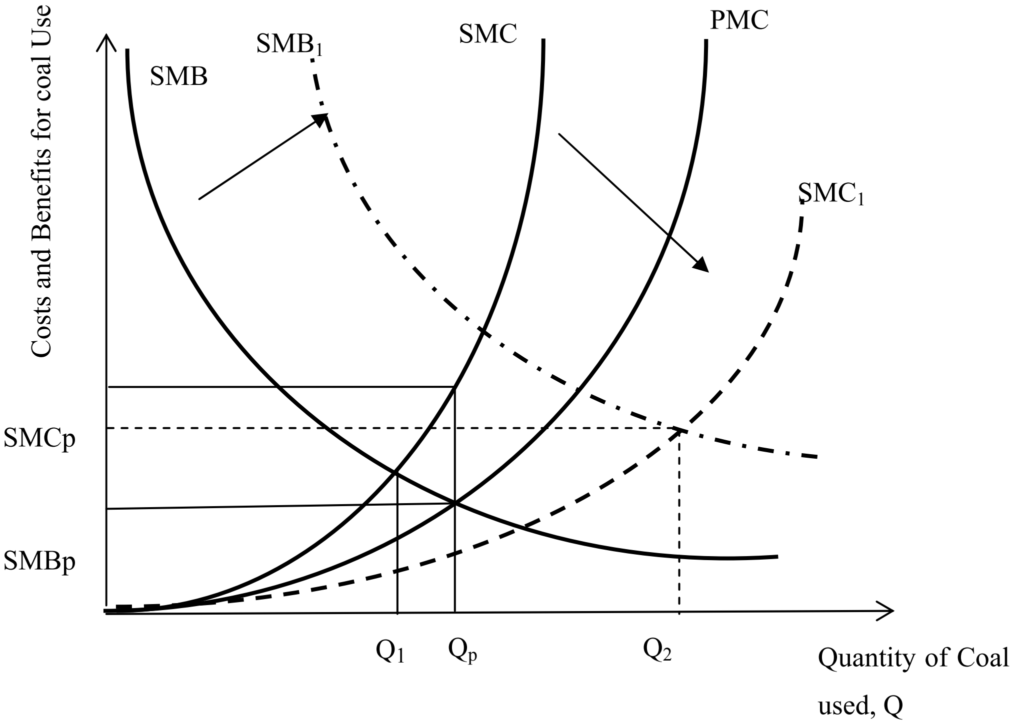
This expression shows that when any of Technology (A), Capital Endowment (K), Labour (L) increase, MPR will increase. In normal circumstances, technical progress, capital, labour and other non-resource inputs will generally increase over time. So does marginal productivity of the resources.

This increase of MPR can be applied to coal. The same unit of coal will become more productive in future than it is today. Put another way, this means that the value of coal will be higher in the future. Therefore, in a cost-benefit analysis, even when the costs are not declining, the increased benefits will favour coal over time.

4.2. Internalisation of Costs by Environmental Regulations

Another rationale for increased benefits is that non-renewable resources will become scarcer in the future and thus their market values will increase too. Coal is a non-renewable and a scarce resource, which means that, in a given time, any extra (marginal) unit of use will have higher costs and lower benefits than the former unit. That is, there is an increasing social marginal cost (SMC) and a decreasing marginal benefit. In Figure 11 at point Q_1, the social marginal benefit (SMB) equals the SMC, where coal is used most effectively. Any additional unit of output will bring a net loss to society.

Figure 11. Economic Impacts of Environmental Regulations.



Without environmental regulations, more than the optimal quantity of coal will be used because some costs are externalised and are not be paid by consumers. Therefore, the consumers' private marginal cost (PMC) curve would lie below the SMC curve, except at the point of origin, where they meet. At the same time, the SMB curve, except at the point of origin, where they meet. At the same time, the SMB curve, whether it pertains to the whole society or to an individual average, would remain the same. For the individual, the private optimum quantity will be at Q_p, which is higher than Q_1. At this point, the whole society will suffer a marginal net loss to SMC_p–SMB_p. The greater the externalities, the higher the quantity of coal used (Q_p), and, thus, the higher the marginal social net loss.

Environmental regulations can internalise the costs of coal utilisation, thus drive the PMC close to the SMC. This would lead coal to be used in a socially optimal manner, even based on individual decisions, and would make coal more attractive to society.

4.3. Benefits of Environmental Regulation to the Coal Industry

Environmental regulations not only increase the costs of coal use, but also bring many benefits to coal and the coal industry. For example, environmental regulations can help the coal industry attract foreign investment by clearly identifying environmental liabilities. States with inadequate environment regulations will have difficulty in attracting foreign investment in the mining sector (Otto and Barberis, 1994) because responsibility for environmental problems is uncertain. In 1997, the US Environmental Protection Agency showed that the net present value (NPV) of the benefits resulting from the *Clean Air Act* between 1970 and 1990 (with a 5 per cent discount rate) was US$21.7 trillion (Tietenberg, 2002).[7] Specifically, the following benefits can be identified.

First, environmental regulation might bring economic advantage. In the case of internalisation costs (Figure 11), it is easy to see that some low-grade coal resources, the quantity at Q_p–Q_1, are saved. When new technologies (for example, sulphur emission controls) cut costs or when social marginal benefits rise (that is, when the SMB and the SMC move to SMB_1 and SMC_1, respectively), those previously saved marginal resources could be used without a negative social impact. The changes of SMB and

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[7] Here, benefits include improvement in human health, natural beauty and agricultural production, but cannot include all the benefits. There are two kinds of costs: 1) the high prices generated, and 2) the cost to implement regulations.

SMC could lead to optimisation of the amount of coal used (Q_2), which is higher than at present (Q_1). This mechanism is the economic basis upon which the use of coal can be harmonised with environmental regulation.

Secondly, environmental regulation can promote the upgrading of enterprises and the optimisation of industrial structures. Regulation can help building a level playing field for competition through the internalisation of costs. Those companies that are unable to upgrade in line with new environmental standards, or have lost their competitive capacity, will be closed and this will improve the performance of the entire coal industry.

Thirdly, environmental regulation inspires companies to innovate. Strict environmental regulation can make enterprises achieve better technological standards (Warhurst, 1994). Firms can even benefit from properly designed environmental regulation because it leads to unexpected technological innovation, which in turn could reduce pollution and total costs (Porter and Claas, 1995). That is, new technology with lower production costs and causing less environmental harm could, to some extent, offset environmental costs.

Finally, environmental regulation can facilitate the cleaning up of coal use. With proper pollution control instruments in place, miners and users of coal have to apply technologies to reduce pollution. This helps coal become more compatible with the environment. Environmental regulations were used to push the development of pollutant-specific control technology which could force emission reduction in the US in the 1970s (Yeager and Baruch, 1987). Regulations can also encourage the use of clean-coal technologies, the best option for achieving emission reduction (Yeager and Baruch, 1987).

4.4. Coal and Its Alternatives

Renewable energy has not matured sufficiently to provide all energy needs in the foreseeable future. Although renewable energy will develop rapidly, it is, however, still likely to play a limited role for some time. There are uncertainties surrounding nuclear energy and hydroelectricity (EIA, 2001). Nuclear energy is criticised by many people for its waste problems and security threats (Correspondent's Diary, 2009) and these risks may not be less than those posed by climate change. Most environmentalists exclude hydroelectricity from the category of renewable energy because history has demonstrated that large dams have high external costs and high environmental and social risks (Andrews-Speed, 2007). Hydroelectricity is also problematic because of seasonal fluctuations in water flow. Finally, in some places the available resources have already been heavily exploited.

Solar and wind power seem to be promising. However, wind power is constrained by the availability of land and wind resources. Solar photovoltaic power generation has a high cost characteristic. And it may need a considerable time for the cost to reduce to an economically viable level.

Biomass energy is limited by land and other natural resources and thus cannot develop on a large scale. For example, the development of biomass may add pressure on the scarcity of water. The development of bio-fuels is thought to be a main factor causing the food crisis and surging grain prices in 2008 (Rosegrant, 2008).

In terms of climate change, coal may be not more physically disadvantaged than renewable energy. Contrary to popular belief, hydroelectricity can seriously damage the climate because it produces greenhouse gases[8] and thus ‘any weighting of the emissions impacts for time preference will strongly favour fossil fuel alternatives over hydroelectric generation’ (Fearnside, 2004). Coal is often used as feedstock in chemical plants, during which carbon dioxide will not be formed. In addition, there is the hope that coal can reduce carbon emissions from the transportation sector, where carbon emission is traditionally thought to be difficult to reduce[9] (CIAB, 2008).

Since there is no simple solution to the energy and climate change issues, nuclear energy, hydroelectricity, renewable energy and fossil energy should be considered equally by governments (World Energy Council, 2007). Since no feasible alternative to coal has emerged on a sufficient scale and coal has various advantages over renewable energy, coal is likely to dominate the world’s electricity generation in the near future.

5. Discussion

5.1. Coal in a Carbon-Constrained Future: Issues of Climate Change

The biggest challenges for the future development of the coal industry are carbon dioxide emission and climate change. Many global measures have been and will be initiated to control greenhouse gas emissions. The progenitor was the Kyoto Protocol, under which industrial countries agreed to reduce their greenhouse gas emissions by at least 5 per cent below 1990 levels in the commitment period 2008–12. Although the

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[8] For example, methane emitted from turbines and spillways; methane produced from the growth and decomposition of soft green vegetation when water levels fall and rise, and carbon dioxide emissions from above-water decay of standing trees.

[9] The delivery vehicle is hydrogen, which will probably be a major transportation fuel in the future and coal gasification could produce the cheapest hydrogen.

United States—the world’s largest emitter of carbon dioxide—refused to ratify the Kyoto Protocol, it nonetheless became effective on 16 February 2005. In the future, more stringent regulations and restrictions on carbon dioxide emissions can be expected and thus on the use of fossil energy. A recent example is Australia, which is progressing toward a national emissions trading scheme.

In a carbon-constrained world, if the coal industry wants a long-term future, it must achieve near zero-emissions (Garnaut, 2008). Zero or near-zero emissions from coal-fired power plants through carbon capture and storage (CCS) are technologically feasible (Energy Committee of the ASME Council on Engineering, 2005; Keay, 2003; Shimkus, 2005), but their economic viability is still to be tested.

Many international cooperation programs and some experimental projects have been initiated to test the feasibility of zero emissions. The US government has launched a public–private partnership to develop a coal-fired electricity-generating facility with near-zero emissions (Shimkus, 2005). The ‘FutureGen’ project is planning to demonstrate CCS technology on a commercial scale: Integrated Gasification Combined Cycle (IGCC) coal power plants, which will be the cleanest coal-fired plants in the world, are expected to be operational in 2015 (US DOE, 2008). Rio Tinto and BP are working together to generate almost carbon-free electricity from coal (Macalister, 2007). South Africa has declared CCS a national research priority (Naidoo, 2009). Europe's first underground CCS site was put into use in Germany in July 2008 and is expected to pump up to 60,000 tonnes of carbon dioxide underground over a two year period (Physorg, 2008). The EU Commission is funding research to reduce the cost of CCS technology to less than €20 per tonne, with capture rates above 90 per cent (EurActiv, 2006). Several CCS projects are being implemented or proposed in Australia under government support (Garnaut, 2008).

Carbon capture appears promising for IGCC coal-fired plants, even though the cost and reliability of IGCC have not been proved (Sachs, 2008). A study in the UK shows that even the simple replacement of one or two coal-fired power stations with modern supercritical and ultra-supercritical plants can do more to reduce carbon dioxide emissions than the entire UK renewable programs have done thus far (Keay, 2003).

An emerging but more promising application of CCS is in coal-to-liquids (CTL) plants. Carbon dioxide is more easily captured from syngas plants than from conventional coal-fired plants[10] (Fairley, 2007). The CTL project can also afford to pay a higher cost and thus it is more promising to apply CCS to a CTL plant than to a power generating plant (CIAB, 2008). Several CTL plants in China are being constructed by the Shenhua Group. Currently, this project intends to discharge no pollution other than carbon dioxide and is planned to test the technology of CCS.

Another promising factor is that carbon dioxide can be separated and stored or put to other commercial uses. These multiple benefits make such a sequestration method attractive and promising. China's Shenhua Group is cooperating with the China National Petroleum Company (CNPC) to capture carbon dioxide and inject it into oil fields to increase the oil-recovery rate: carbon dioxide will not be released into the atmosphere and more oil will be extracted from the fields. Compared with conventional recovery methods, this enhanced oil recovery method using carbon dioxide can increase oil production by 4-18 per cent (Tzimas *et al.*, n.d.). Other storage technologies, such as

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[10] Gasification transforms coal into synthesis gas, or 'syngas', which is as clean as natural gas in power plants. Syngas can be further transformed into gasoline and diesel fuel (the process is called coal liquefaction).

the creation of charcoal by the pyrolysis of biomass ("biochar"), can not only reduce atmospheric Green House Gas levels, but can also improve soil fertility, increase agricultural productivity and improve water quality (Lehmann *et al.*, 2006).

If carbon sequestration can reach reasonable cost targets, carbon fuel might achieve a price comparable with or even cheaper than carbon alternatives (Keay, 2003). IGCC fixed investment already made in China is at half the international level of cost.[11] Pollution and carbon prices can accelerate the pace of technical application. If SO_2 and NOx emissions are priced, the IGCC power plants will be more attractive. If a price is put on carbon emissions, these carbon dioxide reduction technologies will become economically viable and thus can lead to an accelerated achievement of zero emissions. Global pricing of carbon dioxide can also encourage investment in clean energy technologies and higher prices of energy will lead to higher efficiency (World Energy Council, 2007). However, putting a price on carbon emissions is not enough to promote innovation. The European carbon-trading system has not led to significant research or application of breakthrough technologies (Sachs, 2008).

The separation of points between capture and storage is not a problem. The technology for long-distance transportation of carbon dioxide has matured and is used in the US: 40 million tonnes of carbon dioxide every year are transported 2500 km through high pressure pipelines to increase the oil recovery rate (IEA, 2001).

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[11] This is based on research by Dr. Kejun Jiang, who I talked with in a workshop held in Beijing on 28 October 2008.

5.2. Role of Clean Coal Technology

The feasible solution to the contradiction between environmental protection and coal industry development is to use coal in cleaner ways. Clean coal technology (CCT) can improve the efficiency of coal utilization, reduce environmental pollution, and promote economic development[12] (National Energy Foundation, 2007). For example, the flue-gas clean-up systems that are currently available commercially and that have long been used in power plants can remove 99.9 per cent of particulates, 95 per cent of sulphur dioxide and 90 per cent of nitrogen oxides (Energy Committee of the ASME Council on Engineering, 2005).

Technologies for reducing traditional pollution, such as Sulphur dioxide, NOx and Soot have matured and are ready to be applied. See Europe Economics (2006) for a list of existing and promising combustion techniques for coal fired power generators. Some of these methods, such as scrubber systems, although straightforward now, seemed unrealistic in the 1970s when the US government started to introduce air-quality standards and regulations (US EPA, 1971; Yeager and Baruch, 1987). These technologies were beset by great difficulties, high costs, and poor performance at the beginning. It took a decade of trial and error to reduce them to confident practice (Yeager and Baruch, 1987).

CCTs have both environmental and economic benefits. Fluidized-bed combustion and IGCC can achieve not only a sustainable emission reduction, but also improve productivity (Yeager and Baruch, 1987). IGCC technology could increase generating

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[12] CCTs are often classified into three kinds: coal cleaning or washing, a pre-combustion method that can reduce sulphur content by as much as 30 per cent; post-combustion treatments, such as flue-gas desulphurization (FGD) systems; and the use of electrostatic precipitators to remove fly ash.

efficiencies by 20 to 30 per cent and reduce emission levels (especially of carbon dioxide and sulphur dioxide) more effectively than present pollution-control technologies (EIA, 2001). Super-critical boilers can be 50 per cent more efficient than conventional coal-fired power plants (EurActiv, 2006).

When facing a future in which coal will continue to dominate the energy mix, high efficiency and clean technology will be crucial for China. The energy intensity per unit of GDP in China is 20 per cent higher than the OCED average (OECD, 2007b). Improvements in combustion efficiency for the large numbers of industrial boilers operating in China—where emissions reduction efficiency is just 65 per cent compared with 80 per cent in Europe (Watson *et al.*, 2000)—could produce even more significant environmental benefits. The Chinese government gives energy conservation and efficiency improvements high priority in its energy development strategy, especially the efficient and clean use of coal and other fossil energy sources.

There is a whole range of coal-based power generation technologies that are already applied or being applied in China, from 30-36 per cent efficiency of sub-critical installations, to the 40 per cents of supercritical, ultra-supercritical and IGCC (IEA, 2007). However, one particular problem for China is not the shortage of feasible technology, but the lack in applications—the result of insufficient incentives and external pressures. For example, most of China's electricity is produced from coal and most coal-fired plants are far dirtier than those found in OECD countries (IEA, 2007). Although China has regulations for the installation of FGD requirements in power plants, in 2005 only 45 Gigawatts (GW) out of 389 GW of installed thermal capacity had a Flue Gas Desulphurization (FGD) unit installed, which helps explain why the target in the nation's tenth Five-Year Plan of a 10 per cent reduction in sulphur dioxide in 2005 compared with 2000 levels has not been achieved (IEA, 2007). As a cheaper alternative to FGD, coal-washing has not been used widely[13] (NDRC, 2007b). Furthermore, coal-washing efficiency in China has only achieved a removal rate of 45 per cent (Watson *et al.*, 2000).

The future of the coal industry in a carbon-constrained world will depend on the commercial success of CCS in the long term (Garnaut, 2008). CCS will maintain coal as a valuable commodity for resource-rich countries and as an affordable source of energy for developing countries. It could also maintain the value of large-scale coal-fired generation fleets in many countries. The feasibility of such technologies is thus of great interest to the coal industry and to countries with a substantial stake in coal. If no such feasible low emission technologies are capable of development, this information should be revealed as early as possible so that communities can start to adjust as early as possible.

The Chinese government treats CCS technology seriously; it is documented in China's eleventh Five-Year Plan under the National High Technologies Program and in the *National Medium and Long-Term Science and Technology Plan Towards 2020*. The first 'green' power project, a 250-megawatt (MW) IGCC power station is due to start operating by the end of 2009 (Greegen, 2008). The technology is available and economical energy use has found increasing favour in recent years due to surging oil prices.

The economic feasibility of CCT will increase over time, not only because technical progress will reduce costs, but also because people are willing to pay more. Since the

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[13] Washed coal accounted for only 32 per cent of total coal consumption in 2005.

environment is a normal good, with economic development, as people become richer, they will be willing to pay more for a cleaner and better environment. This will facilitate the adoption of what are now seen as expensive technologies.

5.3. Policy Implications

The complete phasing out of coal is not practical in next decades because of the dominance of coal in the energy mix in many countries, limitations of alternatives, energy security, affordability, and established interests in coal and related industries. On average, coal accounted for 28.6 per cent of the world's primary energy in 2007 (BP, 2008). Many countries, such as China, Poland, South Africa and Australia, get more than 80 per cent of their electricity from coal (WCI, 2008). Corresponding to this energy structure, coal mining is also entrenched on a large scale in terms of investment, employment and revenue in these countries. There are large scale coal-fired generating fleets, which often last several decades and thus cannot be readily changed in short term. Coal is also a cheap and affordable energy source in many developing countries.

One specific reason that coal will continue to play a leading role in China's future energy mix is that there is not realistic to rein in coal consumption at the current stage. All non-fossil energies together only provide 7.2 per cent of the total national energy consumption in China (NDRC, 2007a). Even with a proactive plan of building 41 nuclear power stations before 2020, it is estimated that China's nuclear capacity will power only 4 per cent of the national total installed electricity capacity at that time (NDRC, 2007a). A suboptimal but feasible choice is substituting coal with cleaner fossil energy, that is, oil and gas. China is extremely abundant in coal reserves but poor in gas and oil. Currently, half of its oil consumption is supplied by imports. Larger imports of oil will cause negative political and economic consequences.

The justification of policy for coal will be different among groups with different perspectives. To environmentalists, coal should be limited and even eliminated as soon as possible. In contrast, the coal and electricity industries have the motivation to maintain coal as long as possible to protect their vested interests. For policy-makers, the position will be somewhere in between. Policy-makers need to think not only about preventing climate change and reducing pollution, but also the costs of doing so.

Democratic governments also need to think about stakeholders' interests and externalities. The climate change policy is such an example. A tough climate change policy may cause problems to current government while benefiting future governments. Although it has been argued that the costs of inaction are higher than the costs of action (Garnaut, 2008), the policy-makers still need to determinate how to act and to what extent. All these different concerns will shape different climate change policies for different governments or the same government at different times. Under whatever policy scenarios, mitigation of climate change is a necessary strategy towards a low carbon economy, whether the low carbon is achieved through reducing the use of fossil energy fuels or through such clean coal technology as CCS.

When facing a future in which coal will continue to dominate the energy mix, high efficiency and clean technology will be crucial. Some East Asia Summit (EAS) members need to face up to a sharp tension between increasing demand of environmental protection including mitigation of climate change, and the continuing dominance of coal in their energy mix. Since there is no practical way to change the dominant role of coal in the energy mix in many EAS countries, in particular, China, India and Australia, it is important to popularise and utilise clean-coal technology to make coal use more environmentally acceptable.

International cooperation and making use of the international cooperation system, such as the Clean Development Mechanism, is important to applying new CCTs and funding environmental protection projects. Since the use of CCT depends on its demand, it is necessary to create an institutional environment that stimulates and forces coal users—particularly large-scale users such as steel makers and power generators—to employ appropriate technology.

Improvement of energy efficiency (EE) is an available and practical way to ease the tension between coal consumption and climate change. EAS has many opportunities in EE improvement because EE is low in many member countries. In addition, Japan is the world leader in EE and thus could help other members to improve their EE. Since improvement of EE can help energy users reduce costs while protecting the environment, the improvement can be delivered through commercial methods.

However, host governments, donor governments and non-government organisations, such as ERIA, can play some facilitating roles by providing public funds to leverage private investment, educating potential demanders, collecting information about the supply of and demand for technologies and services, and creating forums where demand and supply can be matched.

6. Conclusion

This paper reviews the relationship between coal and the environment. Both qualitative and quantitative methods are applied.

This finding sheds light on the future of the coal industry. The view that high costs brought about by environmental regulations will harm the coal industry is challenged by historical cases, which show that environmental regulations have not hurt the coal industry very much. A study of the coal industry in Western Europe reveals that its decline was not caused directly by environmental regulations and therefore does not indicate a general trend of decline in the coal industry globally. The UK case shows that high production costs were the key driver for the decline of their coal industry. The global and the US cases demonstrate that the development of the coal industry can occur in conjunction with environmental protection.

The hypothesis that coal has declining emissions intensity is supported by China's data using two alternative methods. The seemingly unrelated regression of a fixed effects model finds a significantly declining trend of emissions intensity. The Logarithmic Mean Divisia Index (LDMI) approach quantifies the individual effect of six decomposed factors in changing total WGE emissions. The declining emissions intensity had the largest negative effect on emissions changes. The existence of declining emissions intensity provides a way to reconcile coal with the environment.

The declining emissions intensity, which is the key factor that alleviates the tension between the use of coal and the environment, has often been omitted from previous studies. With the prospect of a fall in emissions intensity in the future, the coal industry can be developed while improvements are made to the environment, providing that emissions intensity continues to fall.

The other factors contribute to promising prospects for coal are facts that non-fossil alternatives will not be available on the necessary scale in the foreseeable future, fossil alternatives are limited by global supply and coal will become more valuable over time.

In addition, many economies that rely heavily on coal for energy cannot change their energy mix for social and economic reasons. The coal industry can also prosper even in their worst scenario for the future of - a carbon-constrained world- through technical changes.

The study suggests that environmental regulations should be tightened to a point at which most externalities in the coal industry have been internalised. This will help individuals make rational economic decisions about utilising coal, and in turn will help coal to maximise its contribution to society. Policy makers have to base on current energy mix and balance vested interests of stakeholders. More clean coal technologies should be developed, promoted and implemented. In particular, the feasibility of CCS technology should be revealed as soon as possible. Government needs to create incentives to popularise existing CCTs. In the case of China, a prevailing lack of application of existing clean coal technologies needs the government to take extra measures. East Asia has advantages and potentials to improve energy efficiency significantly and this improvement can be implemented trough commercial methods. Besides, governments can play roles of facilitator. Finally, in order to mitigate the impacts of climate change, it is important to price carbon dioxide globally.

Although this paper argues that the prospects for coal are promising, there is no denial of the importance of a low-carbon economy. The intention of this paper is to show that coal and the environment can be compatible and it seems that in any event coal will remain a practical and dominant, even if higher polluting, energy source for many years to come.

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