China's Energy Economy: Reforms, Market Development, Factor Substitution and the Determinants of Energy Intensity

By

Hengyun Ma

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Supervisors:
Professor Les Oxley
and
Professor John Gibson

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Abstract

The ongoing transition of former communist countries from planned to market economies has been one of the most important economic phenomena in the last few decades. Among these, China is one of the largest and fastest growing emerging economies in the world since the reforms initiated in the late 1980s. China's economic growth has been phenomenal.

Therefore, understanding China's energy economy is crucial in the new millennium for politicians, businessmen and energy economists. In particular, China's energy policy directions will bring about both challenges and opportunities to the world in terms of an increasing share of primary energy consumption and investment in the energy industry. However, after surveying the literature, it is surprising to find that a few major areas of China's energy economics are missing and the views on China's energy economics are already out dated. Therefore, given the size and growth of its economy and the effect of its energy consumption on global energy markets, reviewing China's energy situation and filling the missing literatures are essential for those who are interested in and concerned about China's economic development in the new millennium.

This study was motivated after conducting a survey of the literature on the study of China's energy economy and reviewing China's energy situation in the new millennium. The goal of the research is focused on providing readers the most important and the newest information on China's energy economy. The study consists of three introductory sections and three core sections. The former includes a survey of literature, China's energy situation in the new millennium, institutional evolution and changing energy

prices. The latter includes tests for the emergence of an energy market in China, factor substitution and demand for energy, and technological change and the determinants of energy intensity.

The main findings are as follows. China's energy economy is still underdeveloped. It is crucial to review China's energy situation in the new millennium. Energy, industrial deregulation and price reforms have been fast in China since the early 1990s. Empirical investigations have found evidence for the emergence of an energy market economy in China. The estimates demonstrate that there appears to be significant substitution possibilities between energy and labor when compared with international findings. Significant effects of substitution mainly come from the adoption of labor-intensive technology. Coal and electricity are significantly substitutable, while the demand for energy is elastic, in general. Finally, decomposing energy intensity shows that the budget constraint (a kind of price effect) reduces energy intensity while technological change increases energy intensity.

These findings bring us to the following major implications. Firstly, it is important to understand the potential effect of new energy regulation and pricing mechanism on the future directions of China's energy economy, which suggests that former predictions of China's energy demand may have to be significantly discounted, and the potential effect on the global energy markets and emissions may need to be re-evaluated. Secondly, significant substitution between energy and labor is potentially good news as China possesses some of the most abundant labor sources in the world. However, because capital more easily substitutes for energy than labor, more policy incentives are needed for labor to substitute for energy. Thirdly, significant substitution between coal-electricity suggests that the effects of environmental taxes, however, may be smaller than expected due to the fact that most primary energy coming from coal. Also any shift from coal to electricity implies more investment in transmission lines rather than railways. Fourthly, energy constraints on energy supply may only slightly impede economic growth in China because the elasticity of substitution between energy and other factors is quite large compared to internationally. Fifthly, while many factors are responsible for the inelasticity of demand for energy, rising income may be one of the most important given the high levels of energy prices. Increasing energy prices may be unable to constrain energy consumption at present. Thus other energy policies need to be considered to encourage or depress certain types of energy consumption. Finally, reducing exports of energy-intensive commodities, reducing the high-level energy-using sectors, lowering capital investment and constraining imports of second-hand and obsolete equipment, would all help reduce growth in energy intensity. Politically, however, this may be at an unacceptable cost to economic growth.

Although this study has conducted a series of investigations into the institutional changes and consumption behavior of China's energy economy, continuous updating required as more data is continually added in a highly dynamic and changing environment.

JEL Classifications: D24, O33, Q41.

Keywords: China, Energy price convergence, Factor substitution and demand.

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Chapter One: Introduction

1.1 The motivations of this study

The motivations for this study come from two aspects. Firstly, the importance of China's energy economy, which is rooted in China's aggregate national economy, which is still in transition The second is the fact that China's energy economy is still in its infancy and therefore there are a number of important topics to be considered.

1.1.1 The importance of China's energy economy

It is well known that China is one of the largest and fastest growing emerging economies in the world since the reforms initiated in the late 1980s. According to China's Statistical Yearbook (CSY), its GDP growth rate has approximated 10% annually and its aggregate GDP has reached 3.1 trillion US dollars by 2006.[1] As a consequence, China's aggregate energy consumption also expanded both in volume and growth rate terms during the same period, especially post 2002. Figure 1-1 demonstrates the historical change of both China's GDP and aggregate energy consumption from 1978 to 2006. It can be clearly seen that GDP grows strongly and consistently, although it does trend downwards between 1996 and 2002, the aggregate energy consumption generally increases consistently with GDP. Apart from the short downward trend, aggregate energy consumption typically tracks GDP after 2002, in fact, the annual growth rate (12.9%) of aggregate energy consumption is slightly higher than that (10.4%) of GDP for the period 2002 to 2006 (CSY, 2007).

[1] Exchange rate of Chinese¥ to US$ is 6.9:1 in the 2006 price base.

With strong growth of GDP and aggregate energy consumption, China has become the second largest consumer of energy products and the third largest oil importer in the world. China's primary energy consumption has reached 1863.4 million tonnes oil equivalent in 2007, the second largest consumer after the USA (BP, 2008). More importantly, China's global shares of primary energy consumption have increased dramatically since 1978, especially after 2002 (Figure 1-2). The global shares of primary energy consumption were only 6.3% for China and as high as 28.6% for USA in 1978. However, China's global share of primary energy consumption soared to 16.8%, in 2007. In contrast, the USA's global share of primary energy consumption decreased dramatically to 21.3% in 2007.

Due to its rising energy demand, China has had to import large quantities of oil to meet its domestic demand. Despite being a net exporter of petroleum in 1990, China's import share of petroleum dramatically increased from less than 8% in 1995 to approximately 50% in 2006 (Figure 1-3). By 2007, China's imports of crude oil and products reached 184 million tonnes, becoming the third largest importer after USA and Japan (BP, 2008).

There are many factors that require China to import more petroleum products. Of them, household car ownership is one of the most important. Private car purchases have increased rapidly. In 2000 there were only 0.5 cars per hundred urban households. By 2006 it had raised to 4.32 cars per hundred urban households (CSY, 2007). The rise in electricity consumption has been driven not only by rapidly growing industrial demand but also an even more rapidly spreading ownership of household appliances (Smil, 1998). For example, household air conditioners and microwave ovens have trebled during in the last six years, from 30 and 17 to 88 and 51 per hundred urban households, respectively. As a result, household electricity consumption has expanded rapidly. Household electricity consumption was 48 billion KWh in 1990, doubling to 101 billion KWh in 1995 and doubling again to 201 billion KWh by 2002. In 2006 this figure had risen to nearly 325 billion KWh. As a consequence, there has been a growing shortage of electricity in China which has attracted growing interest and concern (Lin, 2004).

Raw coal production accounts for most of China's primary energy supply and electricity production is mainly generated from coal. This raises considerable environmental issues. One of the features of China's energy consumption is its overwhelming share of raw coal in aggregate energy consumption. During the past three decades, China's share of raw coal consumption remained steady at 70% of aggregate primary energy consumption (Table 1-1). By 2006 this had risen to approximately 77%. Raw coal is the most important source of electricity where in the last three decades over 80% of electricity consumed was generated from burning raw coal. Electricity from hydro, nuclear and wind accounted for only 8%.

Following three decades of rapid economic growth and rising demand for energy products, Chinese residents are now becoming more environmentally aware. Consequently, policy makers have begun to acknowledge the need for cleaner sources of energy, such as natural gas, electricity and hydropower. Continued movements in this direction will see the share of coal in total energy consumption decline further, with the share of oil, gas, electricity and hydro increasing rapidly. This will push China to import more oil with significant effects on global energy markets (Crompton and Wu, 2005), and meanwhile more power plants are encouraged to be built.

However, raw coal remains the most important energy source in China. Therefore, China may face more severe challenges in dealing with future environmental issues than most rapidly developing countries. Given the size of the economy and its current growth rates and its special features of energy economy, any changes in industrial structure, energy price deregulation, technological progress and improvements in energy efficiency in China will produce a significant effect on the global energy market. Therefore, China's energy economy does matter nationally and globally.

1.1.2 China's energy economics is still in its infancy

Compared with its global importance China's energy economy is less developed and less fully understood in an international sense. Despite some areas having been extensively investigated for example, the relationship between energy consumption and economic growth, and changes in energy intensity, many other important issues, including energy price convergence; energy demand; energy-other factor substitution, and energy economic studies at the disaggregate level, have not been extensively studied or considered at all.

Energy policy reforms play an important role in the development of China's energy economy. Therefore, China has introduced numerous measures to rationalize oil, coal, gas and electricity prices since the early 1980s. At the same time, China's energy reforms have attracted great attention of researchers domestic and international. It has also seen many studies on China's energy reforms, including regulatory and pricing system. For example, Andrews-Speed, Dow and Gao (2000), Xu and Chen (2006), Cherni and Kentish (2007), and Ma and He (2008) discuss the ongoing regulatory reform to China's government and state sector of energy industry. On the other hand, Wu (2003), Wang

(2007) and Hang and Tu (2007) address the reforms of price deregulation over time. Unfortunately, all these studies only introduce concrete institutional reform programs in China's energy industry to the world. They have not econometrically assessed any potential effects of those reform programs on the development of China's energy economy as well as on the whole national economic growth. No strongly supported econometric policy suggestions have yet been provided to policymakers. Therefore, it is not surprising that the gradualism strategy was adopted in the reforms of China's energy industry.

1.1.3 The importance of understanding China's energy economy

Understanding China's energy economy in the new millennium is crucial for politicians, business people and energy economists. In particular, China's energy policy directions will present both challenges and opportunities to the World in terms of an increasing share of primary energy consumption and investment opportunities (Wang, 1995; CIAB, 1999). China's industrialization, modernization and urbanization affect the way in which energy resources will be developed as the basis of economic growth (Dean, 1974).

1.2 The focuses of this thesis

This thesis starts by conducting a survey of the literature on China's energy economy. This is followed by a review of China's energy situation in the new millennium. By doing this, I want to narrow my study to provide readers with the most important information on China's energy economic research. After this, I found the following topics worthy of study and also important to those who are concerned of China's energy economy and environmental issues as well as global energy markets. Specifically and logically, these topics are:

- A survey of literature on the study of China's energy economy.
- China's energy situation in the new millennium.
- The regulation and pricing system of China's energy industry.
- Energy reforms and market development.
- Energy price convergence and cointegration.
- Substitution of and the demand for energy
- The driving forces of the changes of energy intensity

These topics comprise my thesis based upon the following specific reasons for inclusion.

1.3 The motivation for each topic

1.3.1 A survey of the literature

Given the importance and rapid pace of economic growth and the special features of energy consumption and trade, there is need for an up to date and critically assessed information on China's energy economy. Such information will inform both academic and political decision making including environmental policies. Because of the political importance of energy, leaders in all countries have typically demanded that predictions be made on energy efficiency, energy consumption and energy trade. Those charged with negotiating and managing China's energy trade agreements, including the nation's top leaders, also need to have accurate predictions about future energy demand, imports and crucially impacts on economic growth and employment. More importantly, researchers on the energy economy need to know what has been done well and what has not; what resources they can access to for them to conduct China's energy economy study and which are biased and dubious. Unfortunately, there has been no such a review paper that is able to provide such information until now. This survey will review existing research and help facilitate future research to better understand and study China's energy economy.

1.3.2 China's energy situation in the new Millennium

Many authors have focused on the energy situation in China (Dean, 1974; Dorian and Clark, 1987; Kambara, 1992; Wu and Li, 1995; Smil, 1998; CIAB, 1999), however, many energy related issues in China still remain unanswered, for example, what are the potential forces driving energy demand; what are the potential forces driving energy supply? Previous reviews focused only on fossil fuel based energy and ignored other important elements including renewable and 'clean' energy sources. Therefore, a comprehensive and complete review of the energy situation in China is timely and necessary. The work presented here is intended to fill this gap by bringing the research on fossil-based and renewable energy economic studies together and identifying the potential drivers behind both energy demand and supply to provide a complete picture of China's energy situation in the new millennium. This will be of interest to anyone concerned with the development of China's economy in general and the energy economy, in particular.

1.3.3 Energy reforms and market development

To conduct an academic study on China's energy economy, we not only have to understand the situation of China's energy economy and to survey the literatures on the studies of China's energy economy, but have to have a comprehensive understanding of the regulatory system and price reforms in China's energy industry. Although many studies have mentioned the changes to the regulatory system and price reforms, their presentation of these issues is often incomplete and sometimes outdated. Therefore, for this present study, we need to have a thorough understanding of changes to the regulatory system and price reforms in China's energy economy over time so as to better approach our issues and derive accurate policy implications. This particular chapter will review the changes of regulatory bodies and evolution of price reforms as well as their effects on the changes of energy prices and on the emergence of energy market economy in China.

1.3.4 Tests for the emergence of an energy market

The ongoing transition of former communist countries from planned to market economies has been one of the most important economic phenomena in the last few decades. It is interesting, therefore, to consider whether liberalization of domestic trade prompts major shifts in price structures that were highly distorted under central planning (Fan and Wei, 2006). Moreover, in the context of China, there is continued debate about whether gradualist reform has been successful (see Lau, Qian and Roland, 2000; Young, 2000; Poncet, 2003 and 2005). Since China embarked on its economic reform and adopted an open door policy in the late 1970s, its economic development has been greatly enhanced by active participation in international trade. But recently there has been more debate about domestic trade with China's major trading partners urging further opening of the domestic market, especially post-accession to the World Trade Organization (WTO). Moreover, even if the Chinese government removes remaining barriers to international trade, the effectiveness of this policy might be compromised by regional trade barriers within China itself (Fan and Wei, 2006; Poncet, 2003 and 2005). It is thus useful to investigate whether domestic markets in China are in fact integrated

Prices play an important role in determining the allocation of resource inputs. Therefore, energy prices have been extensively analyzed in the literature over the past three decades the world wide (Lanza, Manera and Giovannini, 2005). Much of the applied research and policy studies have also examined the role played by the price of energy in determining economic growth and inflation rates both in developed and developing countries (Adrangi et al., 2001; Asche et al., 2003; Stern, 2000; Girma and Paulson, 1999; Gjolberg and Johnsen, 1999; Serletis, 1994; Shaked and Sutton, 1982). Given its high energy intensity and huge economic volume, it is surprising to find that little work has been done on the role that energy prices play in determining the economic growth and energy consumption in China. The reasons for that have been unclear yet, however, it is most likely the concern whether there has been a market-oriented energy economy in China.

The emergence of a market economy has been successfully tested for China's agricultural commodity sector (Huang and Rozelle, 2006). However, as the second special industry, the convergence of prices has not been well investigated for China's energy economy. Energy market integration has also been extensively investigated for other countries (Asche, Osmundsen and Tveteras, 2002; Asche, Osmunddsen and Sandssmark, 2006; Bachmeier and Griffin, 2006; De Vany and Walls, 1999; Narayan and Smyth, 2005; Adrangi et al., 2001; Asche, Gjolberg and Volker, 2003; Gjolberg and Johnsen, 1999; Serletis, 1994; Weiner, 1991). Recent work, however, reveals only one study, Fan and Wei (2006), which tests the price convergence of gasoline and diesel, which one might expect, *a priori* to be the most likely, to show market integration among the key energy inputs. More importantly, the study of Fan and Wei (2006) did not take into consideration of the effect of the gradual reforms on the course of energy economic development in China. To the best of my knowledge, there has been no specific study on energy market integration using data from China, which also considers two other key fuels, coal and electricity.

1.3.5 Factor substitution and the demand for energy

Given the present energy situation, many studies have made great efforts to predict China's energy demand (Shiu and Lam, 2004; Zou and Chau, 2006; Han et al., 2004; Wang, Tian and Jin, 2005; Garbaccio et al., 1999; Fisher-Vanden et al., 2004; Price et al., 2001; Sinton and Levine, 1998; Sinton and Fridley, 2000; Hu and Wang, 2006). It is clear, however, that predictions of China's energy demand should be based on empirically estimated parameters, such as elasticities of factor and energy substitution, and price elasticities of energy demand (Ozatalay et al, 1979). Thus, it is crucial to know the substitution possibilities between energy and non-energy inputs if one is interested in deriving the implications of increasingly scarce and higher priced energy inputs (Berndt and Wood, 1975), including the implications for economic growth (Hogan and Manne, 1977). Yet when one looks for estimates of inter-factor and inter-fuel substitution possibilities and price elasticities of energy demand for China, they are almost non-existent. The few papers that do exist (e.g., Han et al., 2007b; Hang and Tu, 2007; Fan, Liao and Wei, 2007) say little about factor substitution between energy and non-energy and they do not consider technological effects on the change in energy intensity. Moreover, their empirical methods use only a simple cost function approach (Hang and

Tu, 2007) and some important independent variables or interaction terms are excluded due to price data limitations and small sample size (Fan, Liao and Wei, 2007).

1.3.6 The changes and determinants of energy intensity

Ever since the 1973 world petroleum crisis encouraged the development of energy efficiency strategies, energy-related departments and agencies have studied energy efficiency.[2] The Office of Energy Efficiency and Renewable Energy of the United States Department of Energy (OEERE, 2005), for example, created a new system of indexes of energy intensity which were designed to measure the change in national energy efficiency and that of strategic industries. A series of Energy Efficiency Trends in Canada published by the Canada Natural Sources Committee systematically analyzes and assess changes in Canadian energy efficiency trends (NRC, 2005). Moreover, the International Energy Agency began to explore energy efficiency assessment indicators in 1995 and currently publishes a series of reports of energy efficiency for OECD countries (IEA, 2004).

Energy efficiency has recently become an important topic in China and has as a consequence been extensively investigated. China's energy intensity is relatively high by world standards for example, it's energy intensity was 0.91 ton oil equivalent per thousand US$ GDP at 2000 prices in 2005 compared with 0.32 for the world as a whole and 0.195 in OECD countries (CESY, 2007). Given its size and high energy intensity, any improvement in energy efficiency in China will affect world energy demand and in turn the world energy price. China's energy intensity has dramatically declined since 1978 (Ma, Oxley and Gibson, 2008a). There is considerable debate about the major factors responsible (Garbaccio, Ho and Jorgenson, 1999; Fisher-Vanden et al, 2004);

[2] The energy intensity is simply defined as the ratio of energy consumption to output (gross domestic products-GDP), which reflects the energy efficiency.

about the timing of the decline (Zhang, 2003); about whether the decline is secular or fluctuating (Liao, Fan and Wei, 2007) and even about the measures of energy intensity used (Qi, Chen and Wu, 2007).

Most of the previous studies on China's energy intensity employ an index number approach to decompose the change in energy intensity into the effects of industrial structure change and the change in industrial energy intensity (Ma, Oxley and Gibson, 2008a). As a consequence, these studies cannot derive an economic explanation of the change in energy intensity as they cannot separate out price change from factor substitution. Moreover, even though technological change is well known to be an important driver of the change in energy intensity, the index number approach cannot show the contribution coming from this source.

In addition, since the existing studies provide conflicting results, they are unable to explain the reasons why aggregate energy intensity declined, especially after 2000. For example, the measured contributions of industrial energy intensity and industrial structural change to the change in energy intensity vary between 42:58 (Qi and Chen, 2006), 70:30 (Gao and Wang, 2007), 46:54 (Ma and Stern, 2008), 20:80 (Zhang and Ding, 2007), 55:45 (Zhou and Li, 2006) and 69:31 (Shi, 2007).

Finally, most studies ignore the fact that China is a vast territory with large variations in geography, climate and economic growth. Even just considering the broad regions shown in Figure 1-4 there are large apparent differences in energy intensity. The highest energy intensity can be found within the industrial and transportation sectors where it ranges from 13.5 in region 2 to 40.0 in region 7 for the industrial sector and from 15.1 in region 1 to 27.2 in region 7 for the transportation sector (Table 1-2). The differences are also evident in other sectors across regions. Thus, energy demand and factor substitution possibilities between energy and non-energy and determinants of energy intensity are important issues for regional policy-makers. Table 1-3 presents data on regional energy production and balance from which it can be seen that regional energy production is quite uneven, especially in terms of coal production. For example, total coal production in region 1 accounts for almost 50% of national total coal output, while in region 2 little coal is produced. Crude oil production comes mainly from regions 1, 3 and 7. Natural gas production is also unevenly distributed across regions, with approximately 75% coming from regions 6 and 7 which are located in the west of China. Due to the uneven distribution and rising demand for energy, shortages of particular types of energy might be expected in some regions. For example, most regions run a coal shortage except for regions 6 and 7 where there is a surplus of approximately 120 million metric tones. Similar effects exist for electricity and natural gas, but in contrast most regions run a deficit of crude oil – the exception is region 6. With such uneven energy supply across regions, interregional energy transportation is inevitable which in turn leads a huge investment in pipeline and railway construction. These interregional characteristics of energy production and consumption undoubtedly have an impact on regional economic growth and regional energy intensity.

Following a series of policy adjustments during the last three decades, the price of major primary energy sources appear to be converging over time (Ma, Oxley and Gibson, 2008b). They also appear to be rising and becoming more dependent upon those in international markets (Hang and Tu, 2007; Wu, 2003). However, regional level energy price heterogeneity appears to remain endemic for some forms of energy. Table 1-4 displays the energy spot prices and their changes over time for four energy fuels over seven regions in China. Firstly, note all energy prices have increased significantly in the past decade for example, prices almost doubled for coal, gasoline and diesel and increased by 54% for electricity during the last decade as a whole. Secondly, variations in the price level are also evident across regions for example, coal prices are over ¥470/ton in regions 2 and 4, while they are below ¥340/ton in region 6 and even as low as ¥260/ton in region 7 (in 2005, US$1=¥8.18). Thirdly, price changes over time are also apparent across regions, for example, coal prices increased by approximately 150% in regions 1 and 2 in the last decade, while they only increased by 50% in regions 5 and 7 over the same period. The same can be seen for the price of electricity. Finally, the prices of gasoline and diesel products seem fairly similar both in levels and changes over time across region. However, this result is to be expected due to their similar physical and functional characteristics.

1.4. Organization of the thesis

The thesis is organized as follows. Chapter 2 conducts a survey of literature on the China's energy economy followed in Chapter 3 by an investigation of China's energy situation in the new millennium. Chapters 4 and 5 present the methodologies and data used in my thesis, respectively. Energy reforms and market development are reviewed in Chapter 6. Factor substitution and the demand for energy are discussed in Chapter 7 and the changes and decomposition of energy intensity are investigated in Chapter 8, respectively. Graphical and statistical tests for the emergence of an energy market in China are conducted in Chapter 9. Chapter 10 presents my conclusions and implications.

1.5. The work that has been published

At the end of this chapter, I want to introduce my research work, Chapters or Sections which have been or will be published as follows:

- Parts of Chapter 3 and Section 4 of Chapter 10, titled "China's Energy Situation in the New Millennium", have been published by ***Renewable and Sustainable Energy Reviews*** (2009), doi:10.1016/j.rser.2009.01.018.
- Section 1 of Chapter 7 and Section 1 of Chapter 8, titled "China's energy economy: technical change, factor demand and interfactor/interfuel substitution", have appeared in ***Energy Economics*** 30 (2008):2167-2183.
- Section 2 of Chapter 7 and Section 1 of Chapter 8, titled "Substitution possibilities and determinants of energy intensity for China", have appeared in ***Energy Policy*** 37 (2009):1793-1804.
- Section 3 of Chapter 7 and Section 2 of Chapter 8, titled "China's Industrial Energy Demand: An Empirical Analysis of Substitution Possibilities", will appear in ***Environmental Modelling and Software***.

Table 1-1. The roles of coal in China's energy demand and supply

Year	Share of raw coal in primary energy consumption	Share of raw coal in primary energy production	Share of electricity generated from coal
1978	70.7	70.3	-
1980	72.2	69.4	80.6
1985	75.8	72.8	77.5
1990	76.2	74.2	79.6
1991	76.1	74.1	80.1
1992	75.7	74.3	81.2
1993	74.7	74.0	81.6
1994	75.0	74.6	80.4
1995	74.6	75.3	79.8
1996	74.7	75.2	81.3
1997	71.7	74.1	81.5
1998	69.6	71.9	81.0
1999	69.1	72.6	82.3
2000	67.8	72.0	82.2
2001	66.7	71.8	80.0
2002	66.3	72.3	80.9
2003	68.4	75.1	82.7
2004	68.0	76.0	81.5
2005	69.1	76.5	81.9
2006	69.4	76.7	82.7

Data source: calculated based on China Statistical Yearbooks, 1996-2007.

Table 1-2. Regional aggregate energy intensity in 2006

Region [a]	Agriculture	Industry	Construction	Transportation	Commerce	Others
Region 1	4.3	22.0	4.4	15.1	3.6	1.8
Region 2	11.4	13.5	5.2	26.1	6.6	2.7
Region 3	4.8	22.1	2.8	19.5	5.3	2.9
Region 4	4.0	16.6	3.0	18.9	2.7	1.3
Region 5	3.7	17.1	2.9	21.4	5.2	1.7
Region 6	4.8	28.4	3.6	25.8	8.0	1.9
Region 7	6.6	40.0	3.5	27.2	10.7	3.5

Note: calculated based on 1978 price and unit is ton coal equivalent/¥1000.

Data source: China Statistical Yearbook and China Energy Statistical Yearbook, 1997 and 2007. Beijing: China Statistical Publisher.

[a] Region 1: Hebei, Shanxi, Anhui, Shandong and Henan; Region 2: Beijing, Tianjin, and Shanghai; Region 3: Liaoning, Jilin and Heilongjiang; Region 4: Jiangsu, Zhejiang, Jiangxi and Hubei; Region 5: Fujian, Hunan, Guangdong, Guangxi and Hainan; Region 6: Chongqing, Sichuan, Shaanxi, Gansu, Guizhou and Yunnan; Region 7: Inner Mongolia, Qinghai, Ningxia and Xinjiang.

Table 1-3. Regional energy balance sheet in 2006

Region [a]	Regional energy production				Regional energy balance			
	Coal	Crude oil	Electricity	Natural gas	Coal	Crude oil	Electricity	Natural gas
Region 1	1084.3	38.6	763.7	4.0	-1.0	-22.2	29.6	-2.4
Region 2	6.5	19.6	129.5	1.6	-113.6	-15.7	-76.0	-6.1
Region 3	206.5	62.5	210.4	3.9	-101.4	-21.1	-13.3	-0.5
Region 4	69.7	2.7	604.8	0.2	-370.3	-54.1	22.1	-4.9
Region 5	85.6	13.5	474.5	5.1	-219.1	-27.6	-57.1	0.7
Region 6	539.6	20.9	437.3	24.9	194.1	4.9	52.6	5.2
Region 7	380.4	26.9	245.5	18.9	34.6	-17.2	59.0	7.9

Note: the units for coal, electricity, crude oil and natural gas are million metric tones, billion KWh, million metric tones and million cube meters, respectively.

Data source: China Energy Statistical Yearbook. 2007. Beijing: China Statistical Publisher.

[a] Regional classification refers to Table 1-2.

Table 1-4. Regional energy price changes over time

Region [a]	Coal (¥/ton)		Electricity (¥/ 100 KWh)		Gasoline (¥/ton)		Diesel (¥/ton)	
	2005	Δ%	2005	Δ%	2005	Δ%	2005	Δ%
Region 1	451	144	53	85	5412	100	4556	104
Region 2	470	145	65	51	5458	95	4473	103
Region 3	398	90	61	104	5245	89	4437	94
Region 4	484	95	64	36	5325	96	4351	92
Region 5	444	56	62	34	5527	94	4460	90
Region 6	339	108	52	29	5571	100	4560	94
Region 7	262	54	49	62	5497	102	4640	114

Data source: calculated by taking the average of 10-day interval spot price time series of all capital city market spot prices within region published by State Development and Reform Committee of China.

[a] Regional classification refers to Table 1-2.

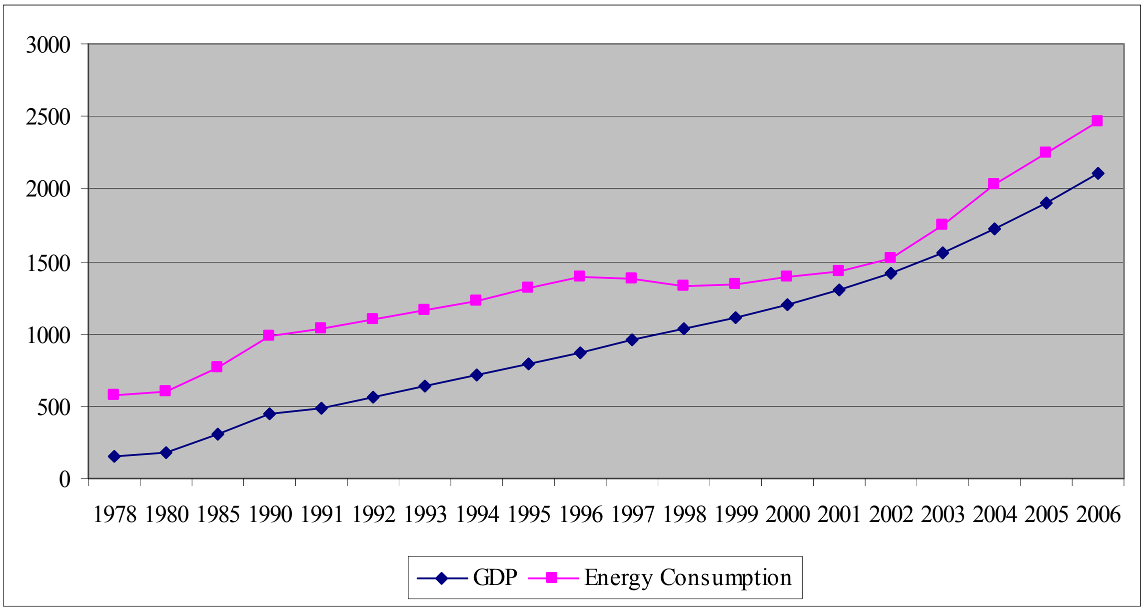


Figure 1-1. China's GDP and aggregate energy consumption

Note: GDP is measured in 10 billion Chinese yuan based on the 2006 price. Aggregate energy consumption is measured in million ton standard coal.
Data source: China Statistical Yearbooks.

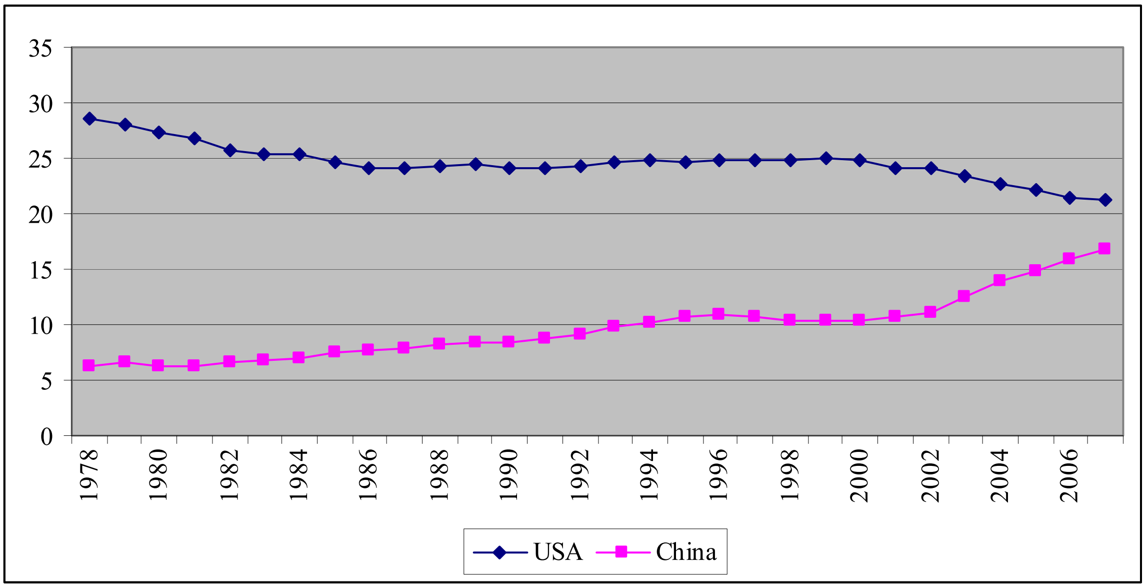


Figure 1-2. Global share of primary energy consumption of China and USA

Data source: BP Statistical Review of World Energy June 2008.

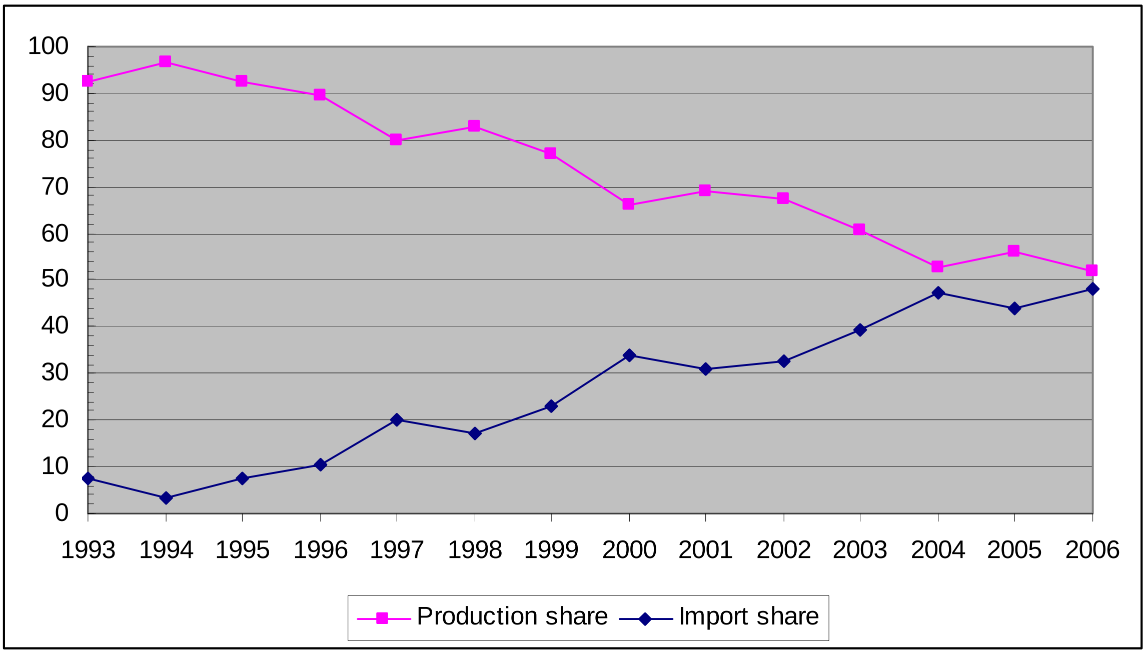


Figure 1-3. Shares of supply and import of petroleum products

Data source: China Statistical Yearbooks, 1994-2007.

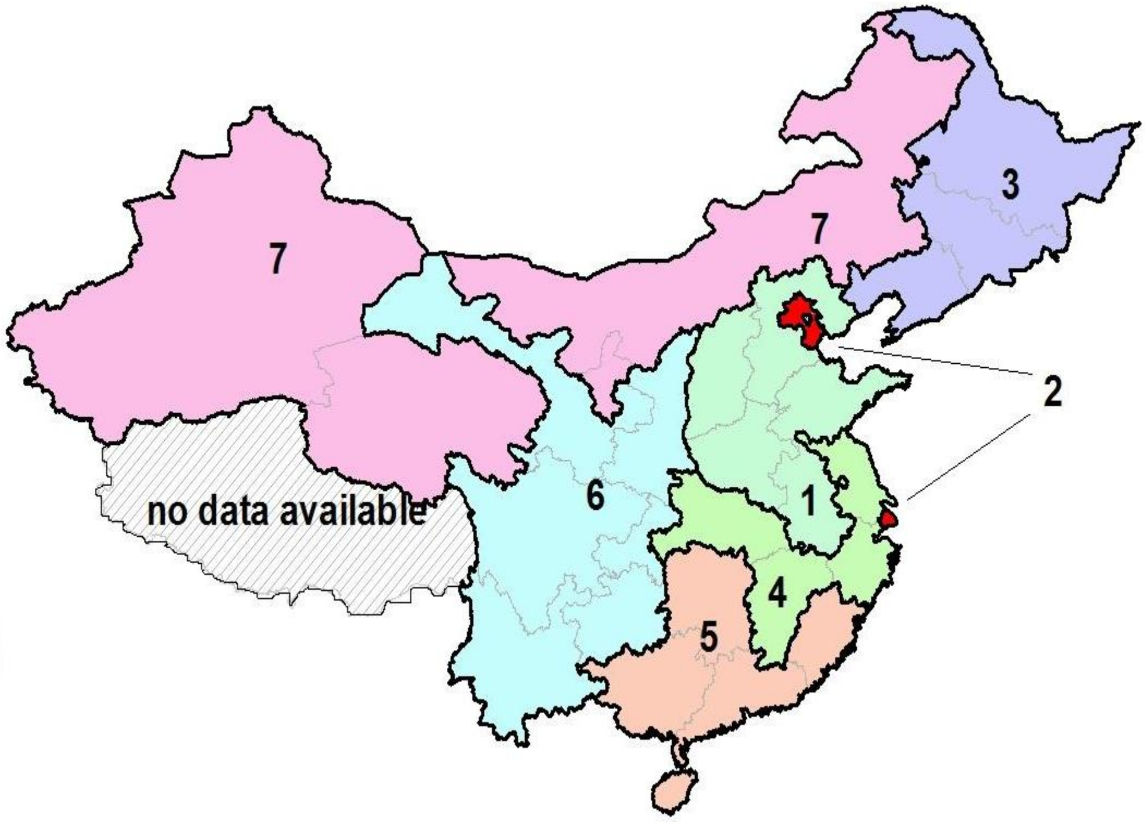


Figure 1-4. Regional Classification of China

Note: Region 1: Hebei, Shanxi, Anhui, Shandong and Henan; Region 2: Beijing, Tianjin, Shanghai; Region 3: Liaoning, Jilin, Heilongjiang; Region 4: Jiangsu, Zhejiang, Jiangxi, Hubei; Region 5: Fujian, Hunan, Guangdong, Guangxi, Hainan; Region 6: Chongqing, Sichuan, Shaanxi, Gansu, Guizhou, Yunnan; Region 7: Inner Mongolia, Tibet (no data), Qinghai, Ningxia, Xinjiang.

Chapter Two: A Survey of the Literature

This Chapter is organized as follows. Section 1 outlines the main topics to be reviewed and approaches used in the review. Sections 2-6 review previous studies on China's energy economy differentiated into five topics. Section 7 presents a summary of the main findings.

2.1 The topics to be reviewed and the approaches to be used

2.1.1 The topics to be reviewed

The energy sector covers a range of activities including energy trade, energy production and employment, energy pricing, energy taxes, and environmental regulation, etc. However, a single review paper cannot address all these elements in a large and complicated economy like China. Therefore, this review will focus on five topics specifically: i) China's energy consumption and economic growth, ii) China's changing energy intensity, iii) China's energy demand and energy - nonenergy substitution, iv) the emergence of energy market in China, vi) and policy reforms in the energy industry. The reasons that we chosen these five topics are: firstly, most of the energy economy literature is covered by these five topics. Secondly, most of the papers published in energy economic journals for example, *Energy Economics, Energy Policy, The Energy Journal*, and *Renewable and Sustainable Energy Reviews*, predominantly include these topics. Thirdly, they are five of the most popular and the most extensively investigated topics.

Finally, other aspects, such as energy trade, energy production, etc, are also important, but these topics are rarely found in energy journals, instead they appear in either specialist production journals or the introductory sections of energy economics papers.

2.1.2 The organizing approaches used in this survey

To organize this review, we first provide a table of existing major studies on the Chinese energy economy for each of four topics mentioned above. We then observe, summarize and analyze their focus and results to ascertain whether there are any differences across the studies. We then discuss the possible reasons for the differences one by one in the order of approaches, period or time span, data source and assumptions if available. After reviewing each topic, we summarize the issues that need to be addressed, the future work required, etc. After reviewing all four topics, we present a summary of our main findings and some policy implications. Finally, we conclude our review by suggesting future areas of study on the Chinese energy economy.

2.2 Energy consumption and economic growth

Here we first look at the existing literature in the relevant areas and then, we present some new results we have prepared in relation to: i) National aggregate energy consumption vs. national aggregate economic growth; ii) National disaggregate energy consumption vs. aggregate economic growth; iii) Provincial aggregate energy consumption vs. aggregate economic growth; iv) Provincial disaggregate energy consumption vs. aggregate economic growth; v) National industrial aggregate energy consumption vs. economic growth; vi) Provincial industrial aggregate energy consumption vs. aggregate economic growth.

2.2.1 What do existing surveys of the literature show?

During the 1990s, China's economic growth and energy consumption did not attract much attention either domestically or internationally. When Tang and Croix (1993) reviewed the interaction between energy use and economic growth in China, they only found two studies on the role of energy sources in China's economic development; Smil (1988) and Owen and Neal (1989). The former provided an insightful analysis of the role of energy in China's economic development since 1949; the later examined the extent of China's energy resources and the potential for energy exports.

Since the 1990s, however, China's energy consumption and economic growth has attracted attention from both domestic and international researchers where the relationship between China's energy consumption and economic growth has been extensively investigated and analyzed. Table 2-1 lists papers that have previously reviewed China's energy consumption and economic growth interactions and implications.

Zhao and Fan (2007) conclude that the relationship between energy consumption and economic growth varies across countries or regions and even during different phases due to the changing priorities given to energy and economic policies in the course of economic development. They were critical of the papers they reviewed (Table 2-1, row 1) that assumed a linear relationship between energy consumption and economic growth without conducting any statistical tests of the linearity assumption between economic growth and energy consumption. As a result, they estimate a nonlinear relationship between economic growth and energy consumption by employing a smooth transfer regression analysis (STR).

Liu, Ceng and Liu (2006) state that the Chinese literature reviewed in their paper (row 2) follows the approaches of the literature published in English and they then apply their methodologies to study China's energy economics and they ultimately come to the same conclusions. They estimate an extended Cobb-Douglas production function, incorporating energy as an input factor, and find that from 1985 to 2003 GDP increases by only 1.4-2.8% following a 10% increase of energy consumption.

Liu (2007) finds that the studies he reviewed (row 3) only focus on aggregate energy consumption and not disaggregated energy use. He then conducts cointegration analysis on economic growth and petroleum consumption, finding that there is no causal relationship between economic growth and petroleum consumption in China.

Guo (2007) also states that the studies he reviewed (row 4) focus on energy consumption and economic growth without taking into account technological change. Therefore, he incorporates technological factors into his growth model and considers technologies embodied in energy and labor.

Similarly, Wang and Yang (2006) argue that the studies they reviewed (row 5) follow traditional time series approaches and focus only on aggregate data. As a result, in their study, they conduct panel cointegration analysis for twelve major industries of China.

As can be seen from the partial review above, previous papers are often incomplete or partial because they were chosen and reviewed only as a means to introduce their own work. Based on these papers it is difficult to have a clear, balanced and up-to-date knowledge of China's current energy economy.

2.2.2 What can be learnt from this survey?

Here we present Table 2-2, Table 2-3 and Table 2-4 that show the papers to be reviewed, approaches, and results, etc. As stated previously, Table 2-2 lists the studies that focus on the relationship between national aggregate energy consumption and aggregate economic growth. Table 2-3 presents the studies that focus on the relationship between disaggregate energy consumption and disaggregate or aggregate economic growth. Table 2-4 presents the articles that focus on national industrial aggregate energy consumption and aggregate economic growth. It can be seen that Table 2-2 is also sorted by time period which will affect methods used, etc and potential changing foci of the papers as issues develop.

2.2.2.1 The focus of existing studies

From Table 2-2, Table 2-3 and Table 2-4, we can observe that the studies to be reviewed focus on six themes, however, most papers focus only on national aggregate energy consumption and aggregate economic growth (Table 2-2). Some focus on national aggregate energy consumption and national disaggregate economic growth (Table 2-3). A few studies focus on provincial economy (Table 2-3, bottom) and national disaggregate economy (Table 2-4).

It is clear, therefore, that the relationship between energy consumption and economic development at a provincial level has not been extensively investigated. Likewise, the relationship between energy consumption and economic development for primary and tertiary industries has not attracted scholarly attention.

2.2.2.2 The results from existing studies in this survey

Generally, we can find five types of results from existing studies of the relationship between energy consumption and economic growth: i) Causal relationships between energy consumption and economic growth; ii) Long-term cointegration based on Engle-Granger or Johansen-Juselius cointegration tests; iii) Long-term elasticities of energy input and income (per capita GDP) derived from a Cobb-Douglas (C-D) production function; iv) Short-term error correction coefficients; and v) Other elasticities from long-term cointegration tests and short-term dynamic adjustment Error Correction Models (ECM) at national or disaggregate economy levels.

We first consider Table 2-2 where three kinds of results can be ascertained. Most previous studies presented there show a causal relationship between energy consumption and economic growth. These causal relations can be classified into three groups. The first is that energy consumption Granger causes economic growth. Papers here include Zhao and Fan (2007), Chan and Lee (1996), Lee and Chang (2008), Wang and Liu (2007) and Huang and He (2006). The second group is where economic growth Granger causes energy consumption. Papers here include Zhang and Li (2004), Fan and Zhang (2005), Wu, Cheng and Wang (2005), Wang and Yao (2007), Wang and Yang (2007), Liu (2006) and Liu, Liu and Pan (2007). The third group concludes that economic growth and energy consumption Granger cause each other, i.e., bi-directional causality. The papers here include; Ma, Wang, He and Li (2004), Yuan et al. (2008) in Press and Han et al. (2004).

It is clear, therefore, that different findings can be found across the studies. On occasion, the causality results conflict across studies even for the same time periods for example, Ma, Wang, He and Li (2004) find that the relationship is bi-directional for the period 1954-2002 while Wang, Tian and Jin (2006) find that the relationship varies ,1953-2002. Liu (2006) finds that the causal relationship is from energy consumption to GDP growth, while Huang and He (2006) find the opposite being, from GDP growth to energy consumption for the same time period, 1985-2003.

Similarly, many studies conclude that there is a long-term cointegrating relationship between energy consumption and economic growth. However, the estimated elasticities of energy input derived from Cobb-Douglas production function differ significantly over a range from minimum -1.06 (Guo, 2007) to 0.88 (Lin, 2001) However, all the elasticities of energy input are less than unity, some are very small, for example, the elasticity of energy input is only 0.06 estimated by Lei, Yang and Wang (2007). These elasticities indicate that a 1% increase in energy consumption leads to significantly less growth in GDP growth than this 1% increase. This probably means that energy consumption is not the long run determinant of GDP growth.

Turning to national disaggregate energy consumption and aggregate economic growth (Table 2-3), a similar story emerges. Firstly, the observed relationship between national coal consumption and economic growth shows differing causal relationships. Despite a very similar sample period Wang and Yang (2007) find that national aggregate economic growth Granger causes coal consumption from 1978 to 2005, but national aggregate economic growth and coal consumption Granger cause each other from 1980-2004.

Next consider the long-term relationships between national oil or petroleum and national aggregate economic growth. The results here are also mixed. Both Zou and Chau

(2006) and Yuan et al (2008 in Press) find that a bi-directional causal relationship between national oil or petroleum and national aggregate economic growth. However, Liu (2007) concludes there is no causal relation between them, 1953 to 2004. In addition, Zou and Chau (2006) find that oil consumption Granger causes GDP growth from 1953 to 2002. A long-term cointegrating relationship between petroleum consumption and national aggregate economic growth is found by Ni and Ling, (2005) with a 0.68 elasticity of energy input from 1977 to 2002.

Finally, the results that are presented on the long-run relationship between national electricity consumption and aggregate economic growth are also highly variable. Most studies find a bi-directional causal relationship between electricity and economic growth (Wang, Tian and Jin, 2005; Yuan et al., 2008; Chen, Ma and Qin, 2007; Yuan et al., 2007), however, Shiu and Lam (2007) conclude that national electricity Granger causes aggregate economic growth. Huang (1993) suggests that there is long-run cointegration between national electricity consumption and aggregate economic growth and estimates a large income elasticity (per capita GDP), which most likely indicates that income growth did drive electricity consumption increases before 1980. However, Lin (2003ab) estimates an income elasticity (per capita GDP) of approximately 0.8, which suggests that income growth doesn't drive electricity consumption post 1980.

Wang and Yang (2006) estimate a series of both long-run cointegration and short-run dynamic adjustment for twelve industries (Table 2-4). It is clear that some industries play a crucial role in reducing energy consumption by improving their energy efficiency, such as ferrous metals processing, petroleum processing and coking, electricity steam and water, nonferrous metals processing, chemical and nonmetal mineral products. Their efficiency elasticities range from -42 to -24. This means that the energy consumption will decrease by 42-24% given a 10% increase of industrial energy efficiency in the long-run (top, column 3).

A similar pattern can be found for the effect of a short-run energy efficiency improvement on the reduction of energy consumption. These industries again include ferrous metals processing, chemical, nonmetal mineral products, nonferrous metals processing, electricity steam and water, and petroleum processing and coking. The estimated elasticities show that energy consumption decreases by 50-30% given a 10% increase of industrial energy efficiency in the short-run (bottom, column 2).

2.2.3 Why do the results differ?

The reasons why the reported relationships between energy consumption and economic growth in both long-run and short-run differ across studies is unclear, possibilities include variations in methods used, time periods studied, lags chosen and importantly data sources.

2.2.3.1 Do the methods used matter?

There are various methods used to model the relationship between energy consumption and economic growth in long-run and short-run (refer to Table 2-2, Table 2-3 and Table 2-4). Typically, the methods can be categorized into two groups. Group One are traditional time series methods including ADF tests, Engle-Granger cointegration tests, Vector Error Correction Models (VECM) and Granger causality. As can be seen from Table 2-2, Table 2-3 and Table 2-4, these methods are extensively used.

Group Two includes modified time series methods, production function analysis and 'other approaches'. For example, Error Correction Model (ECM) plus the Hodrick-Prescott filter (Yuan et al., 2007); panel data cointegration using fully modified ordinary least square (FMOLS) based on a three inputs (capital, labor and energy) production function (Lee and Chang, 2008); generalized forecasting error variance decomposition and generalized impulse response analysis (Liu, Liu and Pan, 2007); smooth transfer regression assuming a nonlinear relationship (Zhao and Fan, 2007); time varying parameter approaches based on state space models (Wang, Tian and Jin, 2006),[3] and C-D production functions (Liu, Ceng and Liu, 2006; Lei, Yang and Wang, 2007; Dong and Du, 2007).

One might expect that the type of estimation method should not effect the conclusions dramatically, however, empirically this is not the case Wang and Liu (2007) and Wang and Yang (2007) use the same time period and time series methods, but they produce the opposite results (Table 2-2). The reasons are not obvious.

2.2.3.2 Does the time period make a difference?

The time period used is the most likely reason why estimated relations differ across studies. This can be expected from Figure 1-1 of Chapter One which shows that national aggregate energy consumption and GDP growth have different trends over different sub-periods. Prior to 1996 the trends coincide, but then energy consumption starts to decline from 1997 while GDP maintains the same pace of growth. Energy consumption starts to climb from 2002, but GDP grows a little faster than usual until 2006. For the purpose of

[3] For state space model refers to Hamilton (1994).

this review, therefore, we cannot conclude whether the variation in results come from the different periods, as most studies mix different development stages.

2.2.3.3 Do the differences arise from data sources?

Data may be the least likely reason for differences as most studies use the national aggregate data which is readily available, however, data transformation is another potential reason for differences. Some studies use logarithms, others not. This will affect measures such as short and long run elasticities for example, the contradictory results from Wang and Liu (2007) and Wang and Yang (2007) may come from such a data transformation issue (Table 2-2).

2.2.3.4 Does the coverage of independent variables matter?

The use of independent variables is another potential reason why results differ in part because of possible omitted variable bias. Some studies include three input variables (Lee and Chang, 2008; Yuan et al., 2008 in Press), while others only include one energy input variable (Chan and Lee, 1996; Tang and Croix, 1993 and Zou and Chau, 2006; Yuan et al., 2007; Huang, 1993). Other relevant variables include the incorporation of variables to proxy technological change or time in the model. Estimates that suggest a large negative elasticity of energy input may be due to the incorporation of technological variables in the model (e.g., Guo, 2007).

The studies discussed above have made a contribution to our understanding of China's energy economy, however, it is hard to be confident what relationship actually exists between national aggregate energy consumption and aggregate economic growth in

China as it seems impossible to derive a consistent set of results based on the studies reviewed. There are several comments at this stage:

a. There is a need to distinguish between different stages of economic development and identify the major factors or policy reforms in place at the time which may have had a significant effect on energy consumption and economic growth. It may be helpful, therefore for policy reform dummy variables to be incorporated into the various models.

b. There may be a need to break long time periods into different shorter periods as long periods have the potential to mix the different stages of economic development and some policy reforms variables may be incorrectly treated econometrically if the time span is too long. For example, in the early stages of economic development, energy consumption may Granger cause economic growth. However, economic growth may Granger cause energy consumption for more developed economies. If the time periods are combined the net effect may be to show no causality or bi-directional causality.

c. Most studies focus on the study of energy consumption and economic growth at the national level. Little attention is paid here to the study of the relationships between energy consumption and economic growth at the provincial level. A recent study by Ma et al. (2008) shows that there are significant differences in the determinants of the changes in energy intensity across regions in China. This likely means that, for policy purposes, it is unlikely that national level results will be helpful.

d. Long-run relationships between energy consumption and economic growth are important, however, the short-run relations may be different and more crucial. Unfortunately, of the literature pays little attention to this matter. Table 2-2 shows that a large number of studies did not present any results on the short-run dynamic relation between energy consumption and economic development.
e. China has undergone radical economic and social change. It is crucial, therefore, that any studies of China's energy economy are cognizant of such changes and that attempts be made to incorporate proxies and measures of these changing economic development and policy reforms.

2.3 The changes in energy intensity of China

The 1973 world petroleum crisis led to an evaluation of energy efficiency and led to various strategies of national energy development. As a result, more and more energy related departments and agencies have studied energy efficiency. The Office of Energy Efficiency and Renewable Energy of the United States Department of Energy (OEERE, 2005), for example, created a new system of indexes of energy intensity which were designed to measure the change in national energy efficiency and that of strategic industries. A series of Energy Efficiency Trends in Canada published by Canada Natural Sources Committee systematically analyzes and assess changes in Canadian energy efficiency trends (NRC, 2005). Moreover, the International Energy Agency began to explore energy efficiency assessment indicators in 1995 and currently publishes a series of reports of energy efficiency for OECD countries (IEA, 2004).

There has been considerable debate, however, about the major factors responsible for the apparently dramatic decline in energy intensity. Garbaccio, Ho and Jorgenson (1999) stated that energy consumption per unit of GDP fell by 55% from 1978-1995. Other scholars have been concerned to explain China's energy intensity change. For example, Qi, Chen and Wu (2007b) argue about the measure of energy intensity in China. Garbaccio, Ho and Jorgenson (1999) question why the energy-output ratio has fallen in China. Zhang (2003) argues that China's industrial energy intensity fell in the 1990s. Fisher-Vanden, Jefferson, Liu and Tao (2004) are curious what is driving China's decline in energy intensity. Liao, Fan and Wei (2007) want to know what induces China's energy intensity to fluctuate. Moreover, as R&D in energy economy develops, many projects in social sciences and energy efficiency have been launched to investigate China's energy economy performance this century. The National Nature Science Foundation of China (NSFC) financed many projects on energy intensity during this period and, as a consequence, China's energy intensity has been extensively investigated.

To organize this section, we first introduce the definition of energy intensity typically use. Next we review the main methods that are currently used to decompose the change in energy intensity and provide a very simple evaluation of these applications. Then we review the studies on China's change in energy intensity. Finally, we present some comments, suggestions and implications.

2.3.1 The definition of energy intensity

Energy intensity (I) is typically defined as the ratio of energy consumption (E) to output (Q) using Gross Domestic Product (GDP). Empirically, there are several different definitions of energy intensity. For example, the energy coefficient, which is the ratio of the annual growth rate of energy consumption to the annual growth rate of GDP, is usually used as a measure to assess energy efficiency. Likewise, the energy elasticity, which is the ratio of the first derivative of energy consumption to the first derivative of GDP, is also used as a measure of the change in energy intensity (Zhou, Ang and Zhou, 2007). However, there are various definitions of energy intensity, but all of them should measure the same relationship or ratio between energy consumption and economic growth. Here, we always use the definition of energy intensity defined as the ratio of energy consumption to GDP or value-added, namely, $I = E/Q$.

2.3.2 The methods used to decompose energy intensity

The most popular method used to measure the change in energy intensity and identify the contribution share of its determinants is the index decomposition approach. Since its introduction in the late 1970s to study the impact of structural change on energy use in industry, index decomposition analysis has been extensively used for policymaking and its simplicity and flexibility makes it easy to adopt (Ang, 2004). The typical index decomposition of energy intensity is defined as follow:

(2-1) $I = E/Q = \sum_{i=1}^{k} E_i / Q = \sum_{i=1}^{k} (Q_i / Q) \times (E_i / Q_i) = \sum_{i=1}^{k} S_i \times I_i$

Where I is a comprehensive energy intensity; E is aggregate energy consumption; Q is aggregate output (GDP); E_i is energy consumption for the *i*th industry; Q_i is individual industrial output (value-added); S_i is the share of individual industrial output, and $S_i = Q_i / Q$; I_i is energy intensity for the *i*th industry, and $I_i = E_i / Q_i$. Equation (1) implies that aggregate energy intensity is determined by individual industrial energy intensity and its output share. In this case, the change in aggregate energy intensity is decomposed into two components, one due to individual industrial energy intensity and the other due to its output share.

As there are various definitions, the index decomposition approach can be categorized into two types: definitions related to the Laspeyres index and definitions related to the Divisia index (Ang, 2004). The basic feature here is that the Laspeyres index demonstrates the additive relationship amongst the decomposed components, while the Divisia index uses the multiplicative relationship between the decomposed components. In additive decomposition, the change (ΔI) in aggregate energy intensity can be decomposed as follow:

(2-2) $\Delta I = I^t - I^0$

And empirically, it can be further decomposed into two components:

(2-3) $\Delta I = \Delta I_{\text{int}} + \Delta I_{str}$

Where, superscripts t and 0 represent report year and base year, respectively; $\Delta I_{\text{int}} = \sum_i^k S_i^t (I_i^t - I_i^0)$ and $\Delta I_{str} = \sum_i^k I_i^0 (S_i^t - S_i^0)$ are the absolute effects of industrial energy intensity change and industrial structural shift on aggregate energy intensity, respectively. Correspondingly, dividing them by the change (ΔI) in aggregate energy intensity provides their contribution shares. Note that in the additive form the decomposed results are given in the unit in which the aggregate energy-intensity is measured. They are easy to interpret.

In multiplicative decomposition, the ratio (D_I) in aggregate energy intensity can be decomposed as follows:

(2-4) $D_{tot} = I^t / I^0$

and empirically, it can be further decomposed into two components:

(2-5) $D_{tot} = I_{\text{int}} \times I_{str}$

Where $I_{\text{int}} = \sum_i^k S_i^t I_i^t / \sum_i^k S_i^t I_i^0$ and $I_{str} = \sum_i^k I_i^0 S_i^t / \sum_i^k I_i^0 S_i^0$ are the relative effects of industrial energy intensity change and industrial structural shift on the relative change (D_{tot}) in aggregate energy intensity, respectively.

The above discussion provides a revision of the basic principles of index numbers. Equation 2-2 and equation 2-5 provide the governing forms for decomposing aggregate energy-intensity. For a given set of data the application of different decomposition methods leads to different estimates of the terms on the right hand side of the equations. There are, for example, multiplicative arithmetic mean Divisia indices (MAMD), arithmetic mean Divisia indices (AMDI), and logarithmic mean Divisia indices (LMDI). For detailed decomposition formula and a discussion of preferences see Ang (2004, 2005), Liu and Ang (2003) present the formulae of eight index numbers and integral Divisia indices and show the formulae for eight decomposition methods.

In addition to index decomposition, other methods have also been used to study China's energy intensity. For example, Wang (1999) and Wang (2003) use the input-output approach. Zhang, Ding and Yin (2007) use panel data regression models to investigate the effect of structural change on China's energy intensity change.

2.3.3 What can be learnt from existing studies?

Here we first present a table that lists the studies to be reviewed. The table is first arranged by economic or industrial disaggregation and then sorted by time period. Finally, we start our analysis by identifying comparing the estimated results across similar levels of economic disaggregation and similar time periods.

2.3.3.1 Disaggregation of the economy

Depending on the procedure of index decomposition used, researchers need to disaggregate the whole economy into various industries or sectors and calculate the energy intensity and output shares by industry or sector and by year. From Table 2-5, column 1, we can see that most studies disaggregate economy into 3 or 6 industries. Some studies further disaggregate each industry into sectors. three-industry disaggregation normally includes: i) primary industries, covering agriculture and related activities (farming, forestry, husbandry, secondary production and fishing); ii) secondary industries, covering mining, manufacturing, water supply, electricity generation and supply, steam the hot-water and gas, and construction; iii) tertiary industries, covering transportation (postal and telecommunications services), commerce and others. The more disaggregation the more determinants of the change in energy intensity can be derived. This can be seen from Table 2-5 where some studies disaggregate further into more than 30 sectors.

It is noted here that almost all studies focus on the national level energy intensity and industrial disaggregation. It is hard to find any that focus on disaggregation at the regional economy level. There appears to be only one provincial energy intensity study – the case of Guangdong province by Yu (2007).

2.3.3.2 The distribution of contribution shares

According to the definition of energy intensity and industrial disaggregation used, more disaggregation can lead to more determinants of the change in energy intensity. However, no matter how the disaggregation is achieved there are only two types of components that determine the change in energy intensity, namely, individual industrial or sectoral energy intensity and its output shares. Therefore, in Table 2-5, we only present the contribution share of individual industrial or sectoral energy intensity (I_i) and structural change (S_i). In addition, the negative contribution share measures the percentage of energy intensity decline, while a positive contribution share measures the percentage of energy intensity increase. There are several points to note about the results shown in Table 2-5:

a. Most of studies identify decreasing energy intensity during their study periods. For example, those whose study periods ending in 2000 including Qi, Chen and Wu (2007a), Han, Wei and Fan (2004), Qi and Chen (2006), Gao and Wang (2007) Zhang and Ding (2007), Shi (2007), Zhang (2003), Fisher-Vanden et al. (2004). However, some studies show rising energy intensity during their study periods (e.g., Qi and Chen, 2006; Gao and Wang, 2007; Ma and Stern, 2008; Zhang and Ding, 2007; Zhou and Li, 2006; Shi Fu, 2007).

b. Some studies show that declining industrial energy intensity plays a larger part in reducing aggregate energy intensity than structural changes, while some studies show structural changes play a role. What is the explanation? Looking at these two groups of studies shows they belong to different eras. In the 1990s or later industrial energy intensity plays a larger part (Qi, Che and Wu, 2007a; Han, Wei and Fan, 2004 last one; Ding et al., 2007; Qi and Chen, 2006; Gao and Wang, 2007; Ma and Stern, 2008 first two; Zhou and Li, 2006 second; Zhang and Ding, 2007; Shi, 2007; Zhang, 2003). In the 1980s or before structural change plays a *c.* All study periods except that of Qi, Chen and Wu (2007a) that start this century show rising energy intensity (e.g., Qi and Chen, 2006; Gao and Wang, 2007; Ma and Stern, 2008; Zhang and Ding, 2007; Zhou and Li, 2006; Shi Fu, 2007). These results seem consistent with the trend of energy intensity (Figure 2-1).

d. All results in these studies are very consistent although there are some variations reported when disaggregated data are used or the time period varies.

e. Comparing the results from the existing studies and the patterns of economic growth and energy consumption (refer to Figure 1-1 of Chapter One), we may conclude that: i) before the1990s industrial structural change plays a larger part in the decrease of aggregate energy intensity, while after the 1990s it is the decreasing individual industrial energy intensity that plays a larger part in the decrease of aggregate energy intensity; ii) aggregate energy intensity declined steadily before 2002, but after 2002 it started to increase but had little change then until 2006;

f. The reasons that aggregate energy intensity decreased after 2002 cannot be easily ascertained based on the existing studies as their results are mixed. For example, the contribution shares of individual industrial energy intensity and industrial structural change are 42:58 (Qi and Chen, 2006), 70:30 (Gao and Wang, 2007), 46:54 (Ma and Stern, 2008), 20:80 (Zhang and Ding, 2007), 55:45 (Zhou and Li,

2006) and 69:31 (Shi, 2007). However, the ideal distribution of contribution share might be 50:50.

g. Given the observations and comparisons above, the existing studies reviewed have reached a fairly consistent view on the change in and determinants of aggregate energy intensity of China, even though various definitions of index decomposition and methods are used.

2.3.4 Some observations

2.3.4.1 On the index decomposition approach

The term 'decomposition' simply means disaggregating the economy into industry or sector and then weighting the industrial or sectoral energy intensity (I_i) by their output shares (S_i). That is to say it is actually a nonparametric, weighted average**.** However, it is hard to derive an economic explanation of the change in energy intensity based on the index decomposition approach, which indicates which industry or sector plays the most important part in the change process. Moreover, whether the change in energy intensity is due to technology, growth of income, energy price, urbanization, and consumption behaviors is also impossible to ascertain.

There is little basis for choosing one over the other definition. Howarth et al. (1991) demonstrates this using manufacturing data from OECD countries. The differences between estimates of relative shares of industrial structural change and real intensity change are minimal (Sinton and Levine, 1994). Greening et al. (1997) compare six index decomposition methods applied to aggregate energy intensity for manufacturing in ten OECD countries and the results display little significant variations across the six approaches (refer to Figures 1-3 and Table 2 of Greening et al. 1997). In fact, the results from existing studies that have been reviewed show few significant differences across the definition of index decomposition (see Table 2-5).

2.3.4.2 On the variations of results after 2000

What is the driving force of the change of energy intensity after 2002 is still unclear based on the results of existing studies. In this case, further investigation into the changes in national aggregate energy intensity is required. Empirically, it may be better to break a long period energy intensity change into various homogeneous stages before engaging in any index decomposition of energy intensity. For example, measuring the change in energy intensity over the period 2000-2005 may not make sense as half the period shows an increasing trend while the other and half shows decreasing energy intensity.

2.3.4.3 On the comparison of energy intensity internationally

It may be better to define energy intensity as the ratio of energy consumption (physical units) to output (physical units). Empirically, it is convenient to compare energy intensities across countries and here we are drawn to use aggregate energy intensity calculations. However, comparing aggregate energy intensity raises questions namely, how to measure the output and which price should be used? Qi, Chen and Wu (2007b) question how high energy intensity is in China. It is clear that aggregate energy consumption is fixed because of the physical units used, while aggregate output calculations are affected by the price to be used. It is expected that aggregate energy intensity is normally lower if it is measured by current price than the price ten years ago. No matter what prices are used, it doesn't raise any issues if one only observes the change in national aggregate energy intensity. However, the issue arises when aggregate energy intensity comparisons are made internationally. This involves the use of PPP, which is beyond the scope of this survey.

2.4 Substitution of and demand for energy

Unlike the previous two topics considered above, there are few studies of factor demand and the substitution between energy and other factors, where the exceptions include Ma et al. (2008) and Fan, Liao and Wei (2007). Therefore, we first introduce the existing studies and then provide a short summary.

2.4.1 The existing studies

Table 2-6 provides results for all studies on this topic ordered first by country then scope of study, time period, methodologies and finally results. Qian and Wang (2003) estimate the elasticity of energy-labor substitution using a Cobb-Douglas production function and national aggregate economy time series data. Their estimates are -0.863 for 1993-2000 and 0.117 for 1979-1992 and suggest energy and labor are complementary for the period 1993-2000, but substitutes in the earlier period.

Zheng and Liu (2004a)[4] estimate the elasticity of substitution between energy-capital and energy-labor employing both CES and C-D production functions with and without technological progress assumptions. Their estimated elasticities of substitution of energy-capital are even infinite based on the first order CES production function either with or without a technological progress assumption. However, their estimated elasticities of

[4] They represent the Center for Contemporary Management and Institute of Global Climate Change, Tsinghua University, Beijing, China, which is the third most important institute for the study of Chinese energy economics.

substitution of energy-capital are unity based on the C-D production function either with or without a technological progress assumption. Clearly those elasticities are only for the extreme cases and they may not exist in reality due to the restrictive assumptions required. In other work, Zheng and Liu (2004b) estimate the substitution of energy-capital and energy-labor employing a second-order translog production function using capital, energy and labor as inputs with technological progress assumptions based on the 1978-2000 national aggregated time series data (output-real GDP, inputs-capital, energy and labor) from various China's Statistical Yearbooks. Their estimated elasticities of substitution between factors are fairly stable over time, but the elasticity of substitution between capital and energy is > 2.50. Energy and labor are also substitutable with an elasticity of only 0.50. It is apparent that there are substantial differences in the estimation of elasticities of substitution of capital-energy between Zheng and Liu's two papers. The reason as stated in Zheng and Liu (2004b) may be due in part to different function definitions implying that the second-order translog production function is better able to reveal the real relation between factors than the CES or C-D production functions. However, the estimated elasticity of substitution of energy-capital even based on the translog production function is much larger than those estimated for other countries (Table 2-6, second half section).

Huang and Huo (2006) also estimate the elasticity of energy-capital substitution using a second order CES production function. Their estimate is 0.685 for national aggregate economy-based data. Compared to Zheng and Liu (2004a and 2004b), their estimate seems more reasonable. Unfortunately, they didn't provide the estimates of the elasticity of energy-labor substitution.

The group of Fan, Liao and Wei first study the substitution of energy and other factors in 2007. Following the reforms of product factor markets and prices, Fan, Liao and Wei (2007) break the full period into two subperiods; 1979-1992 and 1993-2003 and conduct their estimates separately. Empirically, they used a second order translog cost function based on national aggregate time series data using capital, energy and labor as inputs and real GDP as output. Their estimates of elasticities are significant and also larger than unity for both substitution and demand for energy. For example, their estimated MES (Morishima Elasticity of Substitution) are 1.406 for energy-capital and 1.133 for energy-labor during 1993-2003, implying that energy is significantly substitutable for both capital and labor. Meanwhile, demand for energy is also elastic, as energy consumption would increase by 12.3% if energy price is reduced by 10%.

Hang and Tu (2007) use a cost function to derive a linear demand regression function for coal, oil and electricity. Following Fisher-Vanden et al. (2004) and using a C-D cost function, they estimate a fuel demand function using the ratio of fuel to GDP as the dependent variables and use foreign direct investment and the price ratios of fuel price to output price as independent variables. They only estimate the elasticities of demand for individual fuel and aggregate energy. Their estimate of elasticity of demand for aggregate energy is -0.649.

Hu (2004) investigates the role of fuel prices in achieving substitution away from coal to alternative fuels at the industry level. He estimates a demand system of fuel shares (coal, oil, electricity, natural gas and petroleum) for four industries (chemical, metal, non-metal material and residential sectors) from 1990 to 2000. Several points can be raised about Hu's results. First, it may be misleading to discuss the substitution of oil and petroleum (defined as crude oil) in any industry because their functions are considerably different. Petroleum is not a kind of fuel (directly used for power) but a kind of intermediate input to be used to produce fuel (such as gasoline, diesel, etc. Secondly, the estimated elasticities of both substitution and demand are extremely unstable over time, in particularly in 2000. For example, the estimated elasticity of substitution of coal-electricity is -1.88 in 2000, but they are minimal in the rest of years for the chemical industry. The same can be seen for elasticities of demand for coal. Thirdly, the elasticities of demand for coal are all positive for all four industries and the author explains this positive elasticity of demand for coal because coal and electricity are substantially complementary over the whole study period. Finally, the data used in this study are all indirect or derived which may partially explain the variation in estimated elasticities.

In addition, Liu, Liu and Pan (2007) observe the possibility of energy-labor substitution as well as the complementary of energy-capital during the last three years of the 1980s.

2.4.2 Some observations

First, it can be seen that there are only a few studies of China's energy demand and energy-other factor substitution. Guo and Wang (2005) and Guo (2005) state that the possibilities of substitution between energy and other factors has been ignored by Chinese scholars on energy economics. Even the effects of substitution between energy and other factors on energy consumption are often mistaken as a kind of technological progress in mainland China (Guo and Wang, 2005). It seems that Wei, Liao and Fan never mention any effects of factor substitution in their Chinese working papers and publications.[5] Likewise, it seems that Shi has not published results on the substitution of energy and other factors in her Chinese academic work.[6] As a result, it is not surprising that there haven't been any regional or industrial studies on energy demand and energy-other factor substitution.

Secondly, when we do find some results in these areas the estimated substitution elasticities of energy and capital vary considerably and some are unrealistic for example, a substitution elasticity of energy and capital of 2.5 reported by Zheng and Liu (2004b) and 0.69 by Huang and Huo (2006) represents a very wide range. Moreover, these elasticities are much larger than those estimated for South Korea (0.78), Portugal (0.89) and Germany (0.87) (see Table 2-6).

Furthermore, the reasons why these estimated elasticies of energy-capital substitution are so large and unstable has not been fully explained, however, there are several potential factors. Firstly, model specification, for example, there is no interaction term for energy price and output in Fan, Liao and Wei (2007). Secondly, short sample period. There are only 13 observations in Fan, Liao and Wei (2007). Thirdly, the difference between MES and AES. Fourthly, only national aggregate output and derived energy price indexes are used in these studies.

[5] They stand for Center for Energy and Environmental Policy Research, Institute of Policy and Management, Chinese Academy of Sciences, Beijing, China, which is the first most important institute for the study of Chinese energy economics.

[6] She represents the Center for Energy Economics, Institute of China's Industry Economics, Chinese Academy of Social Sciences, Beijing, China, which is the second most important institute for the study of Chinese energy economics.

Next, in view of the above, new and more representative datasets and more appropriate robust econometric approaches are needed to be explored in the estimation of the elasticities of substitution of energy-capital and energy-labor and demand for energy in the future for China. As suggested by Xing (2004) and Tong and Tong (2007), there is considerable work for researchers to do, especially to establish energy demand functions and estimate the possibilities of inter-factor and inter-fuel substitution. We will return to this later in the thesis, subsequently published in Ma et al. (2008, 2009) where they conduct a large scale investigation in this area. They estimate a third order translog cost function for China's economy. The datasets are new and appropriate as they are direct measures. The energy price data are spot prices for 30 provincial capital city markets collected by local governmental official. The energy consumption data come from the China Energy Statistical Yearbook by industry and by province. The database comprises time series, cross-sectional disaggregated by industry and province.

2.5 Energy price convergence in China

2.5.1 The importance of energy price convergence

The ongoing transition of former communist countries from planned to market economies has been one of the most important economic phenomena in the last few decades. It is interesting, therefore, to consider whether the liberalization of domestic trade prompts major shifts in price structures that were highly distorted under central planning (Fan and Wei, 2006). Such a study is interesting because of the ongoing debate as to whether China's gradualist reform has been successful (see Lau, Qian and Roland, 2000; Young, 2000; Poncet, 2003 and 2005). Since China embarked on its economic reform and adopted an open door policy in the late 1970s, its economic development has been greatly enhanced by its active participation in international trade. However, recently there has been more debate about domestic trade and China's major trading partners have strongly urged it to further open its domestic market, especially after it has admitted to the World Trade Organization (WTO). However, even if the Chinese government removes the barriers to international trade, the effectiveness of this policy might be compromised by regional trade barriers within China itself (Fan and Wei, 2006). It is thus useful to test whether domestic markets are in fact integrated which can then provide some important information on how the market works in China (Zhou, Wan and Chen, 2000). Such information may help the government decide on the extent to which it should intervene in the market and how (Wyeth, 1992). As energy is one of the most important drivers of economic growth, energy price convergence is one of the important indicators for measuring market liberalization.

2.5.2 An area where less research has been undertaken

As can be seen from the last section, there are only a few studies focusing on China's energy demand and energy-other factor substitution. However, there has been even less research into China's energy price convergence, in fact only one piece of work Fan and Wei (2006), has been found on this topic. Fan and Wei (2006) report their tests for *The Law of One Price* using 72 time series (41 industrial products, 20 agricultural products, 13 other consumer goods and 18 service products). However, their study includes only two fuel variables (gasoline and diesel), which one might expect, *a priori* to be the most likely to show market integration among the key energy inputs.

2.5.3 More work needs to be done

To fill this gap, we report in this thesis some new results on energy price movements using a new, high frequency, dataset that consists of the market prices of four energy types (coal, electricity, gasoline and diesel) from 31 provincial (or autonomous regions and municipal) capital cities collected at 10-day intervals over a maximum of 132 months (from 1995 to 2005). We provide results for two key energy input prices, coal and electricity, whose price convergence has not yet been reported for China. Our conclusions are that the coal market is convergent as a whole in China, but the electricity market may not be integrated as a whole based on the existing electricity network and other relevant energy market factors (Ma, Oxley and Gibson, 2007).

2.6 The reforms in China's energy industry

The institutional reforms in China's energy industry include two aspects. The first is administrative or regulatory system reform; the second is energy pricing deregulation. The introduction of energy reform is a foundation for one to understand China's energy situation and study China's energy economy. Therefore, this section review some studies on China's energy reform by providing major concrete policy reform programs to help understand institutional changes over time in China's energy industry. As most of reforms in energy industry took place in the 1990s, this section is mainly focused on the review of the articles that address the energy reforms since the 1990s.

2.6.1 The reforms of the regulatory system

There are four articles that are mainly focused on the regulatory system reform in China's energy industry recently. Andrews-Speed, Dow and Gao (2000) comprehensively introduce the ongoing reforms to the government and state sector in China's energy industries one after another. First, they recall the old government structure before 1998 and then describe new government structure after 1998 reform. Then they evaluate the new government structure. Finally, they conclude that during the last 15 years countries across the world have initiated major programs of structural reform of their energy industries and China appears to be set to move a similar path. The 1998 announced reforms were intended to reduce the cost of government, to separate the functions of government and enterprises, and ultimately, to increase the effectiveness of government. Their analysis suggests that the first two may have been achieved, but little contribution has been made to the third objective.

The regulatory reform of the electricity industry is the hardest one in China because electricity is a 'staple' consumption good for residential and industry and its supply has been behind demand for most of time in China. Therefore, regulatory reform of the electricity industry has been attracting more attention and it has seen more articles on this issue. The most representatives are, for example, Xu and Chen (2006), Cherni and Kentish (2007) and Ma and He (2008), who have comprehensively described the regulatory reforms of China's electricity industry. According to the regulatory reforms, they distinguish historical regulatory changes into several sub-periods or stages in China.

Coal is the largest source of primary energy supply in China. However, coal is plentiful and even its supply far surpasses its demand in China. Therefore, the reform of regulatory system for coal industry is almost complete in the early 1990s. Andrews-Speed, Dow and Gao (2000) and Wang (2007) have discussed the regulatory reforms for China's coal industry, respectively. The only issue is the mediation system reform for the coal that is sold to state-owned power generation sector. These articles have not seen the solution of this issue because China Taiyuan Coal Trade Exchange (TCTE) was only established on 18 June 2007 (TCTE, 2007) and all power firms are supposed to meet their coal supply by purchases from the TCTE.

Most of these articles on the regulatory reform in China's energy industry have provided the detailed time table of regulatory system reforms a long with main objectives and goals of regulatory reform for petroleum industry. Andrews-Speed, Dow and Gao (2000) demonstrate the relation among policy formulation, regulation and enterprise management.

2.6.2 The reforms of pricing deregulation

Market-oriented pricing systems have been the government's expected goal for pricing deregulation in the development of China's energy economy. Since energy pricing systems play an important role in energy consumption, energy efficiency and energy-environment relationship, many scholars have paid attention to the changes of the pricing system in China's energy industry. Many researchers have deliberately addressed the historical changes of pricing deregulation and decentralization in China's energy demand side, for example, Wu (2003), Hang and Tu (2007), Wang (2007), and Cherni and Kentish

(2007). Similar to regulatory reform, pricing reforms in China's energy industry have also been well documented and extensively introduced. Many articles not only carefully introduce initial pricing deregulation commenced in the early 1990s, but present ongoing pricing reforms since then as well.

2.6.3 Some observations and conclusions

There are several key points that can be drawn based on the review above:

First, the history of both regulatory system reform and pricing deregulation in China's energy industry has been well documented in energy economics literature. The complete historical time tables of energy industry reforms have been provided by the existing studies.

Secondly, some authors not only point out the future objectives and goals of the ongoing reform of China's energy industry, but foresee the possible challenges and difficulties in the course of the development of China's energy economy (Xu and Chen, 2007). However, most of papers reviewed here still remain focused on the simple introduction of concrete policy reform programs.

Thirdly, no single study has deduced the characteristics of the reforms in China's energy industry. They might have felt that the final goal of electricity reform is to separate government function from business and the regulatory bodies have been worrying about the effects of the decentralization on social stability and economic growth, especially on the residential and state-owned enterprises in electricity industry. However, existing articles did not conclude that China's energy reforms took time and were far behind the advanced theory and successful experience in the world. As a fact, gradualism reform was adopted in China's energy industry.

Fourthly, although the existing articles reviewed every single policy reform program, they did not mention or use econometric methods to assess the effects of each policy reform on market integration of the energy economy as well as the economic growth as a whole in China.

Fifthly, concern should have been raised from the existing literatures as to why the progress of energy reforms were so slow given that China has already had three-decades of successful experience in many other industries. There are many reasons, but the following might be two of the most important. Firstly, governments want to separate function from business, but they want to maintain social stability and sustainable economic growth. More importantly, regulatory bodies did not have any academic support, especially econometric, to understand the potential effects of each specific policy reform in the energy industry on energy supply and demand as well as on the energy economy and aggregate economic growth.

Finally, there are no papers that study the effects of energy policy reforms both on the changes in energy intensity and the emergence of energy market in China. As are reviewed previously and presently, the studies on energy intensity did not incorporate any variables for energy reform into the changes in energy intensity, while the studies on energy reforms also did not mention any effects of energy reforms on the changes in energy intensity. Likewise, the studies on energy reforms did not mention any effects of energy reforms on the changes in energy intensity, while the studies on energy market integration did not incorporate any variables of energy reforms into the emergence of energy market. It is clear that the effects of energy reforms on the changes in energy intensity and the emergence of energy market in China have been ignored to date.

2.7 Main findings on the existing studies

Firstly, the methods used to study China's energy consumption are typically traditional time series analysis. Demand functions are seldom employed to model China's energy demand and predict energy consumption in China. For example, it can be seen from Table 2-7 that general decomposition indices are used to investigate China's energy intensity change and almost all of the studies take the view that industrial structural change is the key factor in aggregate energy intensity change. Real demand functions or models for China's energy consumption have rarely been used by existing studies. Most of them choose and estimate a simple C-D production function. Zheng and Liu (2004b) and Fan, Liao and Wei (2007) estimated a translog cost function, but their functional forms are only very simple versions of the translog function (without any second order interaction terms of input prices and output variables). Therefore, many econometric hypotheses cannot be tested (Ma et al. 2008).

Secondly, data used in previous studies are very limited and more data needs to be analyzed. Data availability is always a great challenge for researchers when they study China's energy economy. Rawski (2001) argues that official Chinese statistics contain major exaggerations of real output growth beginning in 1998 and the standard data contain numerous inconsistencies. Similarly, Sinton (2001) concludes that the available information suggests that while energy statistics were probably relatively good in the early 1990s, their quality has declined since the mid-1990s, from which he suggests that China's energy statistics should be treated as a starting point for analysis and explicit judgments regarding ranges of uncertainty should accompany any firm conclusions. Even when faced with these issues, most of the studies still focus on and use national aggregated output and energy consumption data (Tables 2-4 and Table 2-5). On the other hand, existing research on has not analyzed energy market price information as part of the study of China's energy demand and consumption predictions - the exception being a recent study by Ma et al. (2008). Most studies rely only on the time series analysis of two variables to predict China's economic growth and energy demand (e.g., Crompton and Wu, 2005; Chan and Lee, 1996). China's energy demand and consumption issues attracted little research in the traditional economic areas of estimates of price elasticities of demand for energy and substitution elasticities of energy-capital and energy-labor, etc., despite the fact that energy market price data have been available since the early 1990s (for most of energy fuel, such as coal, electricity, gasoline and diesel etc.). These data have are also disaggregated by urban and rural as well as regional market prices, for details see http://www.cpic.gov.cn.

Thirdly, as can be seen from the papers reviewed, most of data used are measured at the national, aggregate, level and few regional or provincial level disaggregate data are explored. Why does using regional disaggregate data matter? There are more than 30 provinces or regions in mainland China, many of which have their own special priority policies that are launched from central government. In addition, the variations in regional or provincial economic development in mainland China are extremely important and apparent. Using national aggregate information masks these differences across regions or provinces and is a particularly important issue when investigating China's market integration (Poncet, 2003 and 2005). However, most of the empirical papers use national aggregate data in their analyses of energy intensity change and economic growth and energy consumption cointegration relationship. Few studies are focused on regional or provincial level data analysis. Therefore, cross sectional economic growth and energy consumption data are seldom explored and utilized to investigate regional or provincial energy demand and consumption. Specially, cross sectional and time series fuel market price data are rarely used, excepts include Ma et al. (2008) and Fan and Wei (2006).

Fourthly, most studies treat the time series data homogeneous. Few break China's economic development into different periods or stages and which may explain why published conclusions often diverge. China's economic development was initiated by the Reforms in the late 1970s. Chinese economic development consists of a series of five-year plans. Each five-year plan period has its special goal (e.g., growth rate) and each of them may have special policy measures. Within a short time period, they may have a similar policy environment, but over longer periods the policy scenario may vary. This is particularly true when using long-run time series analysis estimating the relationship between energy consumption and economic growth. As reviewed previously, some studies actually treat the policy environment before and after the reform as the same. As a result, the long-run cointegration relations derived from the same model differ in their estimates and conclusions.

Fifthly, some production functions have been estimated, but production assumptions and market integration assumptions have not been rigorously tested. Factor market integration and cointegration are one of the most sensitive issues related to China's membership of the WTO. The testing of various commodity market hypotheses have attracted both Chinese and foreign research (e.g., Young, 2000; Fan and Wei, 2006; Poncet, 2003 and 2005), the exception has been the energy market. Although energy has been identified as one of the most important input factors (Berndt and Wood, 1975), China's energy input factor market integration has not been investigated with the exception of a few recent papers. Fan and Wei (2006) use a unit root test to investigate gasoline and diesel market integration across 35 Chinese cities. Warell (2006) incorporates the Chinese coal market into international perspective. Gnansounou and Dong (2004) investigate the opportunity for inter-regional integration of electricity markets. However, it is hard to conclude that China's energy market is well integrated as a whole based on those studies. Ma, Oxley and Gibson (2007) do conduct a series of tests for energy price convergence for energy spot prices of four major fuels at 30 provincial capital cities all over the country. Their tests and results show that oil and coal markets in mainland China are integrated as a whole, but it is hard to say electricity market is also integrated as a whole based on the available information on electricity networks. So, whether electricity market is integrated still needs to be established.

Sixthly, the reasons why energy intensity has changed should have been more carefully investigated. As reviewed previously, many studies that have addressed China's energy intensity and argued why China's energy intensity has declined or increased.

However, all of them only consider a changing industrial structure and individual industrial energy efficiency improvement as the reasons. What is clear, however, is that that do little more than explain how a measure of energy intensity is actually created, normally, by some form of decomposition index approach. It is clear that aggregate energy intensity is a weighted average of individual industrial energy intensities using industrial structure as a weight. More economic analysis is required of why change occurs including the role of technological change, income growth and factor substitution which, with the exception of for a recent study by Ma et al. (2008), have not been addressed.

Seventhly, as official energy data are not transparent, China's energy economy studies are limited to very narrow fields. It seems strange to talk about 18 Asian country's energy consumption and economic growth without China. However, many Asian energy economy studies exclude China (see Liu and Ang (2003)). Why did these studies ignore China? Energy data availability is one of key factors that impede 'Asian' energy economy studies.

Finally, China's energy economics is still in its infancy. Compared with its global importance China's energy economy is less developed and less fully understood in an international context. Despite some areas having been extensively investigated for example, the relationship between energy consumption and economic growth, and changes in energy intensity, many other important issues, including energy price convergence; energy demand; energy-other factor substitution, and energy economic studies at the disaggregate level, have not been extensively studied or considered at all.

It can also been seen that many empirical studies of Asian or developing country's energy economies exclude China from their analysis for example, Mahadevan and Asafu-Adjaye (2007) investigate energy consumption, economic growth and prices for 14 developing countries excluding China. Likewise, Lee and Chang (2007) study the relation between energy consumption and GDP growth for 18 developing countries also excluding China. Table 2-7 lists a number of other papers on Asia which exclude China. The reasons are unclear and may include data availability, but it is extraordinary.

Energy policy reforms play an important role in the development of China's energy economy. Therefore, China has introduced numerous measures to rationalize oil, coal, gas and electricity prices since the early 1980s. At the same time, China's energy reforms have attracted great attention of researchers domestic and international. It has also seen many studies on China's energy reforms, including regulatory and pricing system. For example, Andrews-Speed, Dow and Gao (2000), Xu and Chen (2006), Cherni and Kentish (2007), and Ma and He (2008) discuss the ongoing regulatory reform to China's government and state sector of energy industry. On the other hand, Wu (2003), Wang (2007) and Hang and Tu (2007) address the reforms of price deregulation over time. Unfortunately, all these studies only introduce concrete institutional reform programs in China's energy industry to the world. They have not econometrically assessed any potential effects of those reform programs on the development of China's energy economy as well as on the whole national economic growth. Not any strongly econometrical policy suggestions have been provided to policymakers yet. Therefore, it is not surprising that the gradualism strategy was still adopted in the reforms of China's energy industry.

Table 2-1. Studies on China's economic growth and energy use

Author (s)	Papers reviewed
Zhao and Fan (2007)	Zhao & Wei (1998), Lin (2003a, b), Han et al. (2004) and Ma et al. (2004)
Liu, Ceng and Liu (2006)	Chen et al (1996), Zhao & Wei (1998), Wan et al. (2000), Zhu (2002), Han et al. (2004), Zhang & Li (2004), Zhou (2004), Li (2005), Wu et al. (2005), and Yang (2005)
Liu (2007)	Zhao & Wei (1998), Lin (2001), Ma et al. (2004), Fan & Zhang (2005), Ni and Ling (2005), and Wang et al. (2005)
Guo (2007)	Zhao & Wei (1998), Lin (2003b), Ma et al. (2004), Fan & Zhang (2005) and Ma & Zhang (2005) and Wu et al. (2005).
Wang and Yang (2006)	Jiang (2004), Lin (2004), Wang et al. (2005), and Wu et al. (2005)

Source: check reference section.

Table 2-2. Cointegration between China's energy use and economic growth

Author(s)	Period	Approaches	ECM Coeff. (t-statistics)	Granger Causality
Zhao and Fan (2007)	1953-1976	STR	-	Energy →GDP
Chan and Lee (1996)	1953-1993	JJ, ECM	-0.76**	Energy →GDP
Lin (2001)	1953-1994	JJ, ECM	-0.70 (7.7)	LRC, 0.88 [a] (38)
Ma, Wang, He & Li (2004)	1954-2002	E-G, ECM	-0.05 (2.3)	Bi-direct.
Wang, Tian and Jin (2006)	1953-2002	TVP, Granger	-	Not fixed but vary
Zhang and Li (2004)	1961-2001	Granger	-	GDP→ Energy
Yuan et al. (2008) in Press	1963-2005	JJ, ECM	GDP→ Energy	Bi-direct.
Guo (2007)	1965-2004	JJ, ECM	-0.23 (2.1)	LRC, -1.06 [a] (2.9)[b]
Lee and Chang (2008)	1971-2002	ECM, FMOLS	-	Energy →GDP
Han et al. (2004)	1978-2000	E-G, ECM	-	Bi-direct.
Fan and Zhang (2005)	1978-2002	Granger	-	GDP→ Energy
Wu, Cheng & Wang (2005)	1979-2002	E-G	-	GDP→ Energy
Wang and Yao (2007)	1978-2003	ECM	Not exist	GDP→ Energy
Zhao and Fan (2007)	1977-2005	STR	-	Energy →GDP
Wang and Liu (2007)	1978-2005	E-G, ECM	<0	Energy →GDP
Wang and Yang (2007)	1978-2005	E-G, ECM	-0.39 (-3.3)	GDP→ Energy
Lei, Yang and Wang (2007)	1985-2001	C-D production	-	LRC, 0.06 [a]
Liu (2006)	1985-2003	Granger, ECM	-	GDP→ Energy
Huang and He (2006)	1985-2003	C-D production	-	Energy →GDP
Liu, Ceng and Liu (2006)	1985-2003	C-D production	-	LRC, 0.28 [a]
Liu, Ceng and Liu (2006)	1989-2003	C-D production	-	LRC, 0.14 [a]
Liu, Liu and Pan (2007)	1988-2005	GFEVD, GIR	-	GDP→ Energy
Ma and Zhang (2005)	1990-2001	Grey Linkage	-	LRC, 0.67 [c]
Ma, Wang, He & Li (2006)	1995-2003	Grey Linkage	-	LRC, 0.5-0.8 [c]
Yang, Tian and Ding (2004)	-	LEGM	-	-
Shao and Jia (2006)	-	Descriptive	-	-
Wan, Zhou and Gao (2000)	1957-1997	Descriptive	-	-

Note: STR is smooth transfer regression; JJ is Johansen-Juselius cointegration; ECM is error correction model; TVP is time varying parameter approach; FMOLS is fully modified OLS; E-G is Engle and Granger; STR is smooth transfer regression; GFEVD is generalized forecasting error variance decomposition; GIR is generalized impulse response; LEGM is Lucas economic growth model; LRC is long-run cointegration.
[a] elasticity of energy input; [b] including technological factor; [c] grey linkage coefficient.

Table 2-3. Cointegration between China's economic growth and fuel use

Author(s)	Period	Approaches	ECM (t-stat)	Granger Causality
1. National trade and national aggregate energy consumption:				
Dong and Du (2007)	1978-2004	C-D production	-	LRC, 1.09 [a]
2. National economic growth and national coal consumption:				
Yuan et al (2008) in Press	1963-2005	JJ, ECM	GDP→ Coal	Bi-direct.
Wang and Yang (2007)	1978-2005	E-G, ECM	-	GDP →Coal
Zhang and Li (2007)	1980-2004	Granger	-	Bi-direct.
3. National economic growth and national petroleum consumption:				
Liu (2007)	1953-2004	E-G, Granger	-	Not exist
Ni and Ling (2005)	1977-2002	ECM	-0.76	LRC, 0.68 [a]
4. National economic growth and national oil consumption:				
Zou and Chau (2006)	1953-2002	JJ, ECM	-	Energy →GDP
	1953-1984	JJ, ECM	-0.42 (2.3)	Bi-direct.
	1985-2002	JJ, ECM	-1.14 (2.1)	Bi-direct.
Yuan et al (2008) in Press	1963-2005	JJ, ECM	Bi-direct.	Bi-direct.
5. National economic growth and national electricity consumption:				
	1950-1980	C-D function	-	LRC, 2.72 [b] (12.0)
Huang (1993a)	1950-1970	C-D function	-	LRC, 3.52 [b] (7.0)
	1970-1980	C-D function	-	LRC, 1.56 [b] (15.0)
Shiu and Lam (2007)	1971-2000	E-G, ECM	-	Energy →GDP
Lin (2003a,b)	1978-2001	JJ, ECM	-0.43 (-3.1)	LRC, 0.86 [b]
	1952-2001	JJ, ECM		LRC, 0.78 [b]
Wang, Tian & Jin (2005)	1952-2002	E-G, ECM	-0.65 (-2.6)	Bi-direct.
Yuan et al (2008) in Press	1963-2005	JJ, ECM	Elect→GDP	Bi-direct.
Chen, Ma & Qin (2007)	1949-2004	Hsiao Granger	-	Bi-direct.
Yuan et al. (2007)	1978-2004	ECM, Hodrick-Prescott filter	-	Bi-direct.
6. Provincial aggregate economic growth and energy consumption:				
Tang and Croix (1993)	1952-1989	Panel data	-	LRC, 0.94 [b] (7.8)
Shandong trade and aggregate energy consumption:				
Zhu (2007)	1978-2004	E-G, ECM	0.41(5.0)	Bi-direct.

Note: JJ is Johansen-Juselius cointegration; E-G is Engle and Granger; ECM is error correction model; LRC is long-run cointegration.
[a] elasticity of energy input; [b] elasticity of income (per capita GDP).

Table 2-4. Cointegration between sectoral energy use and economic growth

Industry	Static reliability on energy (α_i)	Income elasticity of energy demand (β_{1i})	Efficiency elasticity of energy demand (β_{2i})
	Long term cointegration		
Food, beverage and tobacco	2.57 (5.6) [a]	0.81 (11.9)	-3.01 (-9.6)
Textile industry	3.83 (3.6)	0.65 (3.9)	-4.59 (-4.2)
Papermaking & paper products	3.94 (11.5)	0.72 (9.9)	-11.71 (-6.5)
Electricity, steam and water	2.86 (3.9)	1.11 (10.4)	-26.7 (-7.3)
Petroleum processing & coking	8.80 (9.2)	0.11 (0.7)	-31.4 (-12.7)
Chemical	4.31 (14.8)	0.82 (17.2)	-25.13 (-11.6)
Medical and pharmaceutical	1.66 (4.7)	0.96 (13.7)	-3.88 (-10.1)
Chemical fibers	3.30 (19.4)	0.78 (25.8)	-9.99 (-8.8)
Nonmetal mineral products	6.03 (15.1)	0.58 (7.9)	-23.63 (-5.9)
Ferrous metals processing	4.24 (9.3)	0.89 (13.2)	-41.62 (-6.7)
Nonferrous metals processing	2.76 (7.8)	1.01 (15.5)	-26.65 (-6.5)
Machinery & electric equipment	6.29 (15.1)	0.29 (5.1)	-0.76 (-3.9)

Industry	Elasticity of GDP growth	Elasticity of energy efficiency	Error correction coefficient
	Short term dynamic adjustment		
Food, beverage and tobacco	0.58 (-4.2)	-2.69 (-5.7)	-0.41 (-1.4)
Textile industry	0.77 (-2.6)	-6.11 (-3.3)	-0.99 (-2.0)
Papermaking & paper products	0.93 (-3.9)	-16.06 (-6.1)	-0.76 (-2.7)
Electricity, steam and water	0.37 (-0.5)	-29.34 (-12.4)	-0.72 (-3.1)
Petroleum processing & coking	0.57 (-2.4)	-29.21 (-10.2)	-0.79 (-3.3)
Chemical	1.21 (-9.6)	-41.95 (-13.9)	-1.14 (-5.7)
Medical and pharmaceutical	0.79 (-3.4)	-5.47 (-9.5)	-0.83 (-4.4)
Chemical fibers	1.01 (-6.0)	-12.61 (-13.1)	-1.08 (-4.1)
Nonmetal mineral products	0.85 (-3.5)	-37.56 (-4.6)	-1.08 (-2.2)
Ferrous metals processing	0.98 (-4.9)	-49.60 (-7.1)	-0.75 (-3.4)
Nonferrous metals processing	1.12 (-1.9)	-30.32 (-4.3)	-0.80 (-1.8)
Machinery & electric equipment	0.85 (-2.2)	-1.13 (-2.9)	-0.91 (-2.4)

Note: panel cointegration: $y_{it} = \alpha_1 + \beta_{1i} x_{it} + \beta_{2i} z_{it} + \upsilon_{it}$, where y and x are natural logarithm energy demand and output, z is energy efficiency (e.g., X/Y), β_{1i} is the income elasticity of the energy demand, α_i measures industrial static reliability on energy, β_{2i} measures the effect of change of energy efficiency on energy demand, and υ_{it} measures the effect of other factors on energy demand.

[a] The numbers in parenthesis are t-statistics.

Data source: from Wang and Yang (2006)

Table 2-5. Index decomposition of energy intensity by Chinese literatures (to be continued)

Author(s)	Economy	Period	Approach	Contribution to change in energy intensity (%)		Note
				Industrial intensity	Industrial structure	
Smil (1988)	Aggregate	1979-1987	-	-50	-50	-
Huang (1993b)	Industry	1980-1988	Divisia index	≈-87	≈-13	GOV
Chen (2007)	Industry	1998-2003	General index	-87	-13	-
Qi, Chen & Wu (2007a)	Light and heavy industry	1995-2000	Laspreyres	-111	11	Modified
Qi, Chen & Wu (2007a)	Light and heavy industry	2000-2005	Laspreyres	-108	8	-
Han, Wei & Fan (2004)	3 industries	1981-1990	General index	-25	-75	-
Han, Wei & Fan (2004)	3 industries	1981-2000	General index	-87	-13	-
Han, Wei & Fan (2004)	3 industries	1991-2000	General index	-125	25	-
Ding et al. (2007)	3 industries	1994-2005	General index	-102	2	substitute
Kambara (1992)	3 industries, 5 subsectors	1980-1990	Descriptive	≈-30	≈-70	-
Sun (1998)	3 industries, 6 subsectors	1980-1994	*Laspeyres*	-124	24	Modified
Qi and Chen (2006)	3 industries, 6 subsectors	1996-2001	Laspreyres	-114	14	Modified
Gao & Wang (2007)	3 industries, 6 subsectors	1996-2001	LMDI	-113	13	Estimated
Qi and Chen (2006)	3 industries, 6 subsectors	2002-2003	Laspreyres	42	58	Modified
Gao & Wang (2007)	3 industries, 6 subsectors	2002-2005	LMDI	70	30	-
Ma and Stern (2008)	3 industries, 34 subsectors	1997-2002	LMDI	-105	5	-
Ma and Stern (2008)	3 industries, 34 subsectors	1994-2003	LMDI	-110	-10	-
Ma and Stern (2008)	3 industries, 34 subsectors	2002-2003	LMDI	46	54	-
Peng & Zhang (2007)	5 industrial subsectors	1995-2003	Laspreyres	-125	25	estimated
Zhou and Li (2006)	6 industrial subsectors	1981-1990	Divisia indices	-40	-60	-
Zhou and Li (2006)	6 industrial subsectors	1991-2001	Divisia indices	-114	14	-
Zhang & Ding (2007)	6 industrial subsectors	1994-2001	General index	-112	12	Modified

Table 2-5. Continued

Author(s)	Economy	Period	Approach	Contribution to change in energy intensity (%)		Note
				Industrial intensity	Industrial structure	
Shi, Fu (2007)	6 industrial subsectors	1995-2000	Laspreyres	-111	11	-
Zhang & Ding (2007)	6 industrial subsectors	2001-2003	General index	20	80	Modified
Zhou and Li (2006)	6 industrial subsectors	2002-2003	Divisia indices	55	45	-
Shi, Fu (2007)	6 industrial subsectors	2000-2005	Laspreyres	69	31	-
Hu (2007)	13 industrial subsectors	1987-1997	IOSDA	-99	-1	-
Lin and Polenske (1995)	18 industrial subsectors	1981-1987	IOSDA	≈ -100	≈0	Lin (1996)
Garbaccio et al (1999)	29 industrial subsectors	1987-1992	IOSDA	< -100	>0	-
Zhang (2003)	29 industrial subsectors	1991-1999	ALI	-82	-18	-
Zha, Zhou & Ding (2007)	36 industrial subsectors	1993-2003	AMDI	-90	-10	-
Liao, Fan and Wei (2007)	36 industrial sbusectors	1997-2002	Törnqvist index	-106	6	-
Fisher-Vanden et al (2004)	National firm level	1997-1999	MAMD	-47	-53	-
Sinton and Levine (1994)	11-49 industrial subsectors	1985-1990	*Laspeyres*	-90	-10	GOV
Yu (2007)	3 industries, 5 subsectors	1990-1995	General index	-120	20	Guangdong
Yu (2007)	3 industries, 5 subsectors	1995-2005	General index	-103	3	Guangdong

Note: Aggregate energy intensity increases if total contribution is positive and vice versa.
MAMD: Multiplicative arithmetic mean Divisia indices; AMDI: arithmetic mean Divisia indices; LMDI: logarithmic mean Divisia indices; IOSDA: Input-output techniques - structural decomposition analysis; ALI: additive Laspeyres index; GOV: gross output value.
Three industries are: i) The primary industry, including only agriculture and related activities (farming, forestry, husbandry, secondary production and fishing); ii) Secondary industry, includes mining, manufacturing, water supply, electricity generation and supply, steam, the hot-water and gas sectors, and construction; iii) Tertiary industry, including transportation (including postal and telecommunications services), commerce and others.

Table 2-6. International comparison of elasticities of energy substitution and demand

Author(s)	Country	Economy	Period	Function, factors included	σ_{EK}	σ_{EL}	η_{EE}
Qian and Wang (2003)	China	National	1979-2000	C-D production, EKL, T	-	-	-0.110
			1993-2000		-	-0.863	-0.399
			1979-1992		-	0.117	-0.311
Zheng and Liu (2004a)	China	National	1978-2000	CES and C-D production, EKL, T	1.000	∞	-
Zheng and Liu (2004b)	China	National	1978-2000	Translog production, EKL, T, no time variable	2.500	0.500	-
Huang and Huo (2006)	China	National	1985-2003	Second order CES production, EKL, T	0.685	-	-
Fan, Liao and Wei (2007) [a]	China	National	1993-2003	Translog cost, EKL, T	1.406*	1.133*	-1.234*
			1979-1992	No interact terms of price-output	-0.369*	-0.447*	0.308*
Hang and Tu (2007)	China	National	1985-2004	Linear fuel demand regression, T	-	-	-0.649
Cho, Nam and Pagan (2004)	South Korea	National	1981-1997	Translog cost, EKL, T	0.783	-1.418	0.356
Welsch and Ochsen (2005)	West Germany	Production sector	1976-1994	Translog cost, EKLM, T	-0.399	-0.075	-
Christopoulos (2000)	Greek	Manufacturing	1970-1990	Translog cost, EKL, T	0.250	0.050	-
Vega-Cervera and Medina (2000)	Portugal	National	1980-1996	Translog cost, EKL, T	0.893	0.812	-0.689
Vega-Cervera and Medina (2000)	Spain	National	1980-1996	Translog cost, EKL, T	-0.012	0.300	-0.122
Kemfert and Welsch (2000)	Germany	Entire industry	1970-1988	CES production, EKL, T	0.871	0.167	-
Frondel (2004)	U.S.A.	Manufacturing	1947-1971	Translog cost, EKLM, T	-3.88	0.660	-
Berndt and Wood (1975)	U.S.A.	Manufacturing	1947-1971	Translog cost, EKLM, T	-3.246	0.644	-0.474
Berndt and Wood (1979)	U.S.A.	Manufacturing	1947-1971	Translog cost, EKLM, T	0.120 [b]	-	-

Note: E stands for energy; K stands for capital; L stands for labor, and M stands for materials. T stands for time series data and TS stands for panel data. σ_{EK} and σ_{EL} are the elasticities (AES) of energy-capital and energy-labor. η_{EE} is elasticity of demand for energy.

[a] Morishima elasticity of substitution (MES); [b] in 1971.

Table 2-7. List of studies on Asian energy economy that exclude China

Author(s)	Topic	Asian or developing countries covered (# of counties)
Mahadevan and Asafu-Adjaye (2007)	Energy consumption, economic growth and prices: a reassessment using panel VECM for developed and developing countries	Argentina, Indonesia, Kuwait, Malaysia, Nigeria, Saudi Arabia, Venezuela, Ghana, India, Senegal, South Africa, South Korea, Singapore and Thailand (14).
Lee and Chang (2007)	Energy consumption and GDP revisited: A panel analysis of developed and developing countries	Argentina, Chile, Colombia, Ghana, India, Indonesia, Kenya, Malaysia, Mexico, Nigeria, Pakistan, Peru, Philippines, Singapore, Sri Lanka, Thailand, Turkey and Venezuela (18)
Sari and Soytas (2007)	The growth of income and energy consumption in six developing countries	Indonesia, Iran, Malaysia, Pakistan, Singapore and Tunisia (6).
Lee (2005)	energy consumption and GDP in developing countries	South Korea, Singapore, Hungary, Argentina, Chile, Colombia, Mexico, Peru, Venezuela, Indonesia, Malaysia, Philippines, Thailand, India, Pakistan, Sri Lanka, Ghana and Kenya (18).
Asafu-Adjaye (2000)	The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries	India, Indonesia, the Philippines and Thailand (4).
Murry and Gehuang (1994)	A definition of the gross domestic product – electrification interrelationship	India, Philippines, Zambia, Colombia, El Salvador, Indonesia, Kenya, Mexico, Canada, Hong Kong, Pakistan, Singapore, Turkey, Malaysia and South Korea (15).

Source: refer to reference section.

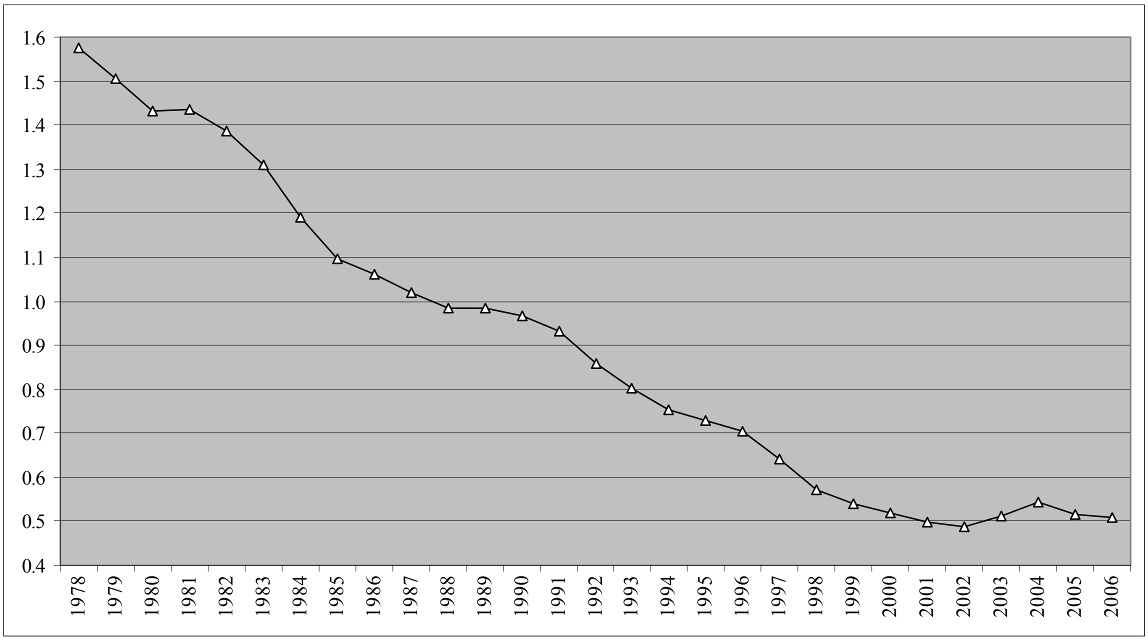


Figure 2-1. China's energy intensity 1978-2006

Note: Measured by the ratio of aggregate energy consumption (million ton standard coal) to GDP (¥billion at 1978 price).

Data source: China Statistical Yearbooks, 1994-2007

Chapter Three: China's Energy Situation in the New Millennium[7]

This Chapter is organized as follows. First, I consider the historical origins of China's current energy situation. This is followed by an investigation and analysis of China's energy resources, including renewable energy. In the third section we consider the energy industry regulations. Section 4 focuses on capacity building in the energy sector. Sections 5 and 6 describe energy transportation (focusing on coal) and energy price information. Section 7 discusses China's energy efficiency in particular, energy intensity over time and across regions. This is followed by a discussion of energy supply, demand and trade in Section 8. Section 9 reviews renewable energy laws, programs and policy**,** and Section 10 discusses the potential factors driving both demand and supply.

3.1 An historical perspective of China's energy situation

As early as 1974, Dean (1974) considered the energy situation in the People's Republic of China and argued that the discovery and initial exploration of new petroleum reserves were significant changes to energy policy and operation. In particular, he was concerned with future developments in the energy industry and the effect on the international energy market. He argued that the size of China's fossil fuel and hydroelectric resources, combining with the commitment to 'self-reliance' made it unlikely that China would

[7] This Chapter was published at Renewable and Sustainable Energy Reviews (2009), doi:10.1016/j.rser.2009.01.018

become a major energy importer. Furthermore, he argued that China would likely become a major exporter in the foreseeable future. By 1992 China had, in fact, become a major energy importer.

Dorian and Clark (1987) discussed potential supply problems and implications for China's energy resources. They stated that primary energy production must increase significantly by the year 2000 if China was to achieve its current modernization and economic objectives. To support and sustain this rapid economic growth, indigenous supplies of primary energy resources would have to be developed at rates greater than those of the time. With a specific concern for China's sustainable energy supplies, they conducted a systematic assessment of China's primary energy resources by Province using the Unit Regional Production Value (URPV) technique, originally developed by Griffiths (1978). What is interesting is that they present the potential for petroleum, natural gas, coal and uranium by Province. The detailed URPV of petroleum, natural gas and coal see Dorian and Clark (1987). Once they had identified the potential supply of petroleum, natural gas and coal by Province they considered the extent to which exploration is restricted by outdated equipment and poor management. Furthermore, they consider whether increased energy production may be limited by inadequate infrastructure combined with high capital requirements, safety and environmental issues.

Kambara (1992) investigated China's energy situation in the 1980s. He considered economic growth and energy consumption and, in turn, the energy intensity by sector and by region, observing the changing patterns of energy supply and demand. He then, raised a number of issues, including the unequal distribution of energy reserves, rising investment cost, limited funds and lack of technology imports which he believed have constrained China's energy supplies. He stated that his review of China's energy situation suggests that supplies of, and demand for, energy will grow in a 'balanced fashion' that will keep pace with economic development. Finally, he argued that the most important task facing China was to totally reform the energy market, particularly pricing to eliminate wasted generation caused by low energy prices. The current 'partially liberalized' market, he argued, actually caused more confusion than benefits.

Wu and Li (1995) studied developments in China's energy situation in the 1980s and early 1990s. They described commercial energy production and consumption and stated that certain features of China's energy production and consumption have had a profound impact on the country's energy development strategies and policies. Much of their work, therefore, focused on explaining these strategies and policies in China, fuel by fuel. Overall, they present two basic characteristics of China's energy industry associated with China's policies for energy development. The first is that China's energy policy has varied over the last several decades consistent with domestic and international situation. The second is that China does not have a unified national energy development strategy as energy resources are not all substitutes and the distribution of energy resources is uneven across regions or Provinces. As a result the 'national' energy policies have become de facto 'regional energy development policies' with each of the major energy industries developing their own strategies. In conclusion the authors recommend that China offer more flexible terms to attract foreign investment in the energy sector, formulate a comprehensive oil import policy, improve the legislative and business climate to support fair competition, ensure balanced growth of coal production and transportation, limit the monopoly power of railway transportation through government intervention, and finally reform electricity pricing system.

There is abundance of coal and a lack of natural gas in China, where coal extraction originates from two types of enterprises - large collieries owned by the state and administrated from Beijing and a variety of local medium and small mines run by county, township, collective and even individual (Wang, 2007). It is a common phenomenon in China that growth in output has not been accompanied by improvements in quality (Smil, 1998). Attempts to open small mines, without geological and technical evaluation, has led to a significant waste of coal resources. Primitive extraction methods and inexperienced operators have led to a very low recovery rate and often extensive destruction of arable and grazing land (Smil, 1998). Rapid economic expansion and the continuing reliance on coal can be expected to more than double China's current carbon dioxide emissions and are forecast to rise significantly with a large increase in the other greenhouse gases (Liang, Fan and Wei, 2007).

It is very surprising that the reviews summarized above have not mentioned any renewable energy at all given that renewable energy has been playing an important role in China's energy supply. China's population is over 1.2 billion where more than 60% live in rural areas where most of households use renewable energy (e.g., biomass, biogas) rather than fossil fuel based energy (Liu et al., 2008; Zhou et al., 2008). For example, since 2000 renewable energy has accounted for approximately 74% of China's total rural residential energy consumption (CESY, 2007). Meanwhile, China's urbanization is gradually reshaping the pattern of rural energy consumption away from biomass energy-based to cleaner energy sources (Cai and Jiang, 2008). This will undoubtedly lead to more pressure on nonrenewable energy demand.

The energy situation in China is highly dynamic. Do the concerns raised above persist? Did China follow the policies suggested above? What does the current energy situation in China look like? Are there any new concerns that have appeared? Are there any new policies that have been proposed? The following Section presents an overview of the current energy situation in China.

3.2 China's energy resources

The issue of China's energy reserves is of long standing interest to researchers and policy makers. Issues related to general energy reserves can be found in BP (2008) and energy potential in Dorian and Clark (1987). Below, we present some figures to illustrate China's energy reserves and their distribution over Provinces as it helps understand issues related to energy transportation and policies on energy exploration and regional development.

3.2.1 Coal reserves

China's proven reserves of anthracite and bituminous coal are 62200 million metric tonnes (mmt) and for sub-bituminous and lignite coal, 52300 mmt (BP, 2008). The total proven coal reserves are therefore 114500 mmt and account for 13.5% of total world stocks. As of the end of 2007, the ratio of reserves to production is 118 years. It is also widely known that China's distribution of coal is extremely uneven across regions. Figure 3-1 shows the distribution of China's coal reserves by Province in 2004. Coal is found almost everywhere in China, but the major deposits are found in the North (Shanxi and Inner Mongolia), Southwest (Guizhou and Yunnan) and Northwest (Shaanxi). Most coal reserves are located in Shanxi Province (over 100 billion metric tons).

3.2.2 Petroleum reserves

Statistics show a clear decline in China's proven and recoverable petroleum reserves. In 1987 there were 2377 mmt declining to 2322 mmt by the end of 1997 and 2117 mmt by 2008. Chinese petroleum reserves presently account for 1.3% of the world total (BP, 2008). As of the end 2007, the ratio of reserves to production was 11.3 years. Finding new oil fields and creating a comprehensive oil import policy package is one of the most important tasks for China to undertake. Similarly, oil reserves are not evenly distributed over Provinces (see Figure 3-2), which shows stocks in favor of Northeast (Heilongjiang), East (Jiangsu) and Northwest (Xinjiang).

3.2.3 Natural gas reserves

China's proven reserves of natural gas are 1.9 trillion cubic meters and account for 1.1% of the world total. As of the end 2007, the ratio of reserves to production is 27.2. Natural gas reserves are mainly located in the Southwest (Sichuan and Chongqing), West (Shaanxi), North (Inner Mongolia) and Northwest (Xinjiang) (see Figure 3-3). There are two types of natural gas reserves – those which are independent of oil fields and those associated with oil reserves. Natural gas development is sluggish due to the absence of production facilities, transportation pipelines and urban gas supply systems. Nevertheless, China's natural gas resources are estimated to be large and more will no doubt be confirmed and developed. The most promising fields are in the Ordos basin, the Caidam Basin, and the Yinggehai Basin off Hainan Island (Smil, 1992).

3.2.4 Renewable energy

There are various renewable energy sources including hydropower, biomass, solar energy, wind energy, geothermal energy and wave energy currently used in China. It is currently estimated that the economically potential exploitable renewable energy resources amount to approximately 7.2 billion tonnes coal equivalent, while the current exploited renewable energy resource is only 0.1 billion tonnes coal equivalent (Zhou, 2006). Here we will consider only hydropower and biomass renewable energy as they are currently two of the most important sources of renewable energy in China.

3.2.4.1 Hydropower energy

China is rich in hydropower energy potential. Maximum exploitable hydropower resources are approximately 680 million KW[8], of which 380-400 million KW is currently economic exploitable potential. To date, there has been total installed capacity of 116 million KW. China plans to install new capacity of 165 million KW by 2010 and 290 million KW by 2020.

Of 380-400 million KW of hydropower economic exploitable, there is 128 million KW from small hydropower stations (under 50,000 KW), located in 1600 counties across the country. Total installed capacity of small hydropower stations was 47 million KW in 2006. Total generation of rural hydropower was 148 billion KWh in 2006 (CSY, 2007).

[8] This unit (KW) comes from China Energy Statistical Yearbook 2007, which only indicates the installed capacity without providing much hydroelectricity generated annually.

China plans to install 50 million KW by 2010 and 75 million KW by 2020 for small hydropower station generation (Zhou, 2006).

Small hydropower stations play an important role in China's rural electricity supply. Currently, approximately half of the territories, one third of counties and a quarter of the total population are dependent upon small-scale hydropower for rural electricity supply.

The distribution of small-scale hydropower generation, however, is uneven. Approximately 65% of small hydropower stations are located in the west and south of the country. In 2005, total installed capacity was approximately 24.7 million KW in the western areas of the country, which generated total hydro electricity of 71.5 billion KWh.

3.2.4.2 Biomass energy

Potential for biomass energy in China includes crop stalks, firewood, foul waste, domestic garbage, industrial organic wastes and waste water, etc. It is estimated that total potential biomass energy is approximately 70-100 mmt coal equivalent, of which 50% comes from crop stalks, i.e., 35-50 mmt coal equivalent (Zhang et al., 2009).

During the period 1995-2006, China produced approximately 620 million tons of crop stalks per year of which 50% comes from the east and central south of China. Crop residues amount to 1.3 times total crop output and 2 times that of the total fodder of grassland. Crop stalks of corn, wheat and rice amounted to 189, 136 and 237 million tons respectively accounting for over 85% of all crop stalks in 2006 (CSY, 2007). At present, energy use accounts for approximately 37.5% of crop stalks, non-energy use accounts for approximately 27.5% of crop stalks with approximately 35.0% of crop stalks either lost during the harvest or discarded in the field (Liu et al., 2008). This means that there is still

35% potential use of crop stalks as biomass energy in China's rural areas equivalent to over 50 mmt coal equivalent.

3.3 Energy industry regulation

The regulatory system plays an important role in energy industrial development and the market economy. The former regulatory system of China's energy industry had two functions. One of them is industrial regulatory function, and other is a business function. In other words, government not only regulated the energy industry, but also ran it as a business. As a result, the energy economy was actually monopolized by state-own enterprises.

However, China's energy industry has experienced several significant policy and management changes. The old regulatory system has significantly changed since 1998. After a series of restructuring of regulatory bodies, China's energy industrial regulatory system has completely changed since 2007. State-owned energy enterprises have also been removed from regulatory function. The new regulatory system has almost completely removed government from the function of enterprise management, where the Government only acts as a regulator. State-owned enterprises also need to negotiate with the Regulator. China's regulatory system will be discussed in detail in Chapter 6.

3.4 Capacity building in the energy sector

Strong economic growth and rising income per capita have produced an increasing demand for energy. Therefore, the development of the energy industry has become an important item on the agenda of the Chinese government. Enhancing energy production is one element of meeting the demand for energy in China. Since the 1990s, China has invested significantly in increasing the capacity of the energy sector and, as a result, total new energy capacity has increased.

Table 3-1 shows the change in capacity building for coal, crude oil and electricity. . In the 1990s, the newly increased capacity in coal extraction was, on average, only 23 mmt, which only accounted for 1.8% of the current year raw coal production. With rapidly increasing investment, however the newly increased capacity of coal extraction reached, on average, 100 mmt, accounting for nearly 5.5% of current year raw coal production in the 2000s. The same pattern can be observed for crude oil extraction for example, the newly increased capacity of crude oil extraction averaged 9.3 mmt, accounting for 5.5% of current year crude oil production in the 1990s. Both doubled in the 2000s, reaching 18.9 mmt and 10.8%, respectively.

In the 1990s, newly installed capacity in coal powered plants was, on average, 11.5 million KW, being 6.4% of current year total installed capacity of coal powered plants nationwide. By the 2000s, newly installed capacity at coal powered plants reached 35.4 million KW, accounting for nearly 10% of current year total installed capacity of coal powered plants. Between 1993 and 1999, newly installed capacity at hydropowered stations was 4.9 million KW per year, while the newly installed capacity nearly doubled each year in the 2000s. Since 1992, the new capacity has been maintained at approximately 10% of current year total installed capacity for hydropower generation.

After observing the patterns of growth in capacity building in the energy industry, it can be noted that the growth of production capacity in raw coal extraction was slower than in crude oil extraction and electricity generation by coal powered plants and hydropower stations in China. Clearly the percentage of new capacity in current year total production capacity is only approximately 5% of raw coal extraction while it is closer to 10% in the other three energy sectors.

China's capacity building in the energy sector is, in general, able to meet its aggregate energy demand. However, there are significant differences across energy sources. For example, from 2000 to 2006, China's capacity for coal extraction averaged 1725 mmt, but its coal consumption only increased 179 mmt each year in the same period. Therefore, China actually ran a surplus of coal capacity building. Likewise, oil capacity building was 172 mmt each year from 2000 to 2006, but its actual increase in oil consumption was only 22 mmt in the same period.

3.5 Energy transportation

Uneven distribution of energy production and consumption across Provinces has produced pressure on the domestic transportation sector. This is particularly true for coal which accounts for 75% of total production because coal is consumed throughout China.

Inter-Provincial total shipments of coal is 2394 mmt, which amounts to 1820 billion metric tonnes km, and accounts for 75% of total rail cargo in 2006. Of total interprovincial coal shipments in 2006, outflows of coal accounted for 40% (993 mmt), and inflows 60% (1400 mmt). Because of the uneven production and special types of coal, there are significant variations across Province in the volume of total interprovincial coal shipment. Table 3-2 presents data on the outflows and inflows of coal and the percentage of total coal shipped in total coal consumption. As can be seen from Table 3-2 that Shanxi, Inner Mongolia, Henan and Shaanxi are major Provinces which export coal, 432, 145, 83 and 80 mmt respectively in 2006, (column 1). Major Provinces importing coal are Shandong, Hebei, Jiangsu and Zhejiang, where the total inflows were 188, 173, 158 and 112 mmt, respectively (column 2). Due to the uneven distribution of production and types of coal, total coal shipments in Shanxi Province amounted to 470 mmt being more than 150% of its total consumption within the Province in 2006 (columns 3 and 4). Total coal shipments were 200 mmt or 75% of total coal consumption within the Province of Hebei. There are several other Provinces where total coal shipments range from 110-160 mmt (Inner Mongolia, Jiangsu, Zhejiang and Henan).

A major feature of interprovincial coal shipments in China is that coal is shipped from West to East and from North to South. These flows are shown in Figure 3-4. In particular, West-East includes: 1) Datong (in Shanxi Province) to Qinhuangdao (in Hebei Province); 2) Shenmu (in Shanxi Province) to Huanghua port (in Hebei Province); 3) Taiyuan (in Shanxi Province) to Dezhou (in Shandong Province); 4) Changzhi (in Shanxi Province) by Jinan to Qingdao; and 5) Houma (in Shanxi Province) by Yueshan (in Henan Province), Xinxiang and Yanzhou (in Shandong Province) to Rizhao. North to South includes: 1) Harbin (in Heilongjiang Province) by Shenyang (in Liaoning Province), Dalian and Shanghai to Guangzhou (in Guangdong Province), including both railway and boats; 2) Tianjin by Jinan, Xuzhou (in Jiangsu Province) and Nanjing to Shanghai, including both railway and boats; 3) Datong (in Shanxi Province) by Taiyuan, Jiaozhuo (in Henan Province), Zhicheng (Hubei) and Liuzhou (in Guangxi Province) to Zhanjiang (in Guangdong Province); and 4) Baotou (in Shanxi Province) by Xi'an (Shaanxi) and Ankang (in Sichuan Province) to Chengdu.

The largest coal producer in China is in Shanxi Province where most coal is shipped to Hebei, Shandong, Tianjin, Jiangsu, Beijing and Liaoning Provinces and accounted for 90% of Shanxi's total outward shipments in 2006. The second largest is Inner Mongolia where a total of 120 mmt, accounting for 83% of total outflow shipments, was shipped to Liaoning, Tianjin, Heilongjiang, Jilin and Hebei Provinces in 2006. See Table 3-3 for data on other Provinces.

When we consider petroleum products they are also shipped throughout China. Major Provinces that export petroleum to other Provinces are Tianjin, Shanghai, Liaoning, Heilongjiang, Shandong and Xinjiang. In 2006, total outflow shipments of petroleum and products was 249 mmt, of which 42 mmt was shipped from Tianjin, 36 mmt from Shanghai, 30 mmt from each of Liaoning and Heilongjiang, 24 mmt from Shandong and 17 mmt from Xinjiang, all of which account for 71% of national total outflow shipment of petroleum and products. There are six Provinces that import petroleum and products of over 15 mmt from other Provinces. Of 291 mmt of inflow shipments of petroleum and products, 39 mmt was shipped to Shanghai, 35 mmt to Liaoning, 26 mmt to Tianjin, 23 mmt to Guangdong, 19 mmt to Beijing and 15 mmt to Shandong, all of which account for 54% of the national total inflow shipments of petroleum and petroleum products in the same year.

China is apparently not rich in natural gas reserves. In fact, there are only a few Provinces that export natural gas. The total outflow shipments of natural gas was 18244 million cubic metres in 2006, while total transportation amounted to 8866 billion cubic meters km in conjunction with an average shipment distance of 486km. The major exports come from a few Provinces the largest being Xinjiang (10254 million cubic metres), followed by Sichuan and Shaanxi (5300 million cubic metres each), and finally Inner Mongolia, Chongqing and Guangdong (3870, 3100 and 2460 million cubic metres, respectively). These Provinces account for 95% of the national outflow shipments of natural gas in 2006. Although gas is shipped throughout China, the variations across Provinces are highly uneven. In 2006 for example, inflow shipments of natural gas were 4057 million cubic metres to Beijing, around 3000 million cubic metres to Jiangsu, approximately 2000 million cubic metres to Shanghai, and around 1000 million cubic metres to Zhejiang, Henan and Gansu. These account for approximately 70% of the national inflow shipments of natural gas in 2006.

In contrast, electricity generation is widespread with more than 80% of demand met within Province, the exception being Beijing where only 35% of demand for electricity was met internally. As a result, only 11% of the demand for electricity is transmitted inter-provincially. The largest surplus of electricity was Inner Mongolia (coal based) and Hubei (hydro-based), each of which exported transmission of approximately 55 billion KWh. Other exporting Provinces in 2006 included Shanxi, 43 billion KWh (coal based); Guizhou 36 billion KWh (coal based), and Jiangsu 25 billion KWh. Most of the surplus electricity was transmitted to Guangdong (61 billion KWh), Beijing (41 billion KWh), and Hebei, Shanghai and Jiangsu (around 30 billion KWh for each), which accounted for over 70% of national inflow transmission of electricity in 2006.

In China there are seven electricity networks; Northwest, Xizang, North China, Central China, Southern China, Northeast and East China, and three major electricity transmission routes; Northern Route, Central Route and Southern Route. China's electricity is typically transmitted from West to East and from North to South. Figure 3-5 shows China's electricity networks and transmission routes.

3.6 Energy pricing mechanisms

Energy pricing plays a crucial role in energy resource allocation. Therefore many researchers argue that energy prices were 'irrational' and caused enormous macroeconomic and microeconomic distortions in the energy sector and throughout the economy in China (Fesharaki *et al.,* 1994). It is true that until the reforms of the late 1970s, energy prices were fully state-controlled in China. As a matter of fact, this energy pricing mechanism was rooted in the old energy industrial regulatory system.

However, as the energy industrial regulatory system was restructured, the energy pricing mechanism has also gradually been reformed. China's energy pricing mechanism has experienced three different stages since the 1960s. The first stage is that energy prices were completely controlled by the country before the 1978 reforms. The second stage is the 'dual track' pricing mechanism which was adopted commencing in the early 1980s and lasted until the early 2000s. A market-oriented energy pricing mechanism has almost been completed adopted since 2007. However, it should be noted that China's energy price reforms are gradual and the time and intensity of reforms are different over different types of energy. China's energy pricing mechanism will be discussed in detail in Chapter 6.

3.7 Energy efficiency

Energy intensity is an important indicator of energy efficiency which is directly related to economic growth and energy consumption. To ascertain the change in China's energy intensity over time, Figure 3-6 shows national aggregate GDP (in 1978 price), aggregate energy consumption and energy intensity measured as the ratio of energy consumption to GDP, since 1978. It appears that energy intensity has generally declined since 1978, while the trend has varied over time. This may suggest that the rates of energy intensity change frequently. It is also clear that since 2000 a different pattern has emerged.

If once considers energy intensity by sector, since 1980, see Table 3-4, one can observe some similarities and some differences. Firstly, the patterns of aggregate energy intensity shown in Figure 3-6 and of industrial energy intensity shown in Table 3-4 are consistent as both industrial energy consumption and output (GDP) comprise most of the aggregate economy. The similar features of stable yet fluctuating energy intensity can be found after 2000 for industrial energy intensity (Table 3-4). Similar patterns can be observed for other sectors. However, more apparent and stronger rising trends appear for the other four sectors. For example, intensity rose from 0.64 in 2001 to 0.76 in 2006 for the transportation sector; from 0.12 in 2001 to 0.19 in 2006 for the construction sector.

Whether these rising trends will maintain in the longer period is unclear, in part they may depend on any changes in energy policies.

What might have induced the changes in China's energy intensity? Based on the survey of literature on China's energy economy in Chapter 2, declining industrial energy intensity plays an important role in the decline in national aggregate energy intensity before 2000 and that rising industrial energy intensity plays an important role in increasing national aggregate energy intensity after 2000. This finding, however, does not identify the factors driving the change in energy intensity. To fill this gap, Ma et al. (2008) estimate a translog cost function using a panel of provincial data for China and they conclude that 'technological change' has driven the increase in energy intensity and factor prices play little role in this process. Specifically, it is energy-using technologies that have been employed in this new millennium in China. If this finding is correct, the implications for current policies on technological and capital investment need to be seriously analyzed by China's decision-makers.

The changes in energy intensity are also not homogenous across regions, territories or Provinces. Table 3-5 shows Provincial aggregate energy intensity and its changes over the period 2001 to 2006 (based on 1978 prices) allowing comparisons to be made among Table 3-4, Table 3-5 and Figure 3-6.

As can be seen from Table 3-5 substantial variation in energy intensity, in both the levels and changes, can be seen across the Provinces for example, energy intensity is low in Beijing, Shanghai, Jiangsu, Zhejiang, Fujian, Guangdong and Hainan. These Provinces are located in the east and south of China and are part of the developed areas. On the other hand, in 2006, energy intensity is relatively high in the less developed area, for example, it measures over 1.4 in Guizhou, Ningxia and Qinghai, and about 1.0 in Gansu and Xinjiang. These Provinces are in the less developed Western region. Energy intensity is also greater than 1.0 in Shanxi and Inner Mongolia which are in the less developed Northern region. In contrast, energy intensity is less than 0.5 in the developed regions in the East and South (e.g., Beijing, Tianjin, Shanghai, Jiangsu, Guangdong and Hainan).

The trends in energy intensity also vary across the Provinces. Energy intensity declined by approximately 50% from 2001 to 2006 in Beijing and by 30% in Tianjin and Shanxi. However, it rose by 30% in Fujian and 20% in Shandong, Hubei and Hunan. It appears that energy intensity and economic growth are closely correlated. Therefore, national energy policies may not be suitable for provincial realities. As a result, provincial energy intensity may need to be studied and regional energy policy developed.

To improve energy efficiency, many projects have been introduced over the past 25 years. Price et al. (2001) reviews China's energy efficiency policies from 1949 to 2000. They explain China's energy efficiency programs, examine the development of a comprehensive energy policy and assess existing energy conservation, regulation and policies. However, China's energy efficiency is still fairly low relative to other developed countries and regions. For example, China's large and medium enterprises consumed 181 kg standard coal equivalent to produce one ton of cement in 2003, while Japan consumed only 128 kg standard coal equivalent in the same year; China consumed 890 kg standard coal equivalent to produce one ton ethylene in 2003, while Japan consumed 629 kg standard coal equivalent to produce one ton ethylene in the same year; the loss ratio of electricity transmission and distribution in Mainland China was 6.8%, but only 4.8% in Taiwan in 2005 (CESY, 2007). As a result, energy intensity remained high at about 0.90 ton oil equivalent per thousand US$ GDP (measured in 2000 US$ price) in mainland China, whereas the world average was only 0.31 ton oil equivalent per thousand US$ GDP (measured in 2000 US$ price) post 2002 (Table 3-6). Mainland China's energy intensity is approximate 3 times higher than the World average.

3.8 Energy supply, demand and trade

3.8.1 Primary energy supply and demand

3.8.1.1 Fossil fuel-based energy

China's energy production and consumption has increased since 1985 due in the main to its high economic growth rate. Table 3-7 shows China's energy production and consumption as well as its composition. There appear to be three distinct periods of energy production during the last two decades. During the decade 1985-1995, the growth rate of energy production is approximately 4% per annum. This is followed during the period 1995-200 by a period of stagnation from. From 2000 production soars at an annual rate of growth of approximately 9.0%. The composition of primary energy production, however, changed little. Coal continues to dominate primary energy production with a share of over 76.7% in 2006. The share of oil production has obviously declined over time and this has accelerated post-2000. Natural gas and other primary energy production have increased, but with fluctuations. The share of natural gas in primary energy supply, for example, remained approximately constant from 1985-1995. The growth rates of natural gas share in total primary energy supply varied considerably, rising to 8.1% from 1995 to 2000, declined to 2.7% in the next five years and then rose to 9.4% post 2005. Other primary energy production shares increased at an average of approximately 3% annually.

As for the energy consumption, a similar scenario can be found for aggregate primary energy consumption and composition. The only difference is that with a higher growth rate for aggregate primary energy consumption the role of coal has seen a decline, from over 75% in the 1980s and the 1990s approximately to 70% by 2006.

3.8.1.2 Hydropower and nuclear energy

It can be seen from Table 3-7 that China's renewable energy supply is very limited. In spite of a high growth rate, the share of renewable energy supply has remained low. In 2006 it was only 8% of the total primary energy supply. Of the renewable energies, hydropower and nuclear energy are two of the most important for China. China's hydropower production has grown rapidly during the last decade, from 1906 billion KWh in 1995 to 4829 billion KWh in 2007. This represents an annual growth rate of approximately 8%. Nuclear energy has grown even faster from 12.8 billion KWh in 1995 to 62.9 billion KWh in 2007, representing an annual growth rate close to 15%. However, as shown previously, the shares of both hydropower and nuclear energy are very small in total electricity generation. The former is 14.7%, while the later is less than 2.0% in 2007 (BP, 2008).

3.8.1.3 Rural biomass consumption

Biomass energy has been playing the most important role in residential energy demand of rural China and has made a great contribution to alleviate the pressure of fossil energy supply of the country. Rural biomass energy consumption (comprising firewood, crop stalks and biogas) in mainland China was 206 million tonnes coal equivalent in 2000 and it rose to 280 million tonnes coal equivalent in 2006. Biomass energy accounts for most of the total of rural energy consumption. Its share in rural aggregate energy consumption was 76% in 2000 and 74% in 2006. Of biomass energy, crop stalk accounts for over 60% (CESY, 2007).

3.8.1.4 Fossil fuel based energy consumption by industry

Industry remains the nation's largest consumer of primary energy. However, as other sectors have expanded its share of primary energy consumption has declined from close to 80% in the 1980s to approximately 70% by 2006 (Table 3-8). Likewise, agriculture's share of primary energy consumption has also declined from approximately 8% in the mid-1980s to around 3.5% in 2006.

It is worth noting the sharp growth of shares in consumption from the transportation and commercial sectors during the last two decades. Transportation was a very small consumer in 1985, only 1.5% and the commercial sector close to 1%. However, since 1985, their shares have grown considerably for example, the share of primary energy consumption in the transportation sector increased to 4.5% in the 1990s and then climbed to 7.5% by 2006. At the same time, the share of primary energy consumption more than doubled from barely 1% in 1985 to 2.2% by 2006 in the commercial sector. It is clear that currently these two sectors now account for approximately 10% of the total national primary energy consumption.

Since 1990, the residential sector has become the second largest consumer of primary energy in China. Its share of primary energy consumption was only 5.4% two decades ago in 1985. Five years later, it jumped to 16.0%. Since 1995 when industrial output began to recover the residential share of consumption has been remained stable at approximately 10%.

By observing growth rates one may be better able understand how the structure has changed over time and over sectors (Table 3-5, bottom section). Some conclusions can be made. Firstly, except for a short period of recovery (1995-2000), a sharply declining share of agricultural sector energy consumption has been evident from 1985 to 2006 Secondly, a rapidly declining rate only occurred in the 1980s and since then the growth has changed little until 2006 for industry; Thirdly, the construction sector has experienced three different phases of growth with effects on its share of energy consumption. The first was a sharply declining rate of energy consumption share for the period 1985-1990 to 1990-1995. This was followed by an extreme move in the opposite direction 1995-2000. Since then the situation is one of stability. Fourthly, the transportation sector has also experienced three phases of share growth. The fastest growth of share occurred during the period 1985-1990 (over 25%) followed by high growth 1995-2000 with the third phase being no share growth in all other periods; Fifthly, a similar share growth rate pattern can be found for the commercial sector where there was first rapid growth, then some decline and finally stability post-2000; Finally, the growth of the residential share of energy consumption is clearly related to the extraordinarily economic growth (24.3%) that occurred during the period 1985-1990. This is clearly unsustainable in the longer term

3.8.1.5 Fossil fuel energy supply and demand across regions

China's primary energy production and consumption varies across Provinces and this causes significant domestic trade within China. Table 3-9 presents data for 2006 on the production and consumption of coal and oil, and the surplus by Province. Firstly, note the largest coal producing Province is Shanxi (North) producing approximately 580 mmt, followed by Inner Mongolia (North) with approximately 300 mmt., and the third largest are Henan (Central) and Shaanxi (West) with approximately 200 mmt. There are several other Provinces including Heilongjiang (Northeast), Shandong (East) and Guizhou (Southwest), whose coal production is approximately 100 mmt. Secondly, crude oil production is very small with many Provinces registering no production. The largest oil field is currently located in Heilongjiang (Northeast), with production of 43 mmt, followed by Shandong (East) with 30 mmt. Twenty mmt oil fields are found in Tianjin (East), Shaanxi (West) and Xinjiang (Northwest) while 10 mmt oil fields are found in Liaoning (Northeast) and Guangdong (South). Thirdly, coal and oil are consumed throughout China for example, Shanxi and Shandong consume nearly 300 mmt of coal and Hebei (North), Jiangsu (East) and Henan (Central) consume approximately 200 mmt of coal. There are many Provinces that consume 100 mmt of coal. However, not all Provinces consume crude oil. The largest consumer of crude oil is Liaoning (55 mmt), followed by Shandong (approximate 40 mmt), and the third is Guangdong (close to 30 mmt). There are several Provinces that consume 20 mmt of crude oil. Fourthly, it is clear that most, but not all, Provinces run a 'deficit' of coal for example, Shanxi, Inner Mongolia and Shaanxi run a 130-300 mmt surplus while Heilongjiang, Guizhou, Guangxi, Gansu and Xinjiang have a surplus of something like 30 mmt. The large coal inflow Provinces are Jiangsu, Shandong, Hebei, Zhejiang and Guangdong, with a deficit of between 150 mmt to 100 mmt respectively. There are only four Provinces that run a petroleum surplus and they are Tianjin, Heilongjiang, Shaanxi and Xinjiang. Liaoning runs the largest petroleum deficit (43 mmt) followed by Zhejiang, Jiangsu, Shanghai and Ningxia, each of which have a deficit of around 20 mmt.

3.8.2 Electricity supply and demand

Although capacity building in the electricity production sector increased rapidly in China, it remains the case that it still cannot meet the rising demand for electricity. China's total installed capacity of electricity supply reached 700 million KW in 2007, of which coal power plants accounted for nearly 80% and hydropower stations accounted for nearly 20%. However, electricity supply is still far behind demand. For example, the excess demand for electricity comes from Beijing and Tianjin who had a 1.1 million KW shortage of electricity in 2007 (Gao, 2008). China is hastening cooperation with Russia to transmit 10 million KW of electricity to the Northeast Grid from the Far East Grid, and negotiating with Inner Mongolia to transmit 12 million KW to the North China Grid from the Sino-Inner Mongolia coal powered plants (Gao, 2008). Other forms of foreign-based electricity cooperation deals are also under negotiation.

3.8.3 Energy trade patterns

In general, China's energy imports are quite limited. Until 1996 China was a net exporter in terms of aggregate energy. Post-1996, China's aggregate energy imports increased, but with no obvious trend (Table 3-10). Only in recent years has a discernable, stable increase in net energy imports emerged rising from 53 million tones standard coal equivalence in 2000 to over 200 million tonnes standard coal equivalence in 2006. This means China's energy import dependence has increased from 3.8% in 2000 to 8.2% in 2006. This pattern of energy trade is determined by two major characteristics of China's energy supply and demand; an abundance of coal deposits and rising demand for petroleum.

China remains a net exporter of coal, but the surplus is declining. To meet the domestic demand for special types of coal, China imports some coal and since 2000 this has been increasing in volume of coal imports to reach nearly 40 million tonnes standard coal equivalence in 2006. On the other hand, the volume of coal exports is still small and hasn't shown an apparent rising trend. As a result, China's net exports of coal have been limited accounting for a small percentage of total domestic coal consumption.

When we turn to petroleum, however, the picture is reversed. China's petroleum imports have increased rapidly since 1995 from 37 mmt in 1995 to (98 mmt) in 2000 more than doubling in 2006 to 195 mmt. When we consider exports we see it has been stable at approximate 25 mmt since 1995. China's reliance on imports of petroleum was only 7.6% in 1995. This increased to 33.8% in 2000, rising to almost 50% since then.

There is little reason to believe that the pattern of energy trade discussed above and presented as Table 3-10 will continue into the foreseeable future given the current energy market situation. Recent volatility in the oil market may lead to some changes, but the rapid growth of the residential sector and demand for private vehicles is likely to exacerbate China's reliance on imported petroleum products. China also faces some other challenges. Firstly, coal is not a good substitute for oil in spite of their abundance of coal deposits. Secondly, automobiles or transportation more generally is one of the largest consumers of petroleum products in the world. Thirdly, rising domestic petroleum consumption appears unavoidable. Finally, this situation will become more severe if no new oil fields are discovered and current oil fields are unable to maintain current output.

3.9 Renewable energy laws, programs and policy

3.9.1 Unfavorable energy situation

As can be seen from above, China is facing two severe challenges of energy shortage and environment protection. Both challenges are mainly rooted in the characteristics of China’s energy supply. China’s petroleum consumption has been sharply increasing, particularly since the new millennium. It is even worse that the ratio of petroleum reserves to production was only 11.3 years as of the end of 2007 (BP, 2008). Since coal is its major source of primary energy, China is facing severe environmental pollution. Therefore, in order to maintain fast and stable economic China has to find a sustainable policy for energy development and consumption.

3.9.2 Renewable energy laws

Energy laws and regulation have also assumed a higher profile in China, against a historic background where energy-saving was not given much attention. For example, the Energy-Saving Law was drafted in 1997, issued in 1998, revised in 2007 and reissued in 2008.

China’s laws for renewable and sustainable energy development and consumption came very late. For example, the Renewable Energy Law of the People's Republic of China was adopted at the 14th Meeting of the Standing Committee of the Tenth National

People’s Congress on February 28, 2005 and went into effect as of January 1, 2006. This Law is to promote the exploitation of renewable energy, increase energy supply, improve the energy structure, ensure energy safety, protect the environment, and attain the sustainable development of the economy and society. In fact, one year after the Renewable Energy Law went into effect, China’s total renewable energy use reached 180 million tons coal equivalent in 2006, accounting for 7.5% of total primary energy consumption (Chen, 2007). Comparatively, renewable energy use was only 63.33 million tons coal equivalent and accounted for only 2.5% of total energy consumption in 2005 (Zhang et al., 2009). As a result, renewable energy use reduced 3 million tons of SO2 emissions and saved 1000 million cube meter of water in 2006 (Chen, 2007).[9]

As China's economy has developed rapidly over the past several decades, the country has struggled to figure out how to maintain a healthy environment. Therefore, the fourth session of the Standing Committee of the 11th National People's Congress adopted Economy Promotion Law of the People's Republic of China on August 29, 2008, with effect from January 1, 2009. This economic law is closely correlated to Renewable Energy Law, with purposes to facilitate recycling economy, raise resources utilization efficiency, protect and improve the environment and realize sustainable development.

3.9.3 Renewable energy research and programs

While China’s renewable energy law was only recently issued, academic research on renewable energy techniques and specific renewable energy projects commenced much

[9] Deming Chen was former deputy director of State Development and Reform Commission at that time. Currently he is the Minister of Commerce of People’s Republic of China.

earlier. For example, The Institute of Nuclear and New Energy Technology (INNET)[10], Tsinghua University, was established in 1960, with its renewable energy research emphasizing hydrogen energy and biofuel studies. Guangzhou Institute of Energy Conversion (GIEC), Chinese Academy of Sciences (CAS), was founded in 1978, and recently emphasizes new and renewable energy utilization technology and energy regeneration technology for environmental pollution abatement.[11] The Center for Renewable Energy Development (CRED), Energy Research Institute of State Development and Reform Commission (NDRC), was established in the 1980s, to focus on economic and development policy of renewable energy.[12] The biogas Institute of the Ministry of Agriculture (BIOMA) was established in 1979 directly associated under the Chinese Academy of Agricultural Sciences (CAAS), with integration of biogas fermentation research, technical development, engineering project design and technical training. Recently, many such institutes have been established, for example, Institute of Energy[13], Shanghai Jiaotong University, and the School of Energy Research[14], Xiamen University. In fact, almost each province has its own energy institute.

China carried out renewable energy programs as early as in the 1970s, while most of large scale programs were launched in the 1990s. For example, the State Planning Commission (changed to State Development and Planning Commission in 1998 and to State Development and Reform Commission in 2003) launched a Bright Project Provide renewable power to 20 million Chinese citizens in 1996, Crop Stalk Gasification Project

[10] For detail refer to: http://www.inet.tsinghua.edu.cn/english2/news.php
[11] For detail refer to: http://www.giec.ac.cn/giec2008_english/index.html
[12] For detail refer to: http://www.cred.org.cn/en/main.asp
[13] For detail refer to: http://energy.sjtu.edu.cn/
[14] For detail refer to: http://energy.xmu.edu.cn/

for the general rural area to promote and extend the crop stalk gasification techniques in 1998, Acceleration Plan for Bright Project to provide a capital of ¥1800 million (approximate US$ 257 million) for solar energy and wind energy projects in 2002, and Rural Household Marsh Gas State Debt Project to construct the marsh gas construction with state debt capital in 2002 (Table 3-11). In addition, other government and international agencies also carried out renewable energy programs in China.

3.9.4 Renewable energy development policies

However, China's renewable energy is still unable to compete with fossil energy, and its development is dependent upon government support. In fact, the Chinese government has issued many priority policies to encourage and develop renewable energy since the late 1970s. Specifically, they are, for example, economic encouragement policy (e.g., financial subsidies, favorable taxation policies, and favorable price policies), industrialized support policies, technical research and development policies, and government renewable resources model projects.[15] However, Chen (2007) noted that much is still to be done to support policies for renewable energy development in China. As Zhang et al. (2009) conclude, for example, there is lack of coordination and consistency in policy, weak and incomplete encouragement systems, no innovation in regional policy, incomplete financing systems for renewable energy projects, and inadequate investment in the technical research and development for renewable energy, etc.

[15] For other laws, regulations and general policies see Zhang et al (2009).

3.10 Looking ahead: challenges and opportunities

The factors that affect China's energy demand and supply have been well documented (Zhao and Wu, 2007; Crompton and Wu, 2005). However, what are the factors that drive energy demand and supply? We attempt to identify them below.

3.10.1 Factors affecting energy demand

3.10.1.1 Rapid income growth

As per capita income grows, consumers will need more energy and potentially cleaner energy. At present per capita energy consumption in China is relatively low for example, electricity consumption per capita in mainland China was 249 KWh in 2006. This is to be contrasted with (in 2005) 8365 KWh for the OECD (All); 11056 KWh in North America; 8482 KWh in OECD (Pacific); 6415 KWh in OECD (European); and 2596 KWh (World average) (CESY, 2007). China's consumption of electricity per capita is therefore only 25% of the world average. As this consumption rises, the demands on China's production sector will become enormous.

3.10.1.2 Growing urbanization

There remains a substantial rural-urban gap in energy consumption per capita in China for example, per capita electricity consumption per capita in urban areas was approximate 370 KWh in 2006, while it was only 190 KWh in rural areas. In addition, the urban population proportion rose rapidly from 30% in 1996 to 44% in 2006 (CSY, 2007).

3.10.1.3 Expanding Transportation

This includes public and private transportation developments. The rapid expansion of the transportation sector has inevitably led to an increase in the demand for energy, especially oil products (Zhao and Wu, 2007). The total annual growth rate of total civilian vehicles was 12.2% between 1995 and 2006. The growth rate for private vehicles was even faster, whose annual growth rate was 18.2% from 1995 to 2006, making total private vehicle from 4.18 million in 1995 to 26.20 million in 2006 (CSY, 2007).

3.10.1.4 Lagging energy pricing reform

The impact of energy prices on energy intensity has been extensively discussed in Hang and Tu (2007). Ma et al. (2008) estimate the elasticity of demand for energy. Fan, Liao and Wei (2008) report measures of the own-price elasticity at -1.236 for the period 1993-2005. The impacts of raising energy prices on energy demand are evident.

3.10.1.5 Increasing energy-intensive exports

China's energy-intensive exports have significantly increased domestic energy consumption. Kahrl and Roland-Holst (2008) estimate that net exports accounted for 15-22% of China's total energy consumption which, since 2002, has significantly contributed to the increase in China's measured energy intensity. This suggests that the energy intensity of exports is higher than that of non exports. The energy intensity of exports rose 8% annually, almost the same rate as national economic growth. Moreover, rising energy-intensive exports exaggerates greenhouse gas emissions and in turn China has been to be blame for having already become the second largest emitter of greenhouse gases. Within 5 years China's CO_2 emissions have nearly doubled, Weber et al (2008) find that in 2005 around one-third of Chinese emissions (1700Mt CO2) were due to the production of exports. It seems that consumption in the developed world is driving China's greenhouse gas emissions.

3.10.2 Factors affecting energy supply

3.10.2.1 Increasing investment

Total investment in the energy industry was ¥521 billion in 1995 (in 2006 price) and ¥1751.3 billion in 2006, the growth rate of 11.6% per annum over the last decade. However, this growth rate could not keep in pace with the whole national investment growth. The share of investment of energy industry in total national investment was 21.4% in 1995, however, this share decreased to 14.7% in 2006, a one percent per annum drop since 1995.

3.10.2.2 Enhancing innovation

Here we will consider issues related to new energy sources and energy supply initiatives. The National Plan for medium- and Long-Term Scientific and Technological Development (2006-2010), written in 2005, raised issues relating to innovation in the sector. Dorian and Clark (1987) assessed China's potential for primary energy distribution based on the similarity of geographical structure between China and U.S. They suggest, for example, that China's Gansu, Qinghai Anhui, Sichuan and Chongqing areas are likely to be oil rich (Dorian and Clark, 1987). However, nothing has eventuated and the statistics don't show crude oil production in these Provinces (Table 3-9).

3.10.2.3 Exploring renewable energy

There are various types of renewable energies, of them hydropower and nuclear energies are two of most important. As discussed previously, exploitable hydropower is approximate 400 million KW. To date 116 million KW have been developed. Nuclear energy has developed very slowly in China. It accounted for only 2.1% of total electricity supply in 2005 while world average for the same period was 15.2% (CESY, 2007). The share of nuclear electricity in total electricity generation in many countries is often as large as 40% for example, France 80%, Ukraine 48%; Sweden 46%; Belgium 55%; Switzerland and Bulgaria 41% (CESY, 2007). In addition, biomass energy plays a more important role in rural household energy demand. For the potential of rural biomass resources and consumption, in particular crop residue, see Liu et al. (2008).

3.10.2.4 Improving energy efficiency

Energy efficiency is actually a two-edged sword. Its improvement can directly reduce energy consumption and at the same it can alleviate pressure on energy supply. With a series of adjustments of the industrial structure and the introduction of many energy efficiency programs, China's energy intensity has been declining during the last two decades. However, China's energy efficiency is still fairly low relative to other developed countries and regions. As a result, energy intensity is still high in the world (see previous section). It is clear that China's energy supply would have increased by 30% had China's energy intensity been only twice as high as the world average. The potential for improving energy efficiency is huge in China. Improving energy efficiency is even more important than exploring existing energy resource in this millennium.

3.10.2.5 Hastening energy reforms

Energy reforms in the energy sector include many forms, involving both supply and demand. China's energy economy has been fundamentally reshaped following the introduction and implementation of a number of reforms (referring to in previous sections). However, a completely competitive energy market hasn't yet been achieved.

For example, competitive wholesale markets and retail access are still in the experimental phase. Once fully implemented these may produce a significant effect on energy efficiency. In addition, China's electricity prices are still low relative to world averages which may reduce demand side efficiencies. Hang and Tu (2007) have modeled the effects of price changes on energy intensity and conclude, not surprisingly, that higher energy prices lead to a decrease in energy intensity. Increasing energy prices will improve energy efficiency and therefore increase energy supply relatively.

3.10.2.6 Alleviating traffic congestion

China's traffic can be one of the most congested in the world. The traffic regulation may be also the worst in the world. Improving traffic administration may be another way to saving energy and improving the energy efficiency of the transport sector. According to research, only 15% of the energy from the fuel is used to move the car. Driving in urban areas, 17.2% of fuel is lost due to idling, stop lights or traffic congestion (Sophia, 2007). Therefore, the potential to improve driving fuel efficiency is enormous.

Table 3-1. New installed capacity and its share in total capacity

Year	Coal exploitation (million ton)		Crude oil exploitation (million ton)		Coal power plant (million KW)		Hydropower station	
	Capacity	Δ%	Capacity	Δ%	Capacity	Δ%	Capacity	Δ%
1993	42.8	3.7	6.9	4.8	9.4	6.6	4.0	9.4
1994	9.5	0.8	6.2	4.3	8.1	5.2	4.2	8.3
1995	23.3	1.7	7.4	4.9	10.7	6.4	3.7	7.1
1996	16.9	1.2	9.0	5.7	13.6	7.4	3.7	7.1
1997	30.0	2.2	12.5	7.8	10.3	5.3	3.7	6.8
1998	9.7	0.8	8.4	5.2	15.4	7.9	6.2	10.8
1999	23.5	2.2	9.5	5.9	12.8	6.0	9.1	16.0
2000	22.6	1.7	9.2	5.6	13.4	5.8	4.5	7.3
2001	14.9	1.3	15.6	9.5	10.1	4.1	3.4	4.3
2002	34.2	2.5	25.4	15.2	33.2	12.0	5.2	6.5
2003	74.4	4.5	17.2	10.1	21.4	6.5	12.7	16.1
2004	154.4	7.8	24.7	14.0	37.0	9.9	11.1	11.3
2005	183.8	8.3	23.9	13.2	52.8	12.4	12.8	11.6
2006	226.5	9.5	16.0	8.7	80.2	16.2	13.0	10.7
Average:								
1990s	22.2	1.8	8.6	5.5	11.5	6.4	4.9	9.4
2000s	101.5	5.1	18.9	10.9	35.4	9.6	9.0	9.7

Note: Coal power capacity was estimated by total coal electricity generation divided by 24 (hour/day)*200 (day/year) and hydropower capacity was estimated by total hydro electricity generation divided by 24 (hour/day)*150 (day/year).
Data source: China Statistical Yearbook 2007. Beijing: China Statistical Publisher.

Table 3-2. Interprovincial coal shipment in 2006

Province	Outflow shipment (mmt)	Inflow shipment (mmt)	Total shipment (mmt)	% of total consumption
Beijing	3.9	26.9	30.8	90
Tianjin	0.0	37.8	37.8	87
Hebei	28.9	173.3	202.2	75
Shanxi	431.6	39.5	471.1	153
Inner Mongolia	145.4	17.9	163.3	95
Liaoning	5.4	77.8	83.2	51
Jilin	4.7	51.8	56.4	71
Heilongjiang	35.1	11.5	46.6	50
Shanghai	1.8	53.3	55.0	95
Jiangsu	7.1	158.1	165.2	81
Zhejiang	0.0	112.1	112.1	96
Anhui	30.8	35.5	66.2	70
Fujian	2.1	31.4	33.5	59
Jiangxi	3.0	20.9	23.9	47
Shandong	28.1	187.9	216.0	70
Henan	83.3	49.9	133.2	60
Hubei	0.0	82.9	82.9	80
Hunan	8.3	34.8	43.1	42
Guangdong	0.0	98.1	98.1	85
Guangxi	10.6	36.7	47.3	102
Hainan	0.0	2.4	2.4	68
Chongqing	5.5	3.1	8.6	21
Sichuan	19.2	20.3	39.5	41
Guizhou	29.2	0.0	29.2	28
Yunnan	6.1	8.3	14.4	16
Tibet	-	-	-	-
Shaanxi	80.0	0.0	80.0	104
Gansu	9.1	10.4	19.5	44
Qinghai	0.0	3.8	3.8	38
Ningxia	11.1	14.2	25.3	70
Xinjiang	2.5	0.4	2.9	6

Note: Physical unit. Average distance of rail shipment was 760 km in the last decade.

Data source: China Energy Statistical Yearbook 2007. Beijing: China Statistical Publisher.

Table 3-3. Major railway coal shipment in 2006

Origin	Coal shipment (mmt)	Of total outflow (%)	Major destinations (Provinces)
Shanxi	390	90	Hebei, Shandong,, Tianjin, Jiangsu, Beijing and Liaoning
Inner Mongolia	120	83	Liaoning, Tianjin, Heilongjiang, Jilin and Hebei
Henan	69	83	Hubei, Jiangsu, Shandong, Jiangxi and Anhui
Shaanxi	66	83	Hubei, Jiangsu, Shandong and Henan
Heilongjiang	34	99	Liaoning and Jilin
Hebei	23	81	Tianjin and Jilin
Shandong	20	74	Jiangsu and Zhejiang
Guizhou	18	64	Guangxi
Anhui	16	55	Jiangsu

Data source: China Transportation Yearbook, 2007. Beijing: China Statistical Publisher.

Table 3-4. The Changes in energy intensity by sector

Year	Agriculture	Industry	Construction	Transportation	Commerce
1980	0.44	1.98	0.54	1.41	0.20
1985	0.25	1.62	0.43	1.11	0.11
1990	0.25	1.38	0.29	0.86	0.16
1991	0.25	1.27	0.28	0.81	0.15
1992	0.24	1.12	0.25	0.79	0.15
1993	0.22	1.00	0.20	0.77	0.19
1994	0.22	0.91	0.18	0.72	0.17
1995	0.23	0.87	0.16	0.67	0.17
1996	0.23	0.81	0.16	0.62	0.18
1997	0.23	0.72	0.13	0.71	0.17
1998	0.21	0.63	0.16	0.70	0.17
1999	0.21	0.55	0.13	0.70	0.18
2000	0.20	0.50	0.13	0.70	0.17
2001	0.21	0.44	0.12	0.64	0.17
2002	0.22	0.48	0.13	0.67	0.17
2003	0.21	0.49	0.12	0.72	0.18
2004	0.23	0.53	0.21	0.75	0.20
2005	0.23	0.52	0.19	0.74	0.19
2006	0.23	0.52	0.19	0.76	0.19

Note: energy intensity (ton/¥1000) = energy consumption (10k ton)/GDP (¥100 million in 1978 price).
Data source: China Statistical Yearbook 1996-2007, China Energy Statistical Yearbook 2007. Beijing: China Statistical Publisher.

Table 3-5. The Changes in energy intensity by provinces

Province	1996	2001	2006	% Change	
				1996-2001	2001-2006
Beijing	0.97	0.66	0.35	-32.0	-46.7
Tianjin	0.97	0.69	0.49	-28.9	-29.4
Hebei	1.11	0.81	0.88	-26.8	7.6
Shanxi	2.26	1.96	1.34	-13.3	-31.6
Inner Mongolia	1.23	1.15	1.10	-6.5	-4.7
Liaoning	1.33	0.93	0.81	-30.2	-12.6
Jilin	1.34	0.83	0.73	-38.1	-12.2
Heilongjiang	1.05	0.74	0.66	-29.5	-10.3
Shanghai	0.71	0.51	0.41	-27.5	-20.7
Jiangsu	0.58	0.41	0.41	-29.7	0.0
Zhejiang	0.50	0.42	0.40	-16.0	-6.5
Anhui	0.83	0.68	0.54	-18.1	-20.0
Fujian	0.40	0.32	0.42	-19.6	30.2
Jiangxi	0.61	0.47	0.47	-23.4	0.5
Shandong	0.66	0.46	0.56	-30.3	21.1
Henan	0.78	0.64	0.61	-17.8	-4.2
Hubei	0.87	0.57	0.67	-34.7	18.2
Hunan	0.89	0.51	0.61	-42.9	21.2
Guangdong	0.51	0.42	0.36	-18.2	-15.0
Guangxi	0.56	0.52	0.54	-6.1	2.9
Hainan	0.38	0.42	0.41	9.3	-2.1
Chongqing	0.00	0.75	0.64	-	-15.4
Sichuan	0.96	0.67	0.68	-30.1	1.6
Guizhou	2.20	1.79	1.45	-18.9	-18.7
Yunnan	0.80	0.74	0.78	-7.9	6.2
Tibet	0.00	0.00	0.00	-	-
Shaanxi	1.29	0.77	0.61	-40.1	-20.3
Gansu	1.69	1.18	0.98	-29.8	-17.1
Qinghai	1.63	1.35	1.40	-17.4	3.5
Ningxia	1.78	0.00	1.86	-100.0	-
Xinjiang	1.52	1.03	0.94	-32.3	-9.1

Note: calculated based on 1978 price, ton/¥1000.
Data source: China Statistical Yearbook and China Energy Statistical Yearbook. Beijing: China Statistical Publisher.

Table 3-6. The world energy intensity (2002-2005)

Country/region	2002	2003	2004	2005
World	**0.310**	**0.320**	**0.320**	**0.320**
OECD Total	0.203	0.201	0.199	0.195
Switzerland	0.107	0.108	0.107	0.105
Japan	0.110	0.108	0.109	0.106
United Kingdom	0.152	0.151	0.146	0.144
Italy	0.158	0.161	0.161	0.164
Germany	0.179	0.181	0.179	0.176
Sweden	0.211	0.201	0.201	0.192
France	0.194	0.196	0.195	0.193
Netherlands	0.201	0.205	0.205	0.201
United States	**0.229**	**0.223**	**0.219**	**0.213**
Spain	0.213	0.214	0.216	0.213
Belgium	0.238	0.248	0.236	0.227
Australia	0.261	0.254	0.249	0.260
Mexico	0.266	0.269	0.267	0.278
Canada	0.334	0.339	0.336	0.331
Korea	0.355	0.354	0.348	0.335
NON-OECD Total	0.750	0.740	0.740	0.720
Hong Kong, China	0.100	0.090	0.090	0.090
Israel	0.180	0.180	0.170	0.150
Argentina	0.230	0.230	0.220	0.200
Brazil	0.310	0.310	0.310	0.310
Chinese Taipei	0.320	0.300	0.300	0.300
Venezuela	0.520	0.520	0.480	0.460
Egypt	0.480	0.500	0.490	0.510
Thailand	0.630	0.630	0.650	0.640
Saudi Arabia	0.660	0.600	0.620	0.610
South Africa	0.810	0.810	0.850	0.800
Indonesia	0.900	0.890	0.880	0.860
People's Rep. Of China	**0.860**	**0.870**	**0.920**	**0.910**
India	1.070	0.900	0.880	0.830
Islamic Republic of Iran	1.140	1.980	1.520	1.610
Russia	2.160	2.080	1.950	1.850

Data source: China Energy Statistical Yearbook 2007. Beijing: China Statistical Publisher.
Note: ton oil equivalent per thousand US$ GDP based 2000 price.

Table 3-7. China's energy production and consumption over time

Year	Aggregate	Of which, %			
	Production	Coal	Oil	Natural gas	Others
1985	855.5	72.8	20.9	2.0	4.3
1990	1039.2	74.2	19.0	2.0	4.8
1995	1290.3	75.3	16.6	1.9	6.2
2000	1289.8	72.0	18.1	2.8	7.2
2005	2058.8	76.5	12.6	3.2	7.7
2006	2210.6	76.7	11.9	3.5	7.9
Growth rate annually (%)					
1985-1990	4.0	0.4	-1.9	0.0	2.2
1990-1995	4.4	0.3	-2.7	-1.0	5.3
1995-2000	0.0	-0.9	1.7	8.1	3.0
2000-2005	9.8	1.2	-7.0	2.7	1.4
2005-2006	7.4	0.3	-5.6	9.4	2.6
	Consumption	Coal	Oil	Natural gas	Others
1985	766.8	75.8	17.1	2.2	4.9
1990	987.0	76.2	16.6	2.1	5.1
1995	1311.8	74.6	17.5	1.8	6.1
2000	1385.5	67.8	23.2	2.4	6.7
2005	2246.8	69.1	21.0	2.8	7.1
2006	2462.7	69.4	20.4	3.0	7.2
Growth rate annually (%)					
1985-1990	5.2	0.1	-0.6	-0.9	0.8
1990-1995	5.9	-0.4	1.1	-3.0	3.6
1995-2000	1.1	-1.9	5.8	5.9	1.9
2000-2005	10.2	0.4	-2.0	3.1	1.2
2005-2006	9.6	0.4	-2.9	7.1	1.4

Data source: China Statistical Yearbook, 1996-2007. Beijing: China Statistical Publisher.

Note: unit is million ton standard coal.

Table 3-8. Sectoral energy consumption over time in China

Year	Agriculture	Industry	Construction	Transportation	Commerce	Others	Resident
Consumption shares (%)							
1985	7.7	79.7	1.7	1.5	0.9	3.0	5.4
1990	4.9	68.5	1.2	4.6	1.3	3.5	16.0
1995	4.2	73.3	1.0	4.5	1.5	3.4	12.0
2000	4.4	68.9	1.5	7.3	2.2	4.2	11.5
2004	3.8	70.5	1.6	7.4	2.4	3.9	10.5
2005	3.6	71.0	1.5	7.4	2.2	3.9	10.4
2006	3.4	71.1	1.5	7.5	2.2	3.9	10.3
Growth rate of shares annually (%)							
1985-1990	-8.6	-3.0	-6.7	25.1	7.6	3.1	24.3
1990-1995	-3.0	1.4	-3.6	-0.4	2.9	-0.6	-5.6
1995-2000	0.9	-1.2	8.4	10.2	8.0	4.3	-0.8
2000-2005	-3.9	0.6	0.0	0.3	0.0	-1.5	-2.0
2005-2006	-5.6	0.1	0.0	1.4	0.0	0.0	-1.0

Data source: China Statistical Yearbook, 1996-2007. Beijing: China Statistical Publisher.

Table 3-9. Energy balance sheet by province in 2006

Province	Raw coal (mmt)		Electricity (billion KWh)		Gasoline (mmt)		Diesel (mmt)	
	Output	Deficit	Output	Deficit	Output	Deficit	Output	Deficit
Beijing	6.5	-24.1	21.5	-40.4	1.73	-1.05	2.05	0.28
Tianjin	-	-38.1	35.9	-8.7	1.30	0.02	3.87	1.40
Hebei	83.6	-129.9	146.1	-27.4	2.13	-0.51	4.12	-0.72
Shanxi	581.4	297.9	152.6	42.8	-	-1.13	-	-2.67
Inner Mongolia	297.6	135.7	141.3	52.8	0.61	-1.51	0.54	-4.39
Liaoning	73.7	-68.4	101.5	-21.3	10.32	6.38	19.11	13.23
Jilin	30.0	-45.5	44.3	3.1	1.60	-0.33	3.44	0.40
Heilongjiang	102.8	12.5	64.7	5.0	3.87	0.42	5.77	0.99
Shanghai	-	-51.4	72.1	-26.9	2.48	-0.21	6.39	2.68
Jiangsu	30.5	-153.8	253.6	-3.4	2.01	-2.49	7.02	1.15
Zhejiang	0.2	-113.1	176.6	-14.3	2.55	-1.50	7.50	-0.92
Anhui	83.3	-5	73.4	7.2	0.87	-0.11	1.94	-0.46
Fujian	19.3	-34.7	90.4	3.7	1.03	-1.05	1.56	-2.24
Jiangxi	27.8	-18.1	44.0	-1.3	0.87	0.21	1.79	-1.35
Shandong	140.7	-149.3	231.5	0.3	5.00	-0.41	10.41	-1.80
Henan	195.3	-14.7	160.1	6.7	1.41	-1.09	2.65	-0.81
Hubei	11.2	-85.3	130.7	41.2	1.78	-2.43	3.52	-1.45
Hunan	59.5	-34.9	75.5	-1.4	1.24	-1.39	2.19	-1.23
Guangdong	-	-111.3	246.6	-53.8	4.01	-3.70	9.94	-3.74
Guangxi	6.8	-34.9	52.3	-5.6	0.25	-1.59	0.42	-2.92
Hainan	-	-3.3	9.7	-0.1	0.66	0.33	0.95	0.32
Chongqing	39.9	2.6	29.1	-11.4	-	-0.86	-	-1.87
Sichuan	86.0	0.7	122.7	16.8	0.32	-2.37	0.61	-2.94
Guizhou	118.2	18.8	98.6	36.6	-	-0.79	-	-1.70
Yunnan	73.4	-1.4	75.4	10.8	-	-1.28	-	-3.32
Tibet	-	-74	1.5	-	-	-	-	-
Shaanxi	182.6	143	58.5	0.4	4.10	1.99	6.05	3.83
Gansu	39.5	30.4	53.0	-0.6	2.39	1.51	5.86	4.68
Qinghai	6.9	-28	28.2	3.6	0.32	0.14	0.48	0.21
Ningxia	32.7	-11.7	38.8	1.0	0.58	0.39	0.78	0.00
Xinjiang	43.2	12.6	35.7	0.1	2.52	1.34	7.59	4.18

Data source: China Energy Statistical Yearbook 2007. Beijing: China Statistical Publisher.

Table 3-10. China's energy trade and reliance

Year	Aggregate trade and reliance (mmt and %)				Coal trade and reliance (mmt and %)				Petroleum trade and reliance (mmt and %)			
	Import	Export	Balance	Reliance	Import	Export	Balance	Reliance	Import	Export	Balance	Reliance
1980	2.6	30.6	-28.0	-4.6	2.0	6.3	-4.3	-0.7	0.8	18.1	-17.2	-19.7
1985	3.4	57.7	-54.3	-7.1	2.3	7.8	-5.5	-0.7	0.9	36.3	-35.4	-38.6
1990	13.1	58.8	-45.7	-4.6	2.0	17.3	-15.3	-1.4	7.6	31.1	-23.5	-20.5
1995	54.6	67.8	-13.2	-1.0	1.6	28.6	-27.0	-2.0	36.7	24.5	12.2	7.6
1996	68.4	75.3	-6.9	-0.5	3.2	36.5	-33.3	-2.3	45.4	27.0	18.4	10.6
1997	99.6	76.6	23.0	1.7	2.0	30.7	-28.7	-2.1	67.9	28.2	39.7	20.2
2000	143.3	90.3	53.1	3.8	2.2	55.1	-52.9	-4.0	97.5	21.7	75.8	33.8
2004	265.9	116.5	149.5	7.4	18.6	86.7	-68.1	-3.5	172.9	22.4	150.5	47.5
2005	269.5	114.5	155.1	6.9	26.2	71.7	-45.6	-2.1	171.6	28.9	142.8	43.9
2006	310.6	109.3	201.3	8.2	38.3	63.3	-25.0	-1.0	194.5	26.3	168.3	48.2
Growth rate annually:												
1980-1990	17.6	6.7	-	-	0.0	10.6	-	-	25.2	5.6	-	-
1990-2000	27.0	4.4	-	-	1.0	12.3	-	-	29.1	-3.5	-	-
2000-2006	13.8	3.2	24.9	13.7	61.0	2.3	-11.7	-20.6	12.2	3.3	14.2	6.1
1997-2006	15.6	4.4	27.3	19.3	38.7	8.4	-1.5	-7.7	14.6	0.1	17.4	10.2

Note: Aggregate energy is measured in million ton standard coal and reliance is the percentage of net import in total domestic consumption.
Data source: China Statistical Yearbooks. Beijing: China Statistical Publisher.

Table 3-11 Government renewable energy model projects in China

Year	Project	Brief introduction	Note
1996	Bright Project	Provide renewable power to 20m Chinese citizens	SPC
1996	Fair Wind Project	During the 10th Five Year Plan, 60–80% or more wind machinery produced by China	SPC
1997	Dual Pluses Project	Invest ¥900m to accelerate wind energy power generation and the wind energy machinery state-manufacturing process	SETC
1998	Crop Stalk Gasification Project	Support the general rural area to promote and extend the crop stalk gasification techniques	SDPC
2000	State Debt Wind Energy Power Generation	Construct $8^{*}10^{4}$ kW China-made wind energy power generation group model wind power field	SETC
2000	Tenth Five Year Plan	Up to 2005, the installed capacity for wind power generation reached 1500 kW	SDRC
2000	Renewable Energy Industrial Development Plan	Up to 2015, the installed capacity for wind power generation reaches 7000 MW	SETC
2002	Acceleration Plan for Bright Project	Provide a capital of ¥1800m for solar energy and wind energy projects	SDRC
2002	Electricity Delivered to Village Project	Solve the domestic power problem for 400k citizens	SDRC
2003	Rural Household Marsh Gas State Debt Project	Construct the marsh gas construction with state debt capital	MOA, SDRC
2006	Scaled Development Project on Renewable Energy	Study and formulate the policy for the development of renewable energy; support the technical advances in renewable energy; construct an industrial system for renewable energy; to realize the scaled development of renewable energy	CG, WB, WEF
2007	Rural Marsh Gas Projects	In 2010, the total marsh gas users reach 40 million; the large- and middle-sized marsh gas projects reach 4700	MOA
2007	Supporting Projects for Biological Mass Energy Science and Technology	Establish technical innovation centers in biological energy regions	MOA
2007	Use of Crop Stalk as Energy Source	Construct 400 village-/town-level crop stalk solidification fuel model spots and 1000 crop stalk central gas providing stations	MOA
2007	Selection and Cultivation Model Base Construction Projects on Energy Crops	Construct energy crops quality seeds selection and cultivation base; construct bases for raw materials for fluid fuel	MOA

Source: from table 2 of Zhang et al (2009).
Note: SPC-State Planning Commission; SETC-State Economy and Trade Commission; SDPC-State Development and Planning Commission; SDRC-State Development and Reform Commission; MOA-Ministry of Agriculture; CG-Chinese Government; WB-World Bank; WEF-World Environment Fund.

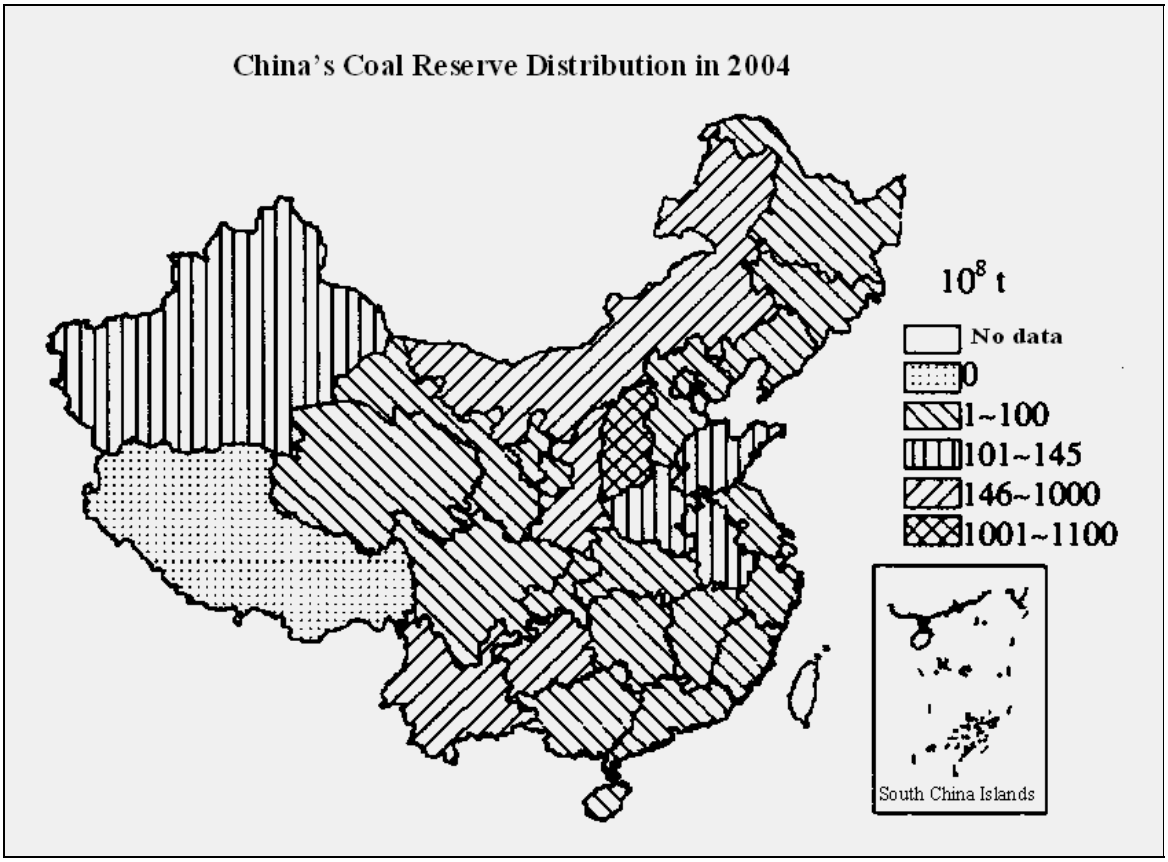


Figure 3-1. China's coal reserve distribution in 2004

Data source: China Statistical Yearbook 2005, Beijing: China Statistical Publisher.
Note: According to BP (2008), China's proved reserve of anthracite and bituminous coal is 62200 million tonnes, and proved reserve of sub-bituminous and lignite coal is 52300 million ones. The total proved coal reserve is 114500 million tones and accounts for 13.5% of world total. The ratio of reserves to production is 118 at the end of 2007.

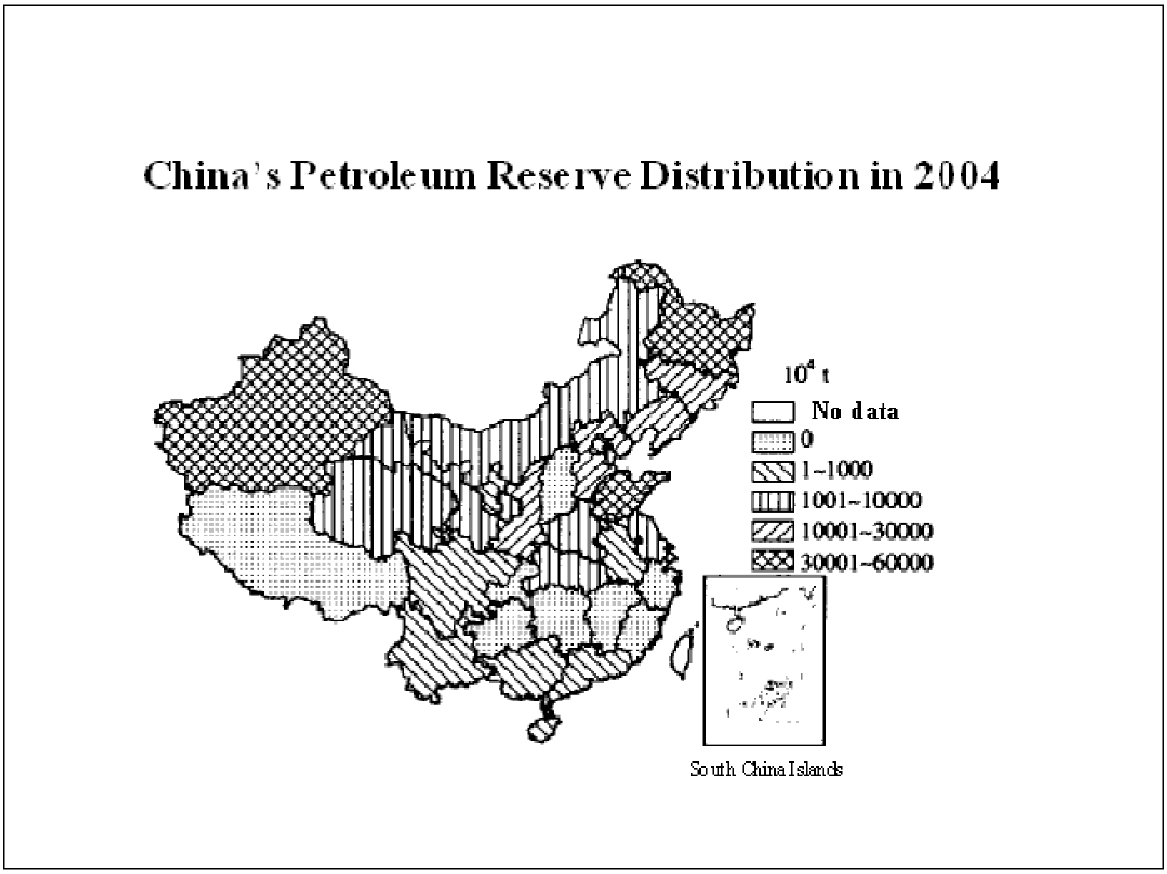


Figure 3-2. China's petroleum reserve distribution in 2004

Data source: China Statistical Yearbook 2005. Beijing: China Statistical Publisher.
Note: China's proved reserve of oil is 2116.6 million tonnes and accounts for 1.3% of world total; the ratio of reserves to production is 11.3 at the end of 2007 (BP, 2008).

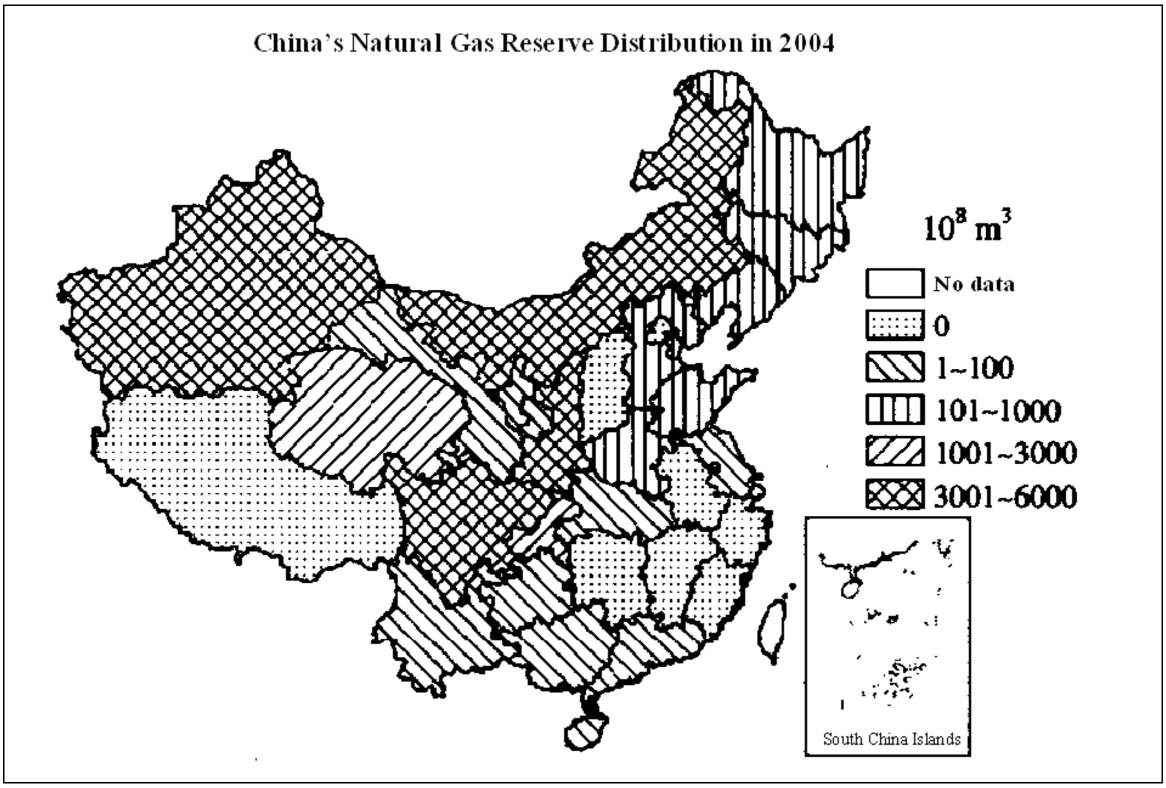


Figure 3-3. China's natural gas reserve distribution in 2004

Data source: China Statistical Yearbook 2005. Beijing: China Statistical Publisher.
Note: China's proved reserve of natural gas is 1.9 trillion cubic meters and accounts for 1.1% of world total. The ratio of reserves to production is 27.2 at the end of 2007 (BP, 2008).

Figure 3-4. China's coal transportation routes

Note: Horizontal lines represent raw coal transported from West to East.

Vertical lines represent raw coal transported from North to South.

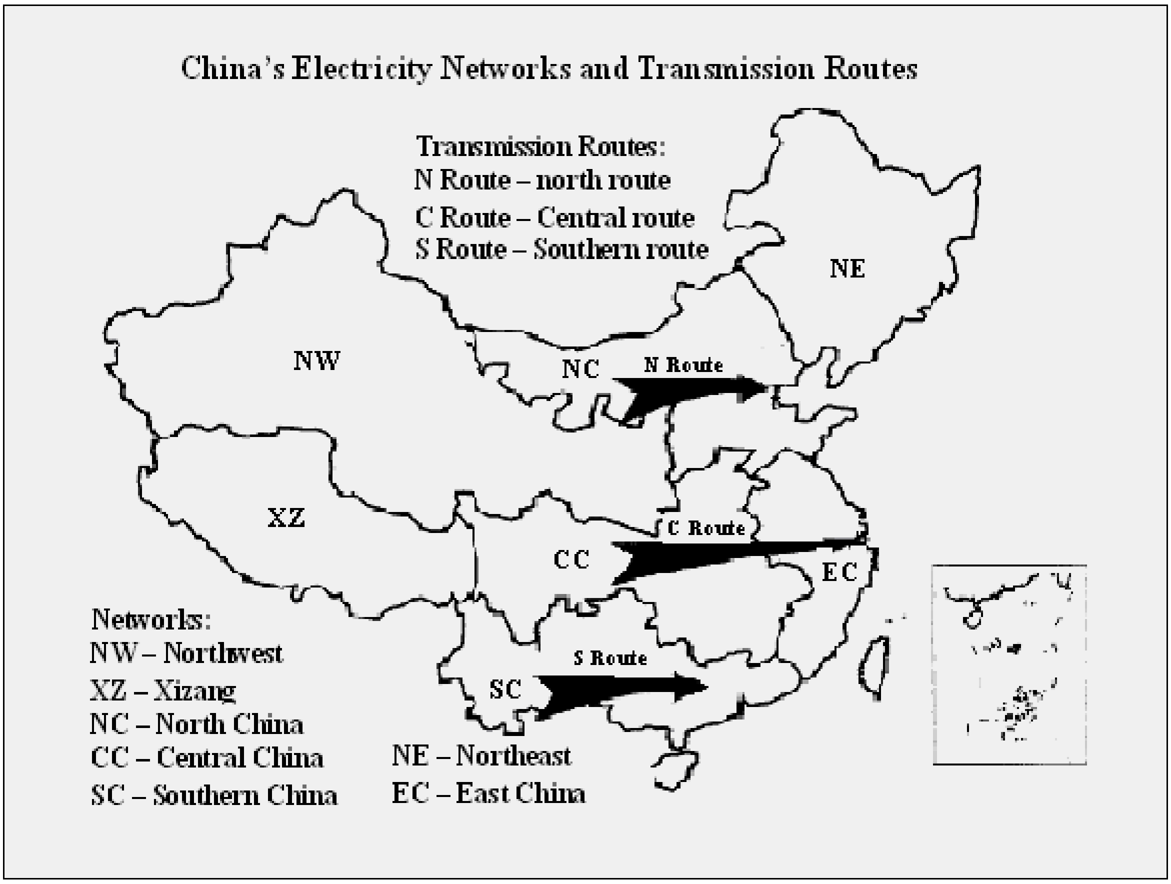


Figure 3-5. China's three major electricity transmission routes

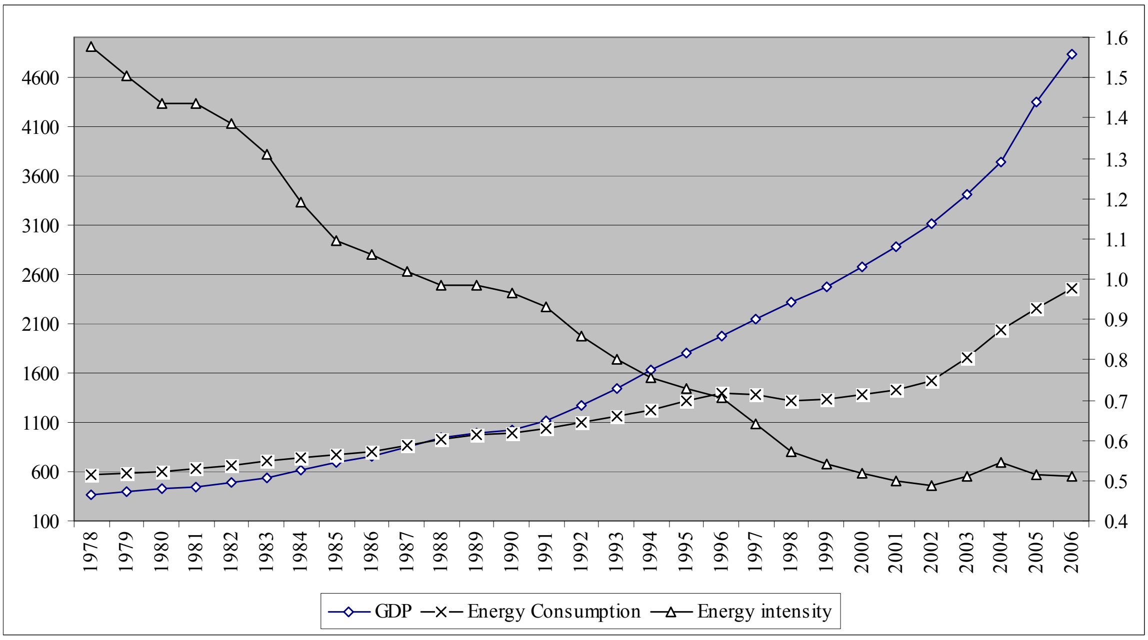


Figure 3-6. GDP, energy consumption and energy intensity

Note: left hand y axis is for GDP (¥billion 1978 price) and energy consumption (million ton standard coal), and right hand y axis is for aggregate energy intensity (ton/¥1000).
Data source: China Statistical Yearbook. Beijing: China Statistical Publisher.

Chapter Four: Methods and Estimation

Having investigated China's energy situation in the new millennium and reviewed the literature on China's energy economy in previous chapters, the remaining chapters address two topics which represent the main new results and the major novel aspects of the thesis.

The first topic relates to the development of China's energy market while the second considers technological change, substitution, demand and their effects on energy intensity in China's energy economy.

In this chapter I will outline the basic methods used to consider these two topics including testing procedures and estimation approaches. The two topics require fundamentally different methods, estimation and testing and this section will outline the relevant methods, their properties and assumptions. This will be followed in subsequent chapters with the new results that arise from the use of the methods.

The approaches and methods used for the first topic are a series of unit root tests, which not only include traditional univariate ADF unit root tests, but also panel unit root and cointegration tests. For the second topic, the approaches used to investigate energy consumption behavior come from the translog cost function literature. We will consider estimation of the substitution of, and demand for, energy at both the aggregate and industry levels. The final approach used addresses the decomposition of energy intensity into its various components.

This chapter is organized as follows: Sections 1 and 2 present univariate ADF unit root test and panel unit root tests, respectively. This is followed in Section 3 by discussion of the estimation of second order translog cost function and the aggregate energy price index, respectively. Sections 4-8 respectively consider an aggregate energy price index (Section 4); introduce the definition of elasticities of substitution and demand (Section 5); assumptions for regional dummy variables (Section 6); estimation procedures (Section 7) and model specification tests (Section 8), respectively. Section 9 discusses how to decompose energy intensity into various components corresponding to various factors.

4.1 Univariate unit root tests

A common approach used to investigate market integration is to apply unit root tests to examine whether price differentials are stationary (see for example, Bernard and Durlauf, 1996; Greasley and Oxley, 1997). Rejection of the unit root hypothesis implies that the time series of relative prices are stationary, such that relative prices will converge in the long run. Otherwise, if the tests fail to reject the null hypothesis, the relative price series will follow a random walk (Fan and Wei, 2006).

The first stage of the time series based tests of price convergence utilises some form of unit root test, for example the Augmented Dickey-Fuller (ADF) test. In our particular example we are interested in testing for integration of the relevant energy market across the major Chinese cities, by testing for price convergence. Tests that suggest the relative price series [$p_{ijt} = \ln(g_{ij,t} / g_{j.t})$] are stationary will provide some evidence of convergence, either absolute or relative. The unit root-based tests utilise a regression of the form:

$$(4\text{-}1) \quad \Delta p_{ij,t} = c_{ij} + \alpha_{ij} p_{ij,t-1} + \sum_{h}^{k} \beta_{ijh} \Delta p_{ij,t-h} + \varepsilon_{ij,t}$$

Where Δ is the first-difference operator; c, α and β are the parameters to be estimated; ε is an identically independently distributed (*i.i.d*) error term; *i*, *j* and *t* refer respectively to city (*i*), energy product (j) and time (t). The ADF unit root test is simply a test of whether α_{ij} is negative and statistically significant. The number of lags, *k*, to be included in equation (4-1) for each product and city series is determined individually using the Lag length chosen via Hannan-Quinn Information Criteria on a city-by-city and product-by-product basis.

All the ADF specifications include an intercept term to capture city-specific fixed effects and a time trend. Such intercept effects may cover, for instance, city-specific transportation, income levels, and local non-traded costs. The inclusion of the intercept term is also used to test whether prices converge to absolute price parity (zero mean) or relative price parity (nonzero mean) (Fan and Wei, 2006).

It is convenient to use group average as a benchmark (g_{jt}) in order to generate relative price series and conduct the ADF unit root tests.[16] Theoretically, it is possible that all of the ADF unit root tests will reject the null hypothesis no matter which city is chosen as a benchmark (g_{jt}) if the energy market is completely integrated. However, there may be apparent differences across energy products in the degree of market integration. Therefore, we firstly conduct the ADF unit root tests using group

[16] We also consider and report some results where we benchmark against an average of all the city prices.

average as a benchmark to see how many tests reject the null. If the ADF unit root tests show almost all of them reject the unit root hypothesis for some energy products, it may not be necessary to further conduct the ADF unit root tests of relative price series on city-by-city basis. However, it may be more likely that the second scenario holds and most of the ADF unit root tests do not reject the null hypothesis. In this case, it can be argued that one city (or regional market) is not integrated with the benchmark (or region), but it does not mean this city (or regional market) is not integrated with other cities (or regional markets). Therefore, we will conduct the ADF unit root tests on a city-by-city basis in these circumstances. This suggests that the markets of some products may not be integrated nationally, but it can be integrated regionally due to, for example, transportation costs or network connections (especially for power supply markets). The city-by-city ADF unit root tests may also provide some clues as to where the regional market is located and which cities are included. If there are regional markets for coal and electricity, as the city-by-city ADF unit root tests suggest, we conduct panel data unit root tests for those groups of cities.

4.2 Panel unit root and cointegration tests

It is now well know that the original unit root tests often suffer from low power when applied to series of only moderate length, and it has been proposed that pooling the data across individual members of a panel helps increase power. Panel cointegration techniques are intended to allow researchers to selectively pool information regarding common long-run relationship from across the panel while allowing the associated short-run dynamics and fixed effects to be heterogeneous across different members of the panel (Banerjee, 1999; Maddala and Wu, 1999). Given the properties of our data, we utilize both panel unit root tests and panel cointegration test techniques.

As is now standard practice, before testing for cointegration we conduct panel unit root tests to consider the order of integration and common unit root properties of the data. Three kinds of panel unit root tests, Levine et al. (2002, thereafter LLC), Im et al. (2003, thereafter IPS) and Hadri (2000), are provided in this study. Each has different assumptions, constraints and statistical power. LLC propose an ADF test with a panel setting that restricts parameters γ_i by keeping them identical across cross -sections (in our case cities) as follow:

(4-2) $$\Delta y_{it} = \alpha_i + \gamma_i y_{it-1} + \sum_{j=1}^{k} \alpha_j \Delta y_{it-j} + e_{it}$$

Where $t = 1,2,\cdots,T$ refers to the time periods and $i = 1,2,\cdots,N$ refers the numbers of the panel. The null hypothesis of LLC test is that $\gamma_i = \gamma = 0$ for all i indicating that the panel data are non-stationary while the alternative hypothesis is $\gamma_1 = \gamma_2 = \cdots = \gamma < 0$. This test is based on the statistics, $t_y = \hat{\gamma} / s.e.(\hat{\gamma})$. The IPS (2003) relaxes this assumption of LLC by allowing γ to vary across units (cities) under the alternative hypothesis. The null hypothesis of the IPS test is that $\gamma_i = 0$ for all *i,* while the alternative hypothesis is $\gamma_i < 0$ for all *i.* This IPS test uses the mean-group approach and obtains the average of t_y to compute the following statistic:

(4-3) $$\widetilde{Z} = \sqrt{N}(\bar{t} - E(\bar{t})) / \sqrt{\text{var}(\bar{t})}$$

where $\bar{t} = (1/N)\sum_{i=1}^{N} t_{y_i}$ $E(\bar{t})$ and $Var(\bar{t})$ represent the mean and variance of each t_y, respectively. The statistic $\widetilde{Z}$ converges to a Normal distribution, and we can compute the significance level in a simple way. By contrast, Hadri (2000) argues that the null hypothesis should be reversed to be a stationary hypothesis in order to increase the power of the test. His Lagrange Multiplier (LM) statistics is given by the follow expression:

(4-4) $$LM = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{T^{-2}\sum_{t=1}^{T}\sum_{j=1}^{t}\hat{\varepsilon}_{ij}}{\hat{\sigma}_{\varepsilon}^{2}}\right)$$

Where $\hat{\sigma}_{\varepsilon}^{2}$ is the consistent Newey-West (1987, 1994) estimate of the long-run variance of disturbance terms (ε_{ij}).

In many circumstances it is hard to judge which panel unit root tests is best as most of time we do not know the properties of the price series. Some authors prefer some types, while others prefer other types of tests. For example, Hlouskova and Wagner (2006) found that the Breitung (2000) panel unit root test generally had the highest power and smallest size distortions of any of the so-called first generation panel unit root tests and therefore Narayan and Smyth (2007) employed this test in their paper. However, this test assumes a common unit root process, which may not reflect the reality, especially for this empirical study, which covers 35 city markets located in 31 provinces in China. Thus, to obtain more robust results, this study uses six panel unit root tests to determine whether the panel dataset is stationary. In addition, three other panel unit root tests: Breitung, Fisher ADF, and Fisher PP are considered. The null hypothesis for LLC and Breitung is a common unit root process; for IPS, Fisher ADF and Fisher PP individual unit root processes are assumed and for Hadri stationarity is the null. Conclusions may (and do) vary in the main because of varying assumptions and restrictions made when testing the underlying data set whose true properties are unknown. We will attempt to explain inconsistencies as and when they arise.

Using these panel unit root tests, we proceed to test for cointegration in the data. Using the heterogeneous panel cointegration test developed by Pedroni (1999) allows for cross-sectional interdependence with different individual effects. If the panel data follow an I(1) series, the Pedroni (1999 and 2004) panel cointegration model is applied to find whether a cointegratiing relationship exists. Pedroni (1999) suggests the following time series panel expression:

(4-5) $y_{it} = \alpha_{it} + \gamma_{it} t + X_i \beta_i + e_{it}$

Where y_{it} and X_{it} are the observable variables with dimension of $(N*T)\times 1$ and $(N*T)\times m$, respectively. He develops asymptotic and finite-sample properties of test statistics to examine the null hypothesis of non-cointegration in a panel. The tests allow for heterogeneity among individual member of panel, including heterogeneity in both the long-run cointegration vectors and in the dynamics, for there is no reason to believe that all parameters are the same across cities.

There are two types of residual-based tests (Pedroni, 1999). The first type is distributed as being standard Normal asymptotically and is based on pooling the residuals of the regression for the within-group. It includes the panel υ-statistic, panel ρ-statistic, panel PP-statistic (or t-statistic, non-parametric) and the panel ADF-statistic (or t-statistic, parametric). The second type is also distributed as standard Normal asymptotically, but is based on pooling the residuals for the between-group. It includes the group ρ-statistic, group PP-statistic (or t-statistic, non-parametric) and the group ADF-statistic (or t-statistic, parametric). Pedroni (1999) presents the following the heterogeneous panel cointegration statistics:

Panel υ-statistic:

$$(4\text{-}6)\quad Z_{\hat{\upsilon}} = (\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{e}_{it-1}^{2})$$

Panel ρ-statistic:

$$(4\text{-}7)\quad Z_{\hat{\rho}} = (\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{e}_{it-1}^{2})^{-1}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_{i})$$

Panel t-statistic (non-parametric):

$$(4\text{-}8)\quad Z_{t} = (\hat{\sigma}^{2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{e}_{it-1}^{2})^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_{i})$$

Panel t-statistic (parametric):

$$(4\text{-}9)\quad Z_{t}^{*} = (\hat{s}^{*2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{e}^{*2}_{it-1})^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\hat{e}^{*}_{it-1}\Delta\hat{e}^{*}_{it}$$

and the following heterogeneous group-mean panel cointegration statistics:

Group ρ-statistic:

$$(4\text{-}10)\quad \widetilde{Z}_{\hat{\rho}} = \sum_{i=1}^{N}(\sum_{t=1}^{T}\hat{e}_{it-1}^{2})^{-1}\sum_{t=1}^{T}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_{i})$$

Group t-statistic (non-parametric):

$$(4\text{-}11)\quad \widetilde{Z}_{t} = \sum_{i=1}^{N}(\hat{\sigma}_{i}^{2}\sum_{t=1}^{T}\hat{e}_{it-1}^{2})^{-1/2}\sum_{t=1}^{T}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_{i})$$

Group t-statistic (parametric):

$$(4\text{-}12)\quad \widetilde{Z}_{t}^{*} = \sum_{i=1}^{N}(\sum_{t=1}^{T}\hat{s}_{i}^{2}\hat{e}_{it-1}^{*2})^{-1/2}\sum_{t=1}^{T}(\hat{e}_{it-1}^{*}\Delta\hat{e}_{it}^{*})$$

Where $\hat{e}_{it}$ is the estimated residual from equation (4-5) above and $\hat{L}_{11i}^{-2}$ is the estimated long-run covariance matrix for $\hat{e}_{it}$. Similarly, $\hat{\sigma}_{i}^{2}$ and $\hat{s}_{i}^{2}$ ($\hat{s}_{i}^{*2}$) are, respectively, the long-run and contemporaneous variances for individual i. The other terms are defined in Pedroni (1999) with the appropriate lag length determined by the Newey-West method. All seven tests are distributed as standard Normal asymptotically. This requires the standardization based on the moments of the underlying Brownian motion function. The panel υ-statistic is one-sided test where large positive values reject the null of no cointegration. The remaining statistics diverge to negative infinitely, which means that large negative values reject the null. The critical values are tabulated in Pedroni (1999).

The statistics above are based on estimators that simply average the individually estimated coefficients for each member, and each of these tests is able to accommodate individual specific short-run dynamics, individual specific fixed effects and deterministic trends, as well as individual specific slope coefficients (Pedroni, 2004). The number of observations available is greatly increased in a panel framework and this can substantially increase the power of the cointegration tests (Rapach andWohar, 2004).

It is easy to form a conclusion if all seven tests reject the null of no cointegration. It is, unfortunately, not always the case that all of them reject the null hypothesis simultaneously. Under this circumstance, therefore, we need to decide which version of the available tests has the greatest power for the panel cointegartion tests. As discussed in Pedroni (2004), in terms of monthly data, with little more than 20 years of data it may be possible to distinguish even the most extreme cases from the null of no cointegration when the data are pooled across members of panels with these dimensions. This condition appears to have been met in our case since we have 36 observations each year or 3 observations each month. Furthermore, if the panel is fairly large so that size distortion is less of an issue, the panel υ-statistic tends to have the best power relative to the other statistics and can be most useful when the alternative is potentially very close to the null. In very small panels, however, if the group-rho statistic rejects the null of no cointegration, we can be relatively confident of the conclusion because it is slightly undersized and empirically the most conservative of the tests. The other statistics tend to lie somewhere in between these two extremes and have minor comparative advantages over different ranges of the sample size. In this study, we choose the panel-υ statistic as the basic panel cointegration test. In other words, even other tests reject the null of no cointegration, we will still accept the null if the panel-υ statistic does so.

Finally, the ADF test statistics are biased toward the non-rejection of a unit root when there are structural breaks in the data (Nelson and Plosser, 1982; Perron, 1989; Enders, 1995). Thus, testing for the presence of structural breaks is necessary. Moreover, energy economic reforms have been carried out since the early 1990s. Therefore, energy reform could likely produce some structural changes of price series.

4.3 The second order translog cost function

The set of methods used to address the second issue which considers technological change, substitution, demand and their effects on energy intensity uses a translog cost function to model energy demand (Cho, et al., 2004; Berndt and Wood, 1979;

Debertin, et al., 1990; Christopoulos and Tsionas, 2002; Welsch and Ochsen, 2005). The translog cost function is a convenient specification of duality theory and as a second order approximation it allows one to avoid the need to specify a particular production function (Stratopoulos et al., 2000). In addition, it avoids the necessity of assuming constant or equal elasticities of substitution (Woodland, 1975).

In this study, we model how a change in an individual fuel price affects fuel consumption through the feedback effect between inter-fuel and inter-factor substitution, assuming that the production function is weakly separable in its major components of energy, capital and labor.[17] This assumption allows us to construct an aggregate energy-price index from fuel prices. We can then assume that energy, capital and labor are homothetic in their components so that we can specify a homothetic fuel cost share equation. Thus, a second-order approximation of cost as a function of time, the logged input price and log output is used for the non-homothetic translog total factor cost function:

$$(4\text{-}14)\quad \ln C = \beta_0 + \sum_{i=1}^{m} \beta_i \ln P_{it} + 0.5 \sum_{i=1}^{m} \sum_{j=1}^{m} \beta_{ij} \ln P_{it} \ln P_{jt} + \beta_t t + 0.5 \beta_{tt} t^2$$
$$+ \beta_y \ln Y_t + 0.5 \beta_{yy} (\ln Y_t)^2 + \sum_{i=1}^{m} \beta_{iy} \ln P_{it} \ln Y_t + \sum_{i=1}^{m} \beta_{it} t \ln P_{it} + \beta_{yt} t \ln Y_t$$

where ln indicates the natural logarithm; C is the equilibrium total cost; P_{jt} (P_{it}) denotes the price of input factor *j* (*i*) at time *T; Y_t* is the level of output in period *T; t* denotes a time trend to capture technical change (Welsch and Ochsen, 2005).[18] With the proper set of restrictions on its parameters, equation (4-14) can therefore be used

[17] The analysis in the paper excludes material inputs due to the general lack of available Chinese data. Material inputs are also excluded in the work of Caloghirou et al. (1997) and Cho et al. (2004) for the same reason.
[18] To test whether the total factor cost equation (1) is the final function form used in this study, we have also estimated various its nested models based on various assumptions (available by request).

to approximate any of the unknown cost and production functions. The symmetry restrictions are:

(4-15) $\beta_{ij} = \beta_{ji} \quad for\, all\ i \neq j$

which implies equality of the cross-derivatives. Linear homogeneity in prices requires the following regularity conditions:

(4-16) $\sum_{i=1}^{m}\beta_i = 1, \sum_{j=1}^{m}\beta_{ij} = 0, \sum_{i=1}^{m}\beta_{iy} = 0, \sum_{i=1}^{m}\beta_{it} = 0,\ i, j = 1, \cdots, m$

By Shephard's lemma, a firm's system of cost minimizing demand functions (the conditional factor demands) can be obtained by differentiating equation (4-14) with respect to input prices to obtain the following system of factor share equations:

(4-17) $S_{factor} = \beta_i + \sum_{j=1}^{m}\beta_{ij} \ln P_{jt} + \beta_{iy} \ln Y_t + \beta_{it} t$

with *i,j*=K, L and E (for capital, labor and energy, respectively).

4.4 Aggregate energy price index

The homothetic translog aggregate energy price index function is given by:

(4-18) $\ln P_E = \gamma_0 + \sum_{i=1}^{n}\gamma_i \ln P_{it} + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij} \ln P_{it} \ln P_{jt} + \sum_{i=1}^{n}\gamma_{it} t \ln P_{it}$

where ln indicates the natural logarithm; P_E is the aggregated energy price; P_{jt} (P_{it}) denotes the price of fuel *j* (*i*) at time *T;* γ's are the parameters to be estimated. An aggregate energy price index is also constructed for each of seven regions where we grouped China's 31 provinces into regions according to the characteristics of energy production and consumption, location and level of aggregate economy.[19]

[19] Region 1 includes Hebei, Shanxi, Anhui, Shandong and Henan; region 2 includes Beijing, Tianjin, and Shanghai; region 3 includes Liaoning, Jilin and Heilongjiang; region 4 includes Jiangsu, Zhejiang, Jiangxi and Hubei; region 5 includes Fujian, Hunan, Guangdong, Guangxi and Hainan; region 6 includes Chongqing, Sichuan, Shaanxi, Gansu, Guizhou and Yunnan; region 7 includes Inner Mongolia, Tibet (deleted due to incomplete data), Qinghai,

By differentiating equation (4-18) with respect to individual fuel price, we have the following fuel share equations:

(4-19) $S_{fuel} = \gamma_i + \sum_{j=1}^{n} \gamma_j \ln P_{jt} + \gamma_{it} t$

with *i,j*=CO, EL, GA and DI for coal, electricity, gasoline and diesel, respectively.[20]

Following a two-stage approach suggested by Pindyck (1979), we can first estimate the homothetic translog fuel cost share equation (4-19) assuming constant returns to scale. The resulting parameter estimates yield the partial own- and cross-price elasticities of the fuel sources. The fitted fuel cost ($\hat{P}_E$) is computed based on equation (4-18) using the estimated parameters of equation (4-19) and serves as an instrumental variable for the aggregate price of energy (P_E). We then estimate the non-homothetic translog factor cost function (equation (4-14)) and factor share equation (4-17) simultaneously with the relevant restrictions imposed (see equation (4-15) and equation (4-16)).

4.5 Elasticities of substitution and demand

To better understand the relations between factors, we can estimate their elasticities of substitution. Uzawa (1962) derives the Allen partial elasticities of substitution (AES) between input *i* and *j* as: $\sigma_{ij} = C * C_{ij} / C_i * C_j$, where $C_i = \partial C / \partial P_i$ and $C_{ij} = \partial^2 C / \partial P_i \partial P_j$. By definition, $\sigma_{ij} = \sigma_{ji}$. With a translog cost function, the AES are:

(4-20) $\sigma_{ij} = 1 + \beta_{ij} / S_i S_j \quad \forall\, i \neq j \quad and \quad \sigma_{ii} = (\beta_{ii} + S_i^2 - S_i) / S_i^2$

Ningxia and Xinjiang.

[20] Similarly, to test whether equation (6) is the final function form used in this study, we have also estimated various nested models based on a range of assumptions (available by request).

These AES are not constrained to be constant, but may vary with the values of the cost shares. The price elasticity of demand for factors of production (η_{ij}) is conventionally defined as $\eta_{ij} = \partial \ln X_i / \partial \ln P_j$, where output (Y) and other input prices are fixed. Hence, although $\sigma_{ij} = \sigma_{ji}$, in general, $\eta_{ij} \neq \eta_{ji}$. Allen (1938) has shown that the AES are analytically related to the price elasticities of demand for factors of production:

(4-21) $\eta_{ij} = \sigma_{ij} S_j \quad \forall\, i \neq j \quad for\ i, j = K, L, E$

where S_i is the cost share of *i*th factor. A positive σ_{ij} between factors *i* and *j* indicates that they are substitutes, while a negative σ_{ij} implies that the factors *i* and *j* are complementary. Similarly, the Allen partial elasticities of substitution (σ_{ij}) between fuels and conditional own-price elasticities (η_{ii}) and conditional cross-price elasticities (η_{ij}) of fuel demand can be estimated by equation (4-20) and equation (4-21) using the estimated parameters from equation (4-19).

The idea of the elasticity of substitution was originally introduced by Hicks (1932) for the purpose of analyzing changes in the income shares of labor and capital in a growing economy. His key insight was to note that the effect of changes in the capital/labor ratio (or the factor price ratio) on the distribution of income (for a given output) can be completely characterized by a scalar measure of curvature of the isoquant. This measure is the two-variable elasticity of substitution (Blackorby and Russell, 1989). Allen and Hicks (1934) suggested two generalizations of the original elasticity concept to the case of more than two inputs. One of the generalizations suggested by Allen and Hicks, and thoroughly investigated by Allen (1938) and

Uzawa (1962), was an attempt to rectify this inadequacy. This concept was called the 'partial elasticity of substitution', but little intuition was provided to convince one that it is a natural generalization of the two-variable elasticity of substitution. Nevertheless, for many years this concept, now called Allen/Uzawa elasticity (AES), has become the standard statistic reported in empirical studies of production and consumption (Blackorby and Russell, 1989). Toevs (1982) discussed approximate variance formulas for the elasticities of substitution obtained from translog cost functions and Berndt and Wood (1975) used empirical AES to consider the USA's technology, price and the derived demand for energy.

Likewise, total own- and cross-price elasticities of fuel demand can be estimated as follows (Pindyck, 1979; Cho et al., 2004):

(4-22) $\eta_{ii}^{*} = \eta_{ii} + \eta_{EE} S_i \;\; and \;\; \eta_{ij}^{*} = \eta_{ij} + \eta_{EE} S_j \quad for\ i,\ j = CO, EL, GA, DI$

where S_i is the cost share of *i*th fuel source in total energy input and η_{EE} is the own-price elasticity of aggregate energy use from equation (4-21). Total own- and cross-price elasticities of fuel demand actually reflect both the effect of a price change under a given level of aggregate energy consumption (the terms η_{ii} and η_{ij} in equation (4-22)) without considering the effect of changes in aggregate energy consumption, and the feedback effect between the inter-factor and inter-fuel substitution resulting from an individual fuel price change (the terms $\eta_{EE} S_i$ and $\eta_{EE} S_j$ in equation (4-9)) between the inter-factor and inter-fuel substitution resulting from an individual fuel price change (see Cho et al., 2004 for detail).

4.6 Assumptions for regional dummy variables

We assume that all parameters, except for the factor price interaction terms, to be estimated vary across regions as a linear function of regional dummy variables in equation (4-14) and that all of parameters, except for the terms of fuel prices, to be estimated vary across regions and are a linear function of regional dummy variables in equation (4-19).[21] To apply these assumptions, we define the parameters as a linear function of regional dummy variables (D_R). They are in equation (4-14):

(4-23) $\beta_0 = \beta_{00} + \sum \beta_{0R} D_R$

(4-24) $\beta_i = \beta_{i0} + \sum \beta_{iR} D_R$

(4-25) $\beta_t = \beta_{t0} + \sum \beta_{tR} D_R$

(4-26) $\beta_{tt} = \beta_{tt0} + \sum \beta_{ttR} D_R$

(4-27) $\beta_y = \beta_{y0} + \sum \beta_{yR} D_R$

(4-28) $\beta_{yy} = \beta_{yy0} + \sum \beta_{yyR} D_R$

(4-29) $\beta_{iy} = \beta_{iy0} + \sum \beta_{iyR} D_R$

(4-30) $\beta_{it} = \beta_{it0} + \sum \beta_{itR} D_R$

(4-31) $\beta_{yt} = \beta_{yt0} + \sum \beta_{ytR} D_R$

And in Equation (4-19):

(4-32) $\gamma_i = \gamma_{i0} + \sum \gamma_{iR} D_R$

(4-33) $\gamma_{it} = \gamma_{it0} + \sum \gamma_{itR} D_R$

Using the assumptions above, equations (4-23)-(4-31), the final form of equation (4-14) can now be expressed as:

[21] It is expected that the terms of fuel prices in equation (6) vary across regions, but when we estimated this system of general fuel share equations, the results are not convergent and thus, empirically we had to drop this assumption.

$$(4-34) \quad \ln TC = (\beta_{00} + \sum \beta_{0R} D_R) + \sum_{i=1}^{m} (\beta_{i0} + \sum \beta_{iR} D_R) \ln P_{it}$$
$$+ \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \beta_{ij} \ln P_{it} \ln P_{jt} + (\beta_{t0} + \sum \beta_{tR} D_R) t$$
$$+ \frac{1}{2} (\beta_{tt0} + \sum \beta_{ttR} D_R) t^2 + (\beta_{y0} + \sum \beta_{yR} D_R) \ln Y_t$$
$$+ \frac{1}{2} (\beta_{yy0} + \sum \beta_{yyR} D_R)(\ln Y_t)^2 + \sum_{i=1}^{m} (\beta_{iy0} + \sum \beta_{iyR} D_R) \ln P_{it} \ln Y_t$$
$$+ \sum_{i=1}^{m} (\beta_{it0} + \sum \beta_{itR} D_R) t \ln P_{it} + (\beta_{yt0} + \sum \beta_{ytR} D_R) t \ln Y_t$$

Similarly, the final of equation (4-6) can be expressed as:

$$(4-35) \quad S_{fuel} = (\gamma_{i0} + \sum \gamma_{iR} D_R) + \sum_{j=1}^{n} \gamma_j \ln P_{jt} + (\gamma_{it0} + \sum \gamma_{itR} D_R) t$$

4.7 Estimation procedure

The final functional forms to be estimated, therefore, are equation (4-34) and equation (4-35). The sequence of estimation and testing proceeds as follows. Using the iterative Zellner's seemingly unrelated regression technique, we first estimate the system of translog fuel cost share equation (4-35). The aggregate energy price index (P_E) is generated using equation (4-18) and the parameters estimated from equation (4-19) at this stage. The parameter γ_0 in equation (4-18) is determined so that $P_E = 1$ in 1995. The next stage involves equation (4-34) and equation (4-35), which are estimated simultaneously using the same iterative Zellner regression technique, imposing the symmetry and homogeneity restrictions, (equation (4-15) and equation (4-16)), and dropping the labor share equation as parameters for this equation can be determined using the 'adding up' restrictions.

4.8 Model specification tests

To test whether equation (4-34) and equation (4-35) should be considered the final functional forms, prices are of separable, consumption behavior vary across regions, there is potential technological change, we estimate the following nested functional forms against equation (4-34):

$$(4\text{-}36)\quad \ln TC = (\beta_{00} + \sum \beta_{0R} D_R) + \sum_{i=1}^{m} (\beta_{i0} + \sum \beta_{iR} D_R) \ln P_{it} + \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \beta_{ij} \ln P_{it} \ln P_{jt} + (\beta_{t0} + \sum \beta_{tR} D_R) t + \frac{1}{2} (\beta_{tt0} + \sum \beta_{ttR} D_R) t^2 + (\beta_{y0} + \sum \beta_{yR} D_R) \ln Y_t + \frac{1}{2} (\beta_{yy0} + \sum \beta_{yyR} D_R)(\ln Y_t)^2 + \sum_{i=1}^{m} (\beta_{iy0} + \sum \beta_{iyR} D_R) \ln P_{it} \ln Y_t + (\beta_{yt0} + \sum \beta_{ytR} D_R) t \ln Y_t$$

$$(4\text{-}37)\quad \ln TC = (\beta_{00} + \sum \beta_{0R} D_R) + \sum_{i=1}^{m} (\beta_{i0} + \sum \beta_{iR} D_R) \ln P_{it} + \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \beta_{ij} \ln P_{it} \ln P_{jt} + (\beta_{t0} + \sum \beta_{tR} D_R) t + \frac{1}{2} (\beta_{tt0} + \sum \beta_{ttR} D_R) t^2 + (\beta_{y0} + \sum \beta_{yR} D_R) \ln Y_t + \frac{1}{2} (\beta_{yy0} + \sum \beta_{yyR} D_R)(\ln Y_t)^2 + \sum_{i=1}^{m} (\beta_{iy0} + \sum \beta_{iyR} D_R) \ln P_{it} \ln Y_t + \sum_{i=1}^{m} \beta_{it0} t \ln P_{it} + (\beta_{yt0} + \sum \beta_{ytR} D_R) t \ln Y_t$$

$$(4\text{-}38)\quad \ln TC = (\beta_{00} + \sum \beta_{0R} D_R) + \sum_{i=1}^{m} (\beta_{i0} + \sum \beta_{iR} D_R) \ln P_{it} + (\beta_{t0} + \sum \beta_{tR} D_R) t + \frac{1}{2} (\beta_{tt0} + \sum \beta_{ttR} D_R) t^2 + (\beta_{y0} + \sum \beta_{yR} D_R) \ln Y_t + \frac{1}{2} (\beta_{yy0} + \sum \beta_{yyR} D_R)(\ln Y_t)^2 + \sum_{i=1}^{m} (\beta_{iy0} + \sum \beta_{iyR} D_R) \ln P_{it} \ln Y_t + \sum_{i=1}^{m} (\beta_{it0} + \sum \beta_{itR} D_R) t \ln P_{it} + (\beta_{yt0} + \sum \beta_{ytR} D_R) t \ln Y_t$$

$$(4\text{-}39)\quad \ln TC = (\beta_{00} + \sum \beta_{0R} D_R) + \sum_{i=1}^{m} (\beta_{i0} + \sum \beta_{iR} D_R) \ln P_{it}$$
$$+ \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \beta_{ij} \ln P_{it} \ln P_{jt} + (\beta_{t0} + \sum \beta_{tR} D_R) t$$
$$+ \frac{1}{2} (\beta_{tt0} + \sum \beta_{ttR} D_R) t^2 + \beta_{y0} \ln Y_t + \frac{1}{2} \beta_{yy0} (\ln Y_t)^2 + \sum_{i=1}^{m} (\beta_{iy0}$$
$$+ \sum \beta_{iyR} D_R) \ln P_{it} \ln Y_t + \sum_{i=1}^{m} (\beta_{it0} + \sum \beta_{itR} D_R) t \ln P_{it}$$
$$+ (\beta_{yt0} + \sum \beta_{ytR} D_R) t \ln Y_t$$

$$(4\text{-}40)\quad \ln TC = (\beta_{00} + \sum \beta_{0R} D_R) + \sum_{i=1}^{m} (\beta_{i0} + \sum \beta_{iR} D_R) \ln P_{it}$$
$$+ \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \beta_{ij} \ln P_{it} \ln P_{jt} + \beta_{t0} t + \frac{1}{2} \beta_{tt0} t^2 + (\beta_{y0} + \sum \beta_{yR} D_R) \ln Y_t$$
$$+ \frac{1}{2} (\beta_{yy0} + \sum \beta_{yyR} D_R) (\ln Y_t)^2 + \sum_{i=1}^{m} (\beta_{iy0} + \sum \beta_{iyR} D_R) \ln P_{it} \ln Y_t$$
$$+ \sum_{i=1}^{m} (\beta_{it0} + \sum \beta_{itR} D_R) t \ln P_{it} + (\beta_{yt0} + \sum \beta_{ytR} D_R) t \ln Y_t$$

$$(4\text{-}41)\quad \ln TC = (\beta_{00} + \sum \beta_{0R} D_R) + \sum_{i=1}^{m} (\beta_{i0} + \sum \beta_{iR} D_R) \ln P_{it}$$
$$+ \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \beta_{ij} \ln P_{it} \ln P_{jt} + (\beta_{t0} + \sum \beta_{tR} D_R) t + \frac{1}{2} (\beta_{tt0} + \sum \beta_{ttR} D_R) t^2$$
$$+ (\beta_{y0} + \sum \beta_{yR} D_R) \ln Y_t + \frac{1}{2} (\beta_{yy0} + \sum \beta_{yyR} D_R) (\ln Y_t)^2 + \sum_{i=1}^{m} (\beta_{iy0}$$
$$+ \sum \beta_{iyR} D_R) \ln P_{it} \ln Y_t + \sum_{i=1}^{m} (\beta_{it0} + \sum \beta_{itR} D_R) t \ln P_{it} + \beta_{yt0} t \ln Y_t$$

$$(4\text{-}42)\quad \ln TC = \beta_{00} + \sum_{i=1}^{m} (\beta_{i0} + \sum \beta_{iR} D_R) \ln P_{it} + \frac{1}{2} \sum_{i=1}^{m} \sum_{j=1}^{m} \beta_{ij} \ln P_{it} \ln P_{jt}$$
$$+ (\beta_{t0} + \sum \beta_{tR} D_R) t + \frac{1}{2} (\beta_{tt0} + \sum \beta_{ttR} D_R) t^2 + (\beta_{y0} + \sum \beta_{yR} D_R) \ln Y_t$$
$$+ \frac{1}{2} (\beta_{yy0} + \sum \beta_{yyR} D_R) (\ln Y_t)^2 + \sum_{i=1}^{m} (\beta_{iy0} + \sum \beta_{iyR} D_R) \ln P_{it} \ln Y_t$$
$$+ \sum_{i=1}^{m} (\beta_{it0} + \sum \beta_{itR} D_R) t \ln P_{it} + (\beta_{yt0} + \sum \beta_{ytR} D_R) t \ln Y_t$$

And the nested functional forms against equation (4-35):

$$(4\text{-}43)\quad S_{fuel} = \gamma_{i0} + \sum_{j=1}^{n} \gamma_j \ln P_{jt} + (\gamma_{it0} + \sum \gamma_{itR} D_R) t$$

$$(4\text{-}44)\quad S_{fuel} = (\gamma_{i0} + \sum \gamma_{iR} D_R) + \sum_{j=1}^{n} \gamma_j \ln P_{jt}$$

$$(4\text{-}45)\quad S_{fuel} = (\gamma_{i0} + \sum \gamma_{iR} D_R) + \sum_{j=1}^{n} \gamma_j \ln P_{jt} + \gamma_{it0} t$$

(4-46) $S_{fuel} = (\gamma_{i0} + \sum \gamma_{iR} D_R) + (\gamma_{it0} + \sum \gamma_{itR} D_R)t$

4.9 Decomposition of energy intensity

To attribute changes in energy intensity (e) to various driving forces, such as factor substitution and technological change, one can observe that $e = E/Q = (P_Q / P_E)S_E$ (Welsch and Ochsen, 2005), where P_Q is the output price, P_E is aggregate energy price, and S_E is aggregate energy factor share in total factor cost function. Following Welsch and Ochsen (2005), we decompose the energy intensity using the estimated parameters of the aggregate energy share equation:

$$
\begin{aligned}
(4\text{-}47) \quad \hat{e} &= E/Q = (P_Q / P_E)S_E \\
&= (P_Q / P_E)(\hat{\beta}_E + \hat{\beta}_{EE} \ln P_E + \hat{\beta}_{EK} \ln P_K + \hat{\beta}_{EL} \ln P_L + \hat{\beta}_{iy} \ln Y + \hat{\beta}_{Et} t) \\
&= [\frac{P_Q}{P_E} \hat{\beta}_E] + [\frac{P_Q}{P_E} \hat{\beta}_{EE} \ln P_E] + [\frac{P_Q}{P_E} \hat{\beta}_{EK} \ln P_K] + [\frac{P_Q}{P_E} \hat{\beta}_{EL} \ln P_L] \\
&\quad + [\frac{P_Q}{P_E} \hat{\beta}_{iy} \ln Y] + [\frac{P_Q}{P_E} \hat{\beta}_{Et} t]
\end{aligned}
$$

where $\hat{\beta}$'s are the estimates of β's. Energy intensity is decomposed into the six terms in square brackets on the right hand side of equation (4-47), denoted by $\hat{e}_0, \hat{e}_1, \hat{e}_2, \hat{e}_3, \hat{e}_4, \hat{e}_5$, respectively. The terms, $\hat{e}_1, \hat{e}_2, \hat{e}_3$, which include input price and associated substitution parameters, represent the contribution of factor substitution to the variation in energy intensity. The term $\hat{e}_4$ measures the effect of the change in output on energy intensity. Since the coefficient on the time trend, $\hat{\beta}_{Et}$ in equation (4-14), is meant to capture the effect of technological change on energy share change, the term $\hat{e}_5$ similarly measures the effect of technological change on energy intensity (under the assumption that such change can be represented by time).[22]

Recall the interpretation of $\hat{\beta}_E$ as the autonomous energy cost share (the first term of equation (4-14)), the variation in $\hat{e}_0 = [P_Q / P_E * \hat{\beta}_E]$ hence measures how price changes contribute to changes in energy intensity at a given cost share. In other words, what is the maximum reduction in energy intensity (or energy consumption) users can afford to bear if energy prices increase? This concept reflects the relationship between energy price and economic growth, which suggests that rising energy prices reduce economic growth. In addition, as the prices of output change, this term also reflects the effect of the marginal output (P_Q / P_E) of energy input on energy intensity. The term is the absolute effect of energy price changes on energy intensity. It may thus be called the budget effect of energy price changes on energy intensity (Welsch and Ochsen, 2005). The straightforward way of allocating changes in energy intensity to these various driving forces mentioned above can be expressed by:

[22] The time trend could also be capturing shifts in the structure of the economy over time which we cannot separate from the effects of technological change (e.g., a growth in less energy intensive industries and fall in more energy intensive industries) over time. However, it should be noted that the economy is measured in monetary terms, and it may not reflect trends in real physical production if sectoral prices do not rise at the same rate. For example, from 1996-2006, agricultural production increased by 44%, while industry production increased by 173%. However, correspondingly, the agricultural GDP share dramatically declined from 20.4% to 10.7% (share reduced by 90%), but the industry GDP share only increased from 40.6% to 44.4% during the same period (share only increased by 9%). Similarly, from 1996-2006, the service sector increased by 130-180%, however, correspondingly, its GDP share only increased from 17.4% to 25.4% during the same period (share only increased by 45%). This means price deflation for agricultural commodities might play an important role in measuring its GDP share. In addition, it is found that some sectoral shares declined, as did their shares of energy consumption (e.g., agricultural sector). Some sectoral shares declined, but their shares of energy consumption increased (e.g., transportation sector). This means that structural shifts might not produce a significant effect on the changing direction of aggregate energy intensity.

(4-48) $\Delta\hat{e} / \hat{e} = \sum_{i=0}^{5} (\Delta\hat{e}_i / \hat{e}_i)(\hat{e}_i / \hat{e})$

where $\Delta\hat{e}_i / \hat{e}_i$ and $\hat{e}_i / \hat{e}$ denote relative changes over time, and $\hat{e}$ and $\hat{e}_i$ indicate the base year level of energy intensity. The terms on the right hand side can have either positive or negative signs, showing whether that particular driver has reduced (negative sign) or enhanced (positive sign) energy intensity. The measures calculated from equation (4-48) provide a richer analysis of changing energy intensity than is possible with the more aggregate calculations used to date for China.

Chapter Five: Data and Description

This Chapter is organized as follows: Section 1 discusses why the particular data used in empirical research matter when studying China's energy economy. Sections 2-5 introduces the data sets used in this study and variable construction in the following order: energy prices, energy consumption, factor inputs, output and deflator. Section 6 presents cost series construction for total factor cost series (including capital, labour and aggregate energy) and total energy cost series (including coal, electricity, gasoline and diesel). In addition, descriptive statistics, including min, max, mean and standard deviation, are provided for each data set and panels.

5.1 The importance of data

Data are crucial for this study, especially for robust estimates of substitution elasticities of and demand for factors in China's energy economy. According to the survey of literature presented earlier, I found few papers which focused on econometric estimates on this topic. Some did conduct econometric estimation of elasticites substitution of energy and non-energy, but they used only aggregate time series data. One of the most important reasons I believe that China's energy economy has not extensively studied econometrically relates to previously used data constraints. Most who have researched China's energy sector have not had access the data used in this study. Therefore, it is important and necessary to introduce my new datasets clearly and completely.

This study has made three major empirical contributions in terms of energy data analysis. Firstly, this study is the first to intensively use energy price data to demonstrate the emergence of energy markets as the regulatory system and pricing mechanisms have changed in China. Secondly, this study is the first to apply a panel data set of energy prices econometrically to estimate the elasticities of substitution between energy and non-energy and demand for energy for both aggregate economy and industrial economy across region and province in China. Thirdly, this study is unique in using energy prices and consumption across regions and across industries to construct a three-factor standard cost function for both the aggregate economy and the industrial economy for China.

5.2 Energy prices

The data used in this empirical study are a panel data set of 10-day prices for four energy types in 35 major Chinese cities.[23] The data used in this study are spot prices and are regularly collected on a ten-day interval (the 5th, 15th and 25th of each month) from local markets by governmental agencies.[24]

[23] The cities are Beijing, Tianjin, Shijiazhuang, Taiyuan, Hohhot, Shenyang, Changchun, Harbin, Shanghai, Nanjing, Hangzhou, Hefei, Fuzhou, Nanchang, Jinan, Zhengzhou, Wuhan, Changsha, Guangzhou, Nanning, Haikou, Chongqing, Chengdu, Guiyang, Kunming, Lhasa, Xi'an, Lanzhou, Xining, Yinchuan, Urumqi, Qingdao, Dalian, Xiamen and Ningbo. They include four municipalities, all the capital cities for the 31 provinces and autonomous regions and other four major cities in mainland China.

[24] The price data are collected to provide price information to the central and local governments for macroeconomic management. According to state law, the local price bureaus are obligated to report price information for a specified list of products to the Price Monitoring Centre. The price information must be collected from fixed local markets. The fuel price information is collected three times a month, on the 5th, the 15th and the 25th day of the month. The fuel names are homogeneous across all cities, and all prices must be market prices.

Unlike other market price data, fuel price data have no missing observations during the study period as fuels are extensively used in all cities. We use four major fuel types; coal, electricity, gasoline and diesel. These panel data are truly nationally representative as they cover the main fuel components, all provincial capital cities of mainland China, and the period, 1995 to 2005. This is to be contrasted with most other empirical studies, which use a price index of lower frequency (typically annual) data. The 10-day frequency of our price data also corresponds well to the time needed for domestic price arbitrage as a lower frequency (monthly) price data are not as useful when we wish to test for price convergence with any degree of precision or sophistication (Taylor, 2001). Furthermore, monthly spot prices are not as rich a data source as 10-day spot prices, particularly if one wants to measure the half-life of subsequent adjustment following the shorter time response (Bachmeier and Griffin, 2006).

Energy price data are obtained from the Price Monitoring Centre (PMC), a division of the State Development and Reform Commission of China (SDRC). There are 5000 monitoring sites over 150 medium and large cities and over 280 counties all over the country. The price database covers consumer goods, various fuels, production factors, cash crops, food grains, medicines, vehicles, and real estate, etc, approximate several thousand of commodities. The price data are categorized into daily, 10-day interval, fortnightly, monthly and yearly. The PMC collects fuel prices from 150 medium and large city price bureaus nationwide. The price data collection covers coal, electricity, natural gas, crude oil, gasoline, diesel, kerosene, fuel oil and rural diesel and electricity. However, here we use only data for coal, electricity, gasoline and diesel consumed by industries as they are the four most important fuels and their consumption data are also available and complete. For this study, when we aggregate the 10-day interval data into annual price series we do so by taking the mean of the 36 periods each year.

The quality of Chinese data are often criticised as reporting in China is often affected by political factors (Rawski, 2001). However, we believe that the data for specific product prices collected by local government agencies under strict government mandates are less likely to be subject to manipulation. Central government requires the collection of prices for specific products at fixed dates and locations and these price data are also available to the public so that local officials would find it hard to report false data. Unlike macro-economic data (such as GDP growth and employment rates), these micro data for prices could hardly serve as indicators when assessing the performance of local officials and hence local officials have little incentive to falsify them.

Descriptive statistics of energy spot prices for 35 city markets are displayed in Table 5-1 to Table 5-4 for coal, electricity, gasoline and diesel, respectively. It can be seen that the energy prices vary and have a large range from min to max. For example, at the national average, the min and max are ¥203 and ¥458/ton for coal, respectively (Table 5-1); the min and max are ¥344 and ¥590/1000 KWh for electricity, respectively (Table 5-2); the min and max are ¥2491 and ¥5798/ton for gasoline, respectively (Table 5-3); and the min and max are ¥2173 and ¥4780/ton for diesel, respectively (Table 5-4). The same can be found for each city market.

5.3 Energy consumption

When energy consumption is used as a factor input, some energy can be used both for intermediate inputs and for final user consumption. To avoid double counting I do not count both coal that is used to produce electricity and electricity that is used by power plants. Instead, I define energy consumption in this study as final user energy consumption, which is disaggregated by five industries (e.g., agriculture, industry, construction, transportation, commerce, and other industry) according to the definitions of the China Statistical Yearbook (CSY).

Energy consumption data come from *China Energy Statistical Yearbook* (CESY). The CESY, published by China Statistical Publisher each year since the early 1990s, provides rich statistical data for China's energy consumption by industry/sector, by province and by fuel type. The energy consumption data cover a variety of indicators. In detail, the CESY covers six chapters (which are general survey, construction of energy industry, energy production, energy balance sheets of China, energy consumption, energy balance sheets by region, and energy data for Hong Kong and Macao Special Administrative Region) and four appendices (which are energy data for Taiwan province, energy data for related countries or areas, explanatory notes of main statistical indicators, and conversion factors from physical units to coal equivalent). The CESY has not been extensively used to study China's energy economy, especially to estimate cost function. Here we only use energy consumption data by region and by fuel, and for aggregate economy and industrial economy.

The descriptive statistics of aggregate energy consumption for 31 provinces (autonomous regions or municipalities) are presented in Tables 5-5 to Table 5-8. It can be seen that the aggregate energy consumption data also change apparently and have a big range from min to max. For example, at the national average, the min and max are 632.9 and 795.8 million ton for coal, respectively (Table 5-5); the min and max are 960.9 and 2063.3 billion KWh for electricity, respectively (Table 5-6); the min and max are 27.5 and 49.2 million ton for gasoline, respectively (Table 5-7); and the min and max are 35.2 and 79.6 million ton for diesel, respectively (Table 5-8). The same can be found for each province. In addition, industrial energy consumption data by type of fuels and by province are displayed in Tables 5-9 to5-11 for coal, electricity and petroleum, respectively. Likewise, the same data range can be observed for industrial energy consumption.

5.4 Factor inputs

Total cost factors cover aggregate energy, labor and capital. Although material inputs are also important, we have to drop it from our estimation as data are unavailable. To estimate a cost function, we only need factor prices and output. Therefore, these factor input data are used to construct series of factor cost shares in conjunction with factor price data. Both labor inputs (including total employment and total labor income) and capital inputs (including capital investment and capital price index) are obtained from CSY, which is published by the China Statistical Press annually.

Labor inputs include total employment (L) and total wage rate (W) by province and by industry. Total labor input cost is calculated by total wage rate multiplying by total employment. However, the CSY does not provide the wage rate for rural labor forces. In this case, I use rural per capita net income multiplying by total rural population to obtain total rural net income, which is divided by total rural labor to obtain a rural average wage rate. For the aggregate economy, total labor cost is the sum of all industrial labor wage income, while total employment is the sum of all industrial employment. Therefore, the aggregate wage rate is equal to total labor cost divided by total employment. Total employment and total wage rates for the aggregate economy are displayed as Tables 5-12 and 5-13. It can be seen that the numbers of total employed changed little, ranging from 623.9 million to 752.0 million (Table 5-12), however, total wage rates almost doubled, ranging from ¥3745 to ¥7095 (Table 5-13) at the national level. Total employment and wage rate for the industrial economy are shown as Tables 5-14 and 5-15.

The capital stock is taken as an input factor as a whole, but empirically with regard to cost accounting, only capital depreciation (K) is accounted for in input factor cost, which depends on the capital stock and depreciation rate. The capital stock estimate is from Chow (1993). We construct a capital stock series by using $K_t = K_{t-1}(1-\delta) + I_t$, where K_t is current capital stock, K_{t-1} is the previous year capital stock, δ is the capital depreciation rate, and I_t is current year capital investment. The total capital stock in 1994 is taken from Table 4 of Li (2003). For more detail refer to Chow (1993). This total stock is disaggregated into agriculture, industry, construction, transportation and commerce, based on the allocation of capital replacement investment in 1994. The total capital depreciation is taken as capital at factor cost, which is consistent with the current cost accounting system in China and the use of GDP as an output indicator. Total capital stock estimates and capital price index for aggregate economy are displayed in Tables 5-16 and 5-17. It can be seen that total capital stock estimates almost doubled, ranging from ¥6387 billion to ¥11921 billion (Table 5-16), however, capital price indices (P_K) did not change much, ranging from 1.87 to 2.15 (Table 5-17) at national level. Total capital stock estimates for industrial economy are shown in Table 5-18.

5.5 Output and deflator

Total output and its deflator are needed in the cost function estimation. They are both taken from the CSY. Total output (Y) is represented by real Gross Domestic Product (GDP). Since the CSY does not provide the GDP's deflator, I take the weighted index of the consumer price index and the fixed assets price index as GDP's deflator (P_Y). This is because GDP mainly consists of labor input and capital depreciation by definition. The GDP and its deflator are obtained for each of the 31 provinces (autonomous regions or municipalities) over time. The descriptive statistics of GDP and its deflator are presented as Tables 5-19 and 5-20 for the aggregate economy. GDP changed sharply and nearly tripled, ranging from ¥6079 billion to

¥15988 billion for aggregate economy (Table 5-19). GDP's deflator ranges from 1.00 to 1.148 at the national level (Table 5-20). Table 5-21 presents the descriptive statistics of GDP for the industrial economy.

5.6 Cost series construction

5.6.1 Total factor cost series

We use aggregate energy use (E), capital depreciation (K) and labor use (L) as the three factor inputs. The total cost series (C) is constructed as the sum of aggregate energy use cost, capital stock cost and labor use cost. Three factor cost share series are calculated based on total cost series and three factor input series, respectively.

5.6.2 Total energy cost series

The aggregate energy input cost (E) is defined as the sum of four fuel inputs: coal (CO), electricity (EL), gasoline (GA) and diesel (DI). Each fuel input cost is the product of its volume consumed and price. Individual fuel consumption and price are used to construct individual fuel cost series and individual fuel cost share series.

Table 5-1. Descriptive statistics of coal prices for 35 markets

City	Min	Max	Mean	STDEV
National	203	458	286	66
Beijing	107	420	261	69
Tianjin	168	347	270	47
Shijiazhuang	120	370	227	58
Taiyuan	112	470	232	105
Hohhot	90	440	190	81
Shenyang	225	429	325	51
Changchun	150	500	308	88
Harbin	150	330	244	37
Shanghai	225	679	358	126
Nanjing	235	387	333	39
Hangzhou	241	488	343	44
Hefei	180	520	327	76
Fuzhou	263	602	375	72
Nanchang	210	450	345	60
Jinan	223	580	308	114
Zhengzhou	148	480	251	85
Wuhan	173	600	327	111
Changsha	173	685	332	119
Guangzhou	258	698	416	124
Nanning	183	438	277	57
Haikou	154	398	340	49
Chongqing	120	630	273	129
Chengdu	179	530	305	85
Guiyang	100	385	246	99
Kunming	121	504	238	111
Lhasa	205	447	284	62
X'ian	140	265	201	30
Lanzhou	160	234	180	19
Xining	96	248	183	26
Yinchuan	96	470	180	113
Urumqi	112	201	143	17
Qingdao	205	447	284	62
Dalian	203	668	437	118
Xiamen	235	588	357	94
Ningbo	203	480	319	73

Note: Unit is ¥/ton from 1995 to 2004.
Source: Price Monitoring Center, State Development and Reform Commission of China.

Table 5-2. Descriptive statistics of electricity prices for 35 markets

City	Min	Max	Mean	STDEV
National	344	590	468	81
Beijing	319	655	452	116
Tianjin	319	636	481	69
Shijiazhuang	319	565	464	89
Taiyuan	240	531	311	94
Hohhot	319	685	530	129
Shenyang	272	633	371	131
Changchun	319	674	543	115
Harbin	280	633	509	138
Shanghai	319	710	548	141
Nanjing	319	672	528	140
Hangzhou	469	619	527	33
Hefei	245	633	395	121
Fuzhou	550	658	586	25
Nanchang	319	633	482	103
Jinan	200	633	480	152
Zhengzhou	249	633	453	97
Wuhan	430	592	504	57
Changsha	319	633	477	98
Guangzhou	540	812	680	98
Nanning	162	652	363	168
Haikou	319	633	507	109
Chongqing	319	633	475	104
Chengdu	260	752	465	117
Guiyang	246	565	397	71
Kunming	310	565	406	88
Lhasa	319	633	489	110
X'ian	319	633	471	66
Lanzhou	319	633	407	77
Xining	140	633	313	128
Yinchuan	230	633	376	125
Urumqi	240	633	384	129
Qingdao	319	633	483	109
Dalian	240	715	469	162
Xiamen	319	713	561	136
Ningbo	340	690	503	108

Note: Unit is ¥/1000KWh, 1995-2005.
Source: Price Monitoring Center, State Development and Reform Commission of China.

Table 5-3. Descriptive statistics of gasoline prices for 35 markets

City	Min	Max	Mean	STDEV
National	2491	5798	3544	893
Beijing	2491	5906	3565	837
Tianjin	2235	5780	3492	944
Shijiazhuang	2280	5779	3561	870
Taiyuan	2168	5838	3349	965
Hohhot	2491	5798	3633	881
Shenyang	2320	5780	3533	907
Changchun	2260	5424	3508	906
Harbin	2339	5427	3597	822
Shanghai	2250	5877	3610	876
Nanjing	2050	5424	3311	946
Hangzhou	2138	5816	3424	1006
Hefei	2050	5804	3417	914
Fuzhou	2491	5839	3686	793
Nanchang	2489	5792	3529	887
Jinan	2195	5873	3466	984
Zhengzhou	2200	5730	3570	861
Wuhan	2491	5810	3681	897
Changsha	2150	5957	3550	888
Guangzhou	2000	5869	3381	1020
Nanning	2300	5940	3556	969
Haikou	2491	6052	3636	876
Chongqing	2150	6004	3588	948
Chengdu	2383	5695	3586	945
Guiyang	2473	5976	3584	959
Kunming	2491	6007	3686	866
Lhasa	2491	6851	3954	1021
X'ian	2297	5763	3547	881
Lanzhou	2491	5828	3543	881
Xining	2473	5424	3490	859
Yinchuan	2491	5786	3568	861
Urumqi	2491	5436	3372	876
Qingdao	2473	5424	3446	919
Dalian	2300	5780	3577	857
Xiamen	2340	5839	3620	859
Ningbo	2090	5850	3420	1008

Note: Unit is ¥/ton and 1995-2005.

Source: Price Monitoring Center, State Development and Reform Commission of China.

Table 5-4. Descriptive statistics of diesel prices for 35 markets

City	Min	Max	Mean	STDEV
National	2173	4780	3068	718
Beijing	2159	4849	3078	693
Tianjin	1700	4811	3043	778
Shijiazhuang	2100	4811	3114	723
Taiyuan	1930	5150	2994	762
Hohhot	2159	4828	3207	714
Shenyang	2159	4811	3119	724
Changchun	1830	4533	3075	742
Harbin	2159	4533	3126	712
Shanghai	2080	4949	3078	713
Nanjing	2000	4533	2867	770
Hangzhou	2000	4802	2988	777
Hefei	1740	4914	2963	724
Fuzhou	2045	4720	3149	673
Nanchang	1980	4820	3009	732
Jinan	2080	4868	3033	767
Zhengzhou	1700	4952	3075	704
Wuhan	2159	4698	3037	704
Changsha	1760	4709	3006	728
Guangzhou	1700	4741	2951	803
Nanning	1800	4806	3031	796
Haikou	2050	4864	3107	711
Chongqing	2159	4871	3020	737
Chengdu	2020	4724	3082	727
Guiyang	2150	4873	3106	722
Kunming	2000	4871	3181	673
Lhasa	2159	5629	3500	843
X'ian	2000	4533	3054	707
Lanzhou	2089	4839	3129	718
Xining	2089	4848	3093	726
Yinchuan	1835	4811	3100	727
Urumqi	1835	4619	2943	769
Qingdao	2159	4533	3027	724
Dalian	2150	4811	3140	689
Xiamen	1950	4720	3038	725
Ningbo	1700	4576	2926	782

Note: Unit is ¥/ton and 1995-2005.

Source: Price Monitoring Center, State Development and Reform Commission of China.

Table 5-5. Descriptive statistics of aggregate coal use

Province	Min	Max	Mean	STDEV
National	632.9	795.8	685.5	49.8
Beijing	10.9	13.5	12.5	0.8
Tianjin	9.3	13.5	10.7	1.1
Hebei	52.0	63.9	55.8	4.2
Shanxi	30.2	41.6	34.0	3.8
Inner Mongolia	16.1	32.2	22.7	4.6
Liaoning	28.6	41.0	33.5	3.7
Jilin	17.3	28.5	21.6	4.1
Heilongjiang	14.6	25.5	18.9	3.6
Shanghai	9.1	11.1	10.4	0.6
Jiangsu	26.8	44.5	34.9	6.4
Zhejiang	20.3	32.1	23.2	3.3
Anhui	27.3	40.8	34.9	4.3
Fujian	10.3	13.8	11.5	1.3
Jiangxi	10.7	17.2	13.0	2.1
Shandong	35.1	60.7	44.9	8.4
Henan	36.8	41.1	38.5	1.2
Hubei	34.3	45.5	38.3	3.4
Hunan	24.4	41.5	31.4	5.7
Guangdong	22.0	31.3	24.5	2.9
Guangxi	12.7	17.0	15.0	1.2
Hainan	0.6	1.2	0.7	0.2
Chongqing	14.9	23.5	18.4	2.8
Sichuan	22.0	48.1	33.1	9.1
Guizhou	24.0	40.5	29.7	4.7
Yunnan	11.3	17.2	14.1	1.9
Tibet	-	-	-	-
Shaanxi	9.9	21.8	15.6	3.6
Gansu	12.2	15.4	13.1	1.2
Qinghai	2.8	4.4	3.2	0.4
Ningxia	3.3	20.2	11.6	8.2
Xinjiang	13.9	17.9	15.5	1.1

Note: Unit is million ton, 1995-2004.
Source: China Energy Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-6. Descriptive statistics of aggregate electricity use

Province	Min	Max	Mean	STDEV
National	960.9	2063.3	1357.8	366.7
Beijing	23.8	46.9	33.9	7.6
Tianjin	17.3	33.6	22.9	6.2
Hebei	56.9	120.1	78.8	20.7
Shanxi	36.6	78.0	50.5	13.8
Inner Mongolia	18.7	41.2	27.0	8.4
Liaoning	58.6	99.8	73.8	12.3
Jilin	24.7	38.3	29.0	4.4
Heilongjiang	36.8	52.8	43.0	5.1
Shanghai	37.9	77.7	53.3	13.1
Jiangsu	63.6	166.9	96.8	33.8
Zhejiang	40.1	133.1	73.5	32.5
Anhui	26.4	51.6	35.6	7.6
Fujian	24.2	61.2	39.2	13.2
Jiangxi	16.6	35.7	21.4	6.1
Shandong	74.1	169.4	108.7	35.6
Henan	52.3	119.1	73.4	21.4
Hubei	37.4	69.9	49.5	11.0
Hunan	32.1	66.3	40.6	10.8
Guangdong	71.9	220.2	124.6	49.3
Guangxi	20.2	42.2	29.2	7.0
Hainan	2.8	6.6	4.1	1.2
Chongqing	15.6	29.5	24.3	5.8
Sichuan	43.0	77.5	54.7	11.4
Guizhou	18.6	55.2	33.9	14.2
Yunnan	20.7	37.2	28.4	5.4
Tibet	-	-	-	-
Shaanxi	21.7	43.1	29.6	7.5
Gansu	22.7	43.3	29.2	6.7
Qinghai	6.5	19.0	10.9	3.8
Ningxia	8.6	21.2	14.8	5.5
Xinjiang	12.0	24.8	17.5	4.2

Note: Unit is billion KWh, 1995-2004.
Source: China Energy Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-7. Descriptive statistics of aggregate gasoline use

Province	Min	Max	Mean	STDEV
National	27.5	49.2	34.7	7.3
Beijing	0.7	2.0	1.2	0.5
Tianjin	0.7	1.2	0.9	0.2
Hebei	1.3	1.7	1.4	0.1
Shanxi	0.8	1.0	0.9	0.0
Inner Mongolia	0.5	1.1	0.7	0.2
Liaoning	1.2	2.4	1.8	0.5
Jilin	0.8	1.1	1.0	0.1
Heilongjiang	1.5	3.2	2.3	0.6
Shanghai	0.8	2.1	1.3	0.4
Jiangsu	1.6	3.6	2.3	0.7
Zhejiang	1.2	2.8	1.9	0.5
Anhui	0.6	0.8	0.7	0.1
Fujian	0.7	1.9	1.1	0.4
Jiangxi	0.4	0.6	0.5	0.1
Shandong	1.7	2.3	1.9	0.2
Henan	1.2	1.6	1.3	0.1
Hubei	1.5	3.0	2.0	0.6
Hunan	1.0	1.6	1.2	0.2
Guangdong	2.6	4.5	3.2	0.6
Guangxi	0.4	1.3	0.7	0.3
Hainan	0.2	0.4	0.3	0.1
Chongqing	0.3	0.8	0.6	0.2
Sichuan	1.0	2.0	1.5	0.3
Guizhou	0.4	0.7	0.5	0.1
Yunnan	0.6	1.1	0.9	0.2
Tibet	-	-	-	-
Shaanxi	0.8	1.4	1.0	0.2
Gansu	0.6	1.0	0.8	0.2
Qinghai	0.1	0.2	0.2	0.0
Ningxia	0.1	0.4	0.2	0.1
Xinjiang	0.9	1.1	1.0	0.1

Note: Unit is million ton from 1995-2004.
Source: China Energy Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-8. Descriptive statistics of aggregate diesel use

Province	Min	Max	Mean	STDEV
National	35.2	79.6	51.3	14.7
Beijing	0.5	1.3	0.8	0.3
Tianjin	0.6	2.2	1.5	0.5
Hebei	1.6	2.1	1.7	0.1
Shanxi	0.6	1.9	1.0	0.4
Inner Mongolia	0.4	1.5	0.7	0.4
Liaoning	1.4	3.1	2.0	0.7
Jilin	0.6	1.0	0.8	0.1
Heilongjiang	2.0	4.6	3.4	0.9
Shanghai	1.2	3.4	2.2	0.6
Jiangsu	2.2	4.8	3.1	0.9
Zhejiang	2.7	6.4	4.1	1.2
Anhui	1.1	1.9	1.4	0.3
Fujian	1.6	3.2	2.1	0.5
Jiangxi	0.6	2.0	1.1	0.5
Shandong	2.4	3.4	3.0	0.3
Henan	1.3	2.1	1.5	0.2
Hubei	2.1	3.8	2.7	0.7
Hunan	1.0	1.9	1.4	0.4
Guangdong	3.9	9.7	6.4	2.1
Guangxi	0.7	2.9	1.4	0.8
Hainan	0.3	0.5	0.4	0.1
Chongqing	0.4	0.8	0.6	0.2
Sichuan	0.8	2.7	1.6	0.6
Guizhou	0.3	1.1	0.6	0.3
Yunnan	0.5	2.1	1.0	0.7
Tibet	-	-	-	-
Shaanxi	0.7	2.0	1.1	0.4
Gansu	0.6	1.1	0.8	0.1
Qinghai	0.1	0.2	0.2	0.0
Ningxia	0.1	0.5	0.3	0.2
Xinjiang	1.2	2.0	1.5	0.3

Note: Unit is million ton from 1995-2004.
Source: China Energy Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-9. Descriptive statistics of industry coal consumption

Province	Min	Max	Mean	STDEV
National	459.7	618.2	500.1	49.2
Beijing	5.7	7.5	6.6	0.6
Tianjin	6.1	8.4	7.7	0.8
Hebei	32.2	45.6	36.6	4.6
Shanxi	21.1	29.5	23.8	2.8
Inner Mongolia	9.7	28.7	16.4	5.8
Liaoning	19.1	28.9	23.2	3.0
Jilin	10.8	21.1	14.7	3.7
Heilongjiang	13.4	17.1	15.3	1.2
Shanghai	7.5	9.0	8.3	0.5
Jiangsu	24.3	38.2	31.1	5.4
Zhejiang	18.5	31.2	21.3	3.7
Anhui	22.5	32.9	28.7	3.3
Fujian	8.4	12.2	9.7	1.3
Jiangxi	7.5	13.1	10.0	1.7
Shandong	25.9	53.2	34.3	8.6
Henan	24.5	44.7	28.8	5.9
Hubei	26.2	38.4	29.9	3.7
Hunan	18.5	28.8	22.6	3.5
Guangdong	20.0	29.9	22.3	2.9
Guangxi	12.2	16.2	14.3	1.1
Hainan	0.0	2.7	0.8	0.8
Chongqing	10.7	19.7	14.8	3.0
Sichuan	15.3	30.4	23.0	5.4
Guizhou	8.7	23.8	13.1	4.4
Yunnan	6.4	10.5	8.1	1.3
Tibet	0.0	0.0	0.0	0.0
Shaanxi	6.5	15.0	11.0	2.7
Gansu	6.6	8.5	7.4	0.7
Qinghai	1.3	2.7	1.8	0.4
Ningxia	2.1	18.9	9.3	7.7
Xinjiang	4.7	7.4	5.9	0.8

Note: Unit is million ton, 1995-2004.
Source: China Energy Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-10. Descriptive statistics of industry electricity consumption

Province	Min	Max	Mean	STDEV
National	702.8	1480.7	965.0	261.5
Beijing	14.7	19.6	16.2	1.4
Tianjin	10.1	23.8	15.7	4.4
Hebei	41.7	86.3	55.0	14.9
Shanxi	29.6	64.7	41.1	11.6
Inner Mongolia	14.2	43.9	22.3	9.5
Liaoning	46.0	75.6	56.1	9.0
Jilin	17.5	25.4	20.0	2.2
Heilongjiang	29.2	38.1	32.6	2.7
Shanghai	28.3	51.1	36.7	7.6
Jiangsu	44.9	130.1	70.8	28.6
Zhejiang	29.4	102.2	54.6	25.4
Anhui	19.1	38.5	25.7	5.9
Fujian	16.1	41.4	25.7	9.7
Jiangxi	11.9	25.2	14.9	4.1
Shandong	57.1	133.4	81.8	27.0
Henan	39.3	89.7	53.4	16.2
Hubei	27.3	51.0	35.1	8.1
Hunan	22.7	46.3	28.3	7.3
Guangdong	45.5	146.3	79.3	33.3
Guangxi	14.8	30.3	21.0	4.7
Hainan	1.2	3.4	1.9	0.8
Chongqing	11.3	20.1	16.5	3.6
Sichuan	29.2	53.3	37.3	7.7
Guizhou	14.0	42.6	25.7	11.4
Yunnan	15.5	28.0	21.5	4.2
Tibet	0.0	0.0	0.0	0.0
Shaanxi	14.6	28.8	19.7	5.1
Gansu	17.6	32.4	21.3	4.7
Qinghai	5.6	17.2	9.6	3.5
Ningxia	0.5	18.8	11.2	6.3
Xinjiang	8.3	17.3	11.6	3.3

Note: Unit is billion KWh, 1995-2004.
Source: China Energy Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-11. Descriptive statistics of industry petroleum consumption

Province	Min	Max	Mean	STDEV
National	16.8	21.7	18.5	1.4
Beijing	0.2	0.4	0.3	0.0
Tianjin	0.3	0.5	0.4	0.1
Hebei	1.0	1.3	1.1	0.1
Shanxi	0.5	0.7	0.6	0.1
Inner Mongolia	0.2	0.4	0.3	0.1
Liaoning	0.5	1.1	0.7	0.2
Jilin	0.2	0.5	0.3	0.1
Heilongjiang	0.6	1.3	1.0	0.2
Shanghai	0.4	0.8	0.5	0.1
Jiangsu	1.0	1.7	1.3	0.2
Zhejiang	0.7	1.3	0.9	0.2
Anhui	0.3	0.5	0.4	0.1
Fujian	0.3	0.8	0.4	0.2
Jiangxi	0.1	0.4	0.2	0.1
Shandong	1.3	2.1	1.6	0.2
Henan	0.4	0.7	0.5	0.1
Hubei	1.0	1.7	1.4	0.2
Hunan	0.3	0.6	0.5	0.1
Guangdong	1.8	3.8	2.9	0.7
Guangxi	0.2	0.6	0.4	0.1
Hainan	0.0	0.1	0.1	0.0
Chongqing	0.2	0.3	0.2	0.1
Sichuan	0.3	0.6	0.4	0.1
Guizhou	0.1	0.2	0.1	0.0
Yunnan	0.2	0.4	0.3	0.1
Tibet	0.0	0.0	0.0	0.0
Shaanxi	0.5	1.1	0.8	0.2
Gansu	0.2	0.4	0.3	0.1
Qinghai	0.1	0.1	0.1	0.0
Ningxia	0.0	0.1	0.0	0.0
Xinjiang	0.3	0.6	0.4	0.1

Note: Unit is million ton, 1995-2004.
Source: China Energy Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-12. Descriptive statistics of aggregate employees

Province	Min	Max	Mean	STDEV
National	623.9	752.0	708.7	37.0
Beijing	6.2	9.0	7.0	1.1
Tianjin	4.0	4.9	4.4	0.4
Hebei	33.7	34.4	34.0	0.2
Shanxi	14.1	14.8	14.5	0.3
Inner Mongolia	10.1	10.5	10.2	0.1
Liaoning	18.0	20.6	19.0	1.0
Jilin	10.4	12.6	11.4	0.8
Heilongjiang	15.5	17.2	16.3	0.5
Shanghai	6.7	8.1	7.3	0.5
Jiangsu	35.1	37.7	36.4	0.9
Zhejiang	26.5	30.9	27.8	1.5
Anhui	32.1	34.5	33.4	0.8
Fujian	15.7	18.2	16.7	0.8
Jiangxi	19.3	20.8	20.0	0.6
Shandong	46.3	49.4	47.2	1.0
Henan	47.0	55.9	52.5	3.4
Hubei	24.5	27.1	25.9	1.0
Hunan	34.4	36.0	35.1	0.5
Guangdong	36.6	43.2	38.9	2.1
Guangxi	23.8	26.5	25.1	0.8
Hainan	3.2	3.7	3.4	0.1
Chongqing	16.2	22.2	17.7	2.4
Sichuan	44.1	63.4	48.5	7.8
Guizhou	18.6	21.7	20.1	1.0
Yunnan	21.9	24.0	22.9	0.7
Tibet	1.1	1.3	1.2	0.1
Shaanxi	17.7	19.1	18.2	0.5
Gansu	11.6	13.2	12.1	0.6
Qinghai	2.3	2.6	2.4	0.1
Ningxia	2.4	3.0	2.7	0.2
Xinjiang	6.6	7.4	6.9	0.3

Note: Unit is million persons from 1995 to 2004.
Source: China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-13. Descriptive statistics of aggregate nominal wages

Province	Min	Max	Mean	STDEV
National	3745	7095	5183	1008
Beijing	7358	25015	14093	5745
Tianjin	5681	15323	9677	3106
Hebei	3481	6176	4638	776
Shanxi	3389	7193	4770	1161
Inner Mongolia	3642	10056	6090	1929
Liaoning	4517	9331	6671	1534
Jilin	4082	8501	6294	1323
Heilongjiang	4640	9839	6573	1655
Shanghai	7737	19251	12707	3954
Jiangsu	4460	8311	5976	1191
Zhejiang	4287	9477	6190	1606
Anhui	2905	4730	3727	479
Fujian	4095	8299	6114	1248
Jiangxi	3394	5953	4555	698
Shandong	3629	7255	5193	1081
Henan	2969	4886	3839	526
Hubei	3943	7646	5660	1117
Hunan	3204	5490	4275	647
Guangdong	6084	9703	7735	1135
Guangxi	3220	5000	4035	484
Hainan	4168	7628	5539	1078
Chongqing	3367	5643	4028	739
Sichuan	2625	5507	3937	866
Guizhou	2389	4054	3076	489
Yunnan	2441	4722	3591	676
Tibet	3211	8848	5537	1952
Shaanxi	2716	5506	3973	879
Gansu	3171	5590	4315	739
Qinghai	3758	7259	5344	1133
Ningxia	3475	7148	5104	1112
Xinjiang	4621	10022	6820	1957

Note: Unit is ¥/year from 1995 to 2004.
Source: China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-14. Descriptive statistics of industry employees

Province	Min	Max	Mean	STDEV
National	89.2	118.7	101.2	11.4
Beijing	1.4	2.0	1.6	0.2
Tianjin	1.3	2.1	1.6	0.3
Hebei	6.2	7.1	6.6	0.3
Shanxi	2.7	3.6	3.0	0.3
Inner Mongolia	1.1	1.8	1.4	0.3
Liaoning	3.5	6.3	4.5	1.2
Jilin	1.4	2.8	2.0	0.6
Heilongjiang	2.5	4.6	3.3	0.9
Shanghai	2.6	3.6	2.9	0.4
Jiangsu	7.7	10.0	8.7	0.9
Zhejiang	6.4	10.1	7.5	1.2
Anhui	3.3	4.2	3.7	0.4
Fujian	2.7	4.0	3.2	0.4
Jiangxi	2.0	3.0	2.5	0.4
Shandong	7.8	9.5	8.3	0.6
Henan	6.2	7.2	6.6	0.3
Hubei	3.1	4.7	3.7	0.7
Hunan	3.4	4.4	3.8	0.4
Guangdong	7.3	9.5	8.0	0.7
Guangxi	1.6	1.9	1.7	0.1
Hainan	0.2	0.3	0.2	0.0
Chongqing	1.4	2.0	1.7	0.2
Sichuan	3.6	7.0	4.6	1.3
Guizhou	1.3	1.5	1.4	0.0
Yunnan	1.3	1.5	1.4	0.1
Tibet	0.0	0.1	0.0	0.0
Shaanxi	2.0	2.5	2.2	0.2
Gansu	1.0	1.5	1.2	0.2
Qinghai	0.2	0.3	0.2	0.0
Ningxia	0.3	0.4	0.4	0.0
Xinjiang	0.6	1.0	0.8	0.1

Note: Unit is million persons, 1995-2004.
Source: China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-15. Descriptive statistics of industry nominal wage rates

Province	Min	Max	Mean	STDEV
National	4069	7949	5737	1329
Beijing	6449	18894	11678	4108
Tianjin	5193	13599	8559	2895
Hebei	3305	5962	4381	926
Shanxi	4006	8852	5387	1567
Inner Mongolia	3889	11084	6319	2272
Liaoning	4374	11682	7293	2500
Jilin	4094	11058	7085	2237
Heilongjiang	3785	10190	6303	2205
Shanghai	6992	14835	10669	2931
Jiangsu	3643	6840	5152	1230
Zhejiang	3138	5574	4250	789
Anhui	3458	5260	4345	560
Fujian	3639	8028	5744	1525
Jiangxi	3257	5175	4366	696
Shandong	3821	8278	5712	1559
Henan	3283	5702	4206	797
Hubei	3845	8483	5805	1605
Hunan	3631	6018	4732	911
Guangdong	4209	7963	6141	1198
Guangxi	4480	8358	5968	1287
Hainan	4833	8170	6463	1065
Chongqing	4249	7458	5561	1154
Sichuan	3640	6877	5176	1078
Guizhou	4122	7164	5333	1036
Yunnan	4794	10189	7228	1735
Tibet	3564	10984	7248	2471
Shaanxi	3658	9282	6075	1943
Gansu	5149	11321	7493	2021
Qinghai	4704	10809	7505	2216
Ningxia	5182	10153	7559	1683
Xinjiang	5855	14824	9669	2791

Note: Unit is ¥/year, 1995-2004.
Source: China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-16. Descriptive statistics of aggregate capital stock

Province	Min	Max	Mean	STDEV
National	6387	11921	8121	1672
Beijing	279	312	296	11
Tianjin	178	263	203	26
Hebei	182	486	304	97
Shanxi	149	301	195	49
Inner Mongolia	107	260	145	48
Liaoning	726	907	796	61
Jilin	120	273	170	43
Heilongjiang	198	372	267	57
Shanghai	450	659	515	61
Jiangsu	561	854	628	90
Zhejiang	292	594	379	96
Anhui	157	374	208	63
Fujian	122	321	193	59
Jiangxi	123	208	144	26
Shandong	414	920	538	156
Henan	275	501	342	67
Hubei	213	512	313	87
Hunan	143	288	191	46
Guangdong	400	808	564	125
Guangxi	98	199	138	33
Hainan	50	79	62	9
Chongqing	97	157	116	19
Sichuan	216	482	307	80
Guizhou	64	145	95	28
Yunnan	105	214	149	36
Tibet	23	34	26	4
Shaanxi	160	279	196	40
Gansu	87	171	114	27
Qinghai	31	68	43	11
Ningxia	33	64	43	10
Xinjiang	115	298	186	61

Note: Unit is ¥billion from 1995-2004.
Source: Estimated based on China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-17. Descriptive statistics of capital price index

Province	Min	Max	Mean	STDEV
National	1.87	2.15	1.99	0.07
Beijing	2.02	2.45	2.26	0.11
Tianjin	1.99	2.20	2.04	0.06
Hebei	2.03	2.28	2.11	0.07
Shanxi	1.82	2.15	1.96	0.09
Inner Mongolia	1.62	1.96	1.78	0.10
Liaoning	2.20	2.52	2.32	0.09
Jilin	1.97	2.40	2.19	0.13
Heilongjiang	1.81	2.12	1.95	0.08
Shanghai	1.79	2.04	1.89	0.07
Jiangsu	1.98	2.34	2.07	0.11
Zhejiang	1.89	2.10	1.95	0.06
Anhui	2.16	2.52	2.30	0.10
Fujian	1.88	2.00	1.94	0.04
Jiangxi	1.94	2.37	2.12	0.11
Shandong	2.02	2.40	2.14	0.11
Henan	1.87	2.25	1.99	0.10
Hubei	1.83	2.16	1.97	0.09
Hunan	2.03	2.52	2.26	0.14
Guangdong	1.24	1.35	1.26	0.03
Guangxi	1.82	2.01	1.89	0.05
Hainan	1.47	1.61	1.51	0.04
Chongqing	1.00	1.13	1.04	0.04
Sichuan	1.78	2.10	1.91	0.08
Guizhou	2.05	2.41	2.22	0.09
Yunnan	2.11	2.69	2.38	0.16
Tibet	-	-	-	-
Shaanxi	2.10	2.85	2.51	0.23
Gansu	2.13	2.63	2.37	0.14
Qinghai	1.65	1.92	1.77	0.08
Ningxia	1.96	2.51	2.25	0.16
Xinjiang	2.03	2.56	2.29	0.16

Note: 1990 is used as base, 1995-2004, and for aggregate economy.
Source: China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-18. Descriptive statistics of industry capital stock

Province	Min	Max	Mean	STDEV
National	4584	8108	5437	1038
Beijing	153	179	168	9
Tianjin	107	180	130	21
Hebei	143	335	212	57
Shanxi	106	214	136	35
Inner Mongolia	84	178	103	29
Liaoning	508	650	567	49
Jilin	98	222	136	34
Heilongjiang	147	251	184	33
Shanghai	295	471	356	51
Jiangsu	422	617	455	59
Zhejiang	218	407	256	58
Anhui	132	288	160	46
Fujian	78	207	114	38
Jiangxi	100	145	110	13
Shandong	325	722	408	121
Henan	217	365	256	42
Hubei	149	366	215	61
Hunan	110	188	129	23
Guangdong	210	472	311	79
Guangxi	79	119	89	13
Hainan	31	38	34	2
Chongqing	61	95	70	10
Sichuan	167	337	212	48
Guizhou	50	92	65	14
Yunnan	85	127	102	12
Tibet	7	9	7	1
Shaanxi	128	186	140	17
Gansu	68	117	83	15
Qinghai	25	42	31	5
Ningxia	27	49	32	7
Xinjiang	78	181	115	32

Note: Unit is ¥billion, 1995-2004.
Source: estimated based on China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-19. Descriptive statistics of aggregate nominal GDP

Province	Min	Max	Mean	STDEV
National	6079	15988	10099	3078
Beijing	139	428	255	94
Tianjin	92	293	170	63
Hebei	285	877	517	179
Shanxi	103	304	179	59
Inner Mongolia	83	271	149	58
Liaoning	279	687	455	130
Jilin	113	296	187	57
Heilongjiang	201	530	333	99
Shanghai	246	745	451	155
Jiangsu	516	1551	894	319
Zhejiang	352	1124	639	245
Anhui	200	481	314	82
Fujian	215	605	388	121
Jiangxi	117	350	212	67
Shandong	500	1549	889	321
Henan	300	882	525	173
Hubei	239	631	420	117
Hunan	215	561	366	102
Guangdong	573	1604	977	328
Guangxi	150	332	220	52
Hainan	36	77	52	13
Chongqing	101	267	167	51
Sichuan	250	656	427	115
Guizhou	63	159	101	30
Yunnan	121	296	197	50
Tibet	6	21	12	5
Shaanxi	100	288	172	58
Gansu	55	156	99	30
Qinghai	17	47	28	10
Ningxia	17	46	28	9
Xinjiang	83	220	136	44

Note: Unit is ¥billion from 1995 to 2004.
Source: China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-20. Descriptive statistics of the GDP's deflator

Province	Min	Max	Mean	STDEV
National	1.000	1.148	1.087	0.037
Beijing	1.000	1.271	1.181	0.082
Tianjin	1.000	1.136	1.078	0.034
Hebei	1.000	1.129	1.072	0.033
Shanxi	1.000	1.182	1.101	0.047
Inner Mongolia	1.000	1.199	1.116	0.053
Liaoning	1.000	1.136	1.073	0.034
Jilin	1.000	1.145	1.086	0.037
Heilongjiang	1.000	1.128	1.080	0.035
Shanghai	1.000	1.184	1.107	0.048
Jiangsu	1.000	1.151	1.080	0.037
Zhejiang	1.000	1.143	1.078	0.035
Anhui	1.000	1.160	1.093	0.039
Fujian	1.000	1.113	1.065	0.028
Jiangxi	1.000	1.157	1.096	0.039
Shandong	1.000	1.181	1.106	0.046
Henan	1.000	1.162	1.090	0.043
Hubei	1.000	1.156	1.088	0.040
Hunan	1.000	1.203	1.112	0.052
Guangdong	1.000	1.081	1.051	0.023
Guangxi	1.000	1.071	1.033	0.026
Hainan	0.998	1.055	1.020	0.021
Chongqing	1.000	1.102	1.058	0.029
Sichuan	1.000	1.219	1.126	0.056
Guizhou	1.000	1.456	1.323	0.151
Yunnan	1.000	1.205	1.121	0.053
Tibet	1.000	1.102	1.064	0.026
Shaanxi	1.000	1.191	1.124	0.050
Gansu	1.000	1.182	1.113	0.048
Qinghai	1.000	1.250	1.143	0.068
Ningxia	1.000	1.183	1.106	0.047
Xinjiang	1.000	1.204	1.128	0.055

Note: 1995 as base and to 2004.
Source: China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Table 5-21. Descriptive statistics of industry nominal GDP

Province	Min	Max	Mean	STDEV
National	2472	6282	3980	1160
Beijing	50	129	77	25
Tianjin	45	144	78	31
Hebei	115	409	228	88
Shanxi	43	157	83	33
Inner Mongolia	25	102	51	22
Liaoning	123	283	197	52
Jilin	41	114	67	23
Heilongjiang	95	281	166	56
Shanghai	130	349	205	69
Jiangsu	247	778	416	166
Zhejiang	163	538	303	115
Anhui	77	174	119	26
Fujian	76	253	149	56
Jiangxi	31	111	64	22
Shandong	211	780	399	173
Henan	127	386	218	78
Hubei	93	259	179	51
Hunan	65	178	120	32
Guangdong	241	801	444	176
Guangxi	46	104	67	16
Hainan	4	12	7	3
Chongqing	37	93	57	17
Sichuan	83	217	143	36
Guizhou	21	57	33	11
Yunnan	48	105	72	16
Tibet	0	2	1	0
Shaanxi	34	106	59	22
Gansu	23	58	35	10
Qinghai	5	16	8	3
Ningxia	6	19	10	4
Xinjiang	22	75	40	16

Note: Unit is ¥billion, 1995-2004.
Source: China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Chapter Six: Energy Reforms and Changing Prices [25]

This chapter is organised as follows: The first section comprises a review of the regulatory system as a whole and for certain energy types to see i) how China has been deregulating energy industry in order to ii) measure how far this regulatory system is from a truly market economy. The second and third sections review, historical, the reforms of energy prices over time and across types of energy followed by changes of energy prices over time and across regions. The fourth section reconciles energy reforms and price changes primarily to show readers how energy prices have been converging over time as regulatory and price reforms have been undertaken. It should be noted that the statistical and econometric analyses of price convergence and tests for the emergence of an energy market will be discussed in detail in Chapters 9.

6.1 Changing energy regulation in China

6.1.1 The previous regulatory system

China's energy industry has experienced several significant policy and management changes. The 'old form' of energy industry regulation system was created in 1993. Figure 6-1 shows the government structure and regulatory system as it used to be. The

[25] This Chapter appears in ***Renewable and Sustainable Energy Reviews*** 2009 and ***Energy Policy*** 2009 together with Chapter 3 and Chapters 7 and 8.

China State Planning Commission (CSPC and now called the State Development and Reform Commission - SDRC) reported to the State Council which stood at the top of the energy policy hierarchy with full responsibility for energy policy. The State Economic and Trade Commission (SETC, from which, since 2001, most functions have been transferred to the SDRC) and the State Sciences and Technology Commission (SSTC, now the Ministry of Sciences and Technology-MST) played a relatively minor and subordinate role in the energy sector. Under this old system, each of the major energy industries was dominated by a single institution which was either a State Corporation or a Ministry. For example, the China National Petroleum Corporation (CNPC) dominated petroleum exploration and production, while the China Petroleum and Chemical Corporation (Sinopec) controlled oil refining and distribution. The Ministry of Electric Power (MEP) and Ministry of Coal Industry (MCI) were in charge of the power and coal sectors, respectively. These Corporations and Ministries were also involved in policy formulation, regulation and enterprise management (Andrews-Speed, Dow and Gao, 2000). The old industrial organization structure and regulatory system of China's energy sector have been well documented and reviewed elsewhere.[26]

6.1.2 The emergence of a new regulatory system

The most important reforms of the energy sector were implemented in 1998. These changes included a strategic reorganization of petroleum enterprises establishing a new vertically integrated management system for the oil industry. In 2002, China's

[26] For example, Wirtshafter and Shih (1990), Wu and Li (1995), Li and Dorian (1995), Smil (1998), Thomson (1996), CIAB (1999), Andrews-Speed and Dow (2000) and Blackman and Wu (1999).

power industry underwent the separation of government functions from those of enterprises and the separation of power plants from lines of operation. The new structure has three main goals: i) removing government from the function of enterprise management; ii) extending market-orientated energy system reform; iii) improving the efficiency of the energy industry (IOSC, 2007).

The latest regulatory system is shown in Figure 6-2 and has emerged after the National Energy Administration (NEA)[27] was established in August 8, 2008. Under the new structure, government functions are completely separated from those of enterprises. The State Council has six parallel ministers or equivalent commissions. For example, the Ministry of Land and Resources (MLR) is responsible for issuing energy enterprises' exploration certificates and levying resource taxes for coal and petroleum enterprises. The China Association of Coal Industry (CACI) acts as a regulator of the coal industry, while the State Electricity Regulatory Commission (SERC) acts as a regulator for the electricity industry. The SDRC is responsible for other aspects, via the NEA, including the setting of energy price ceilings, proposing a highest market access grid electricity price to power generation units, responsibility for energy investment and construction, etc. The lowest level of the new structure covers energy enterprises, which include various coal mines, petroleum exploration and refinery manufacturers, power plants and electricity grids. Under the new system, regulation and business are clearly separated

[27] NEA is only half a level lower than the SDRC and it is likely to soon become The Ministry of Energy.

6.1.3 Deregulation of specific sectors

6.1.3.1 The coal sector

The coal industry has been free of single corporation domination since the 1990s due to the natural features of China's coal industry. Reforms to the coal industry took a crucial step towards decentralization and disaggregation in 1999, when the ownership and operation of Central Government Owned Mines (CGOM) was transferred to the Provinces. Currently, three main types of coal producers exist in China: i) Approximately 100 Provincial Government Owned Mines (PGOM) which were transferred from the CGOM all of which are large scale with an annual output of 10 mmt; ii) Previously local government-owned mines (LGOM), including Provincial government owned mines; and iii) Town- and Village-Owned Mines (TVOM) and private owned mines. According to Huang (2006), there were 21,000 small mines in the LGOM, TVOM and private enterprises in 2005.

Under the new government structure and regulatory system there are no mines owned at the State level and all mines are owned and operated at and below the Provincial level. The China Association of Coal Industry (CACI) and NEA are responsible for coal industry macro management, with NEA responsible for major coal industrial investment decisions and MLR responsible for coal licensing. The regulatory system of the coal industry is a combination of industrial association and government agencies.

6.1.3.2 The electricity sector

Prior to 1985, China's electricity industry was under the control of central government (Wang, 2007). The generation, transmission, distribution and retailing of electricity were all administrated by the Ministry of Water and Power Industry. However, the electricity industry has experienced a series of changes since 1985 (Xu and Chen, 2006). In 1988 the Ministry of Coal Industry, the Ministry of Oil Industry, the Ministry of Nuclear Industry and the Ministry of Water and Power were merged into a newly created Ministry of Energy (MOE). This highly centralized power administration system didn't change fundamentally until 1997, although guidelines to separate the responsibilities of government and business were produced and provincial Bureaus of Electric Power were given some operational autonomy with local governmental jurisdiction over the development of the local power industry. The aim of these changes was to encourage investment in the power sector and promote the generation of electricity.

To free the sector of government intervention and create Vertically Integrated State-Owned Utilities (VISOU), the China State Power Corporation (CSPC) was created in March 1997. One year later, the Ministry of Electric Power was dismantled and its administrative functions assigned to a new department of the SETC.

The 1997-2002 reforms were mainly focused on the separation of government and enterprise as well as the separation of ownership and operation. However, the newly created CSPC became another monopolist controlling 50% of the country's generation assets and most of the technology and development assets. As a result, it became a major obstacle to the development of a market-oriented power industry (Ma and He, 2008).

An important component of the market-oriented power reform process was to dismantle the CSPC. In December 2002 its assets were divided into 11 new corporations, including two grid operators: the State Power Grid (SPG) and the China Southern Power Grid (CSPG),[28] five Independent Power Plants (The Big Five): Huaneng Group, Datang Group, Huadian Corporation, Guodian Corporation and Power Investment Corporation, and four auxiliary corporations: Power Generation Consulting Group Corporation; Hydropower Engineering Consulting Group Corporation; Hydraulic and Hydroelectric Construction Consulting Group Corporation and Gezhouba Group Corporation. The generation and transmission assets were not distributed among the 11 new corporations, but were directly managed and controlled by State Power Grid until 2006. Since then, those assets have been purchased by the State Electricity Regulatory Commission (SERC). Therefore, the regulatory framework has become one where the NEA is mainly responsible for price, planning, investment and construction, etc, and the SERC has become an independent regulator under the State Council, and at the bottom are the various enterprises. For more on the regulatory reforms of China's power industry refer to Wu (2003), Xu and Chen (2006), Wang (2007), and Ma and He (2008).

6.1.3.3 The petroleum sector

As discussed above, prior to 1998, China's petroleum industry was controlled by two

[28] State Power Grid includes five regional grids: Northwest Grid, North Grid, Northeast Grid, Central Grid, and East Grid and also referring to Figure 3-5 of Chapter Three.

state companies: CNPC and Sinopec, both of which combined the roles of government and enterprise management. However, after the 1998 strategic reorganization, the government functions of the petroleum sector were removed from the state companies and placed with SETC. The assets of both CNPC and Sinopec were redistributed to create two regionally and vertically integrated companies that spanned the full range of activities in the petroleum industry. The CNPC and Sinopec have now become ‘pure’ companies. The CNPC’s territory covers the north and west of the country, while Sinopec’s territory now lies in the south and east. Regulatory functions have been transferred to NEA within SDRC. Petroleum prices and transportation are also regulated by two subdivisions within the SDRC. The MLR is responsible for issuing licenses.

In summary, energy market regulation has evolved in China based on the principle of separating regulation and operation. China has progressed significantly, if somewhat gradually, towards an energy market as a consequence of these reforms.

6.2 Reforms of the energy pricing mechanism

Energy price reforms are an integral part of the overall economic reform package in China (Andrews-Speed, Dow and Gao, 2000). Fesharaki *et al.* (1994) argue that energy prices were ‘irrational’ and caused enormous macroeconomic and microeconomic distortions in the energy sector and throughout the economy in China. However, given the fundamental reforms that occurred subsequently, it is interesting to investigate whether energy prices are still irrational and still cause macroeconomic and microeconomic distortions. In this section we firstly review the major policies of energy price adjustment and their corresponding effects. We then report trends in energy prices for the major energy components focusing on the heterogeneity of price levels across provinces.

6.2.1 The features of energy reforms

Since the early 1980s, China has introduced numerous measures to rationalize oil, coal, gas and electricity prices. However, the strategy of energy price reforms that China adopted was gradual and pricing adjustment did not appear to cause major losses in the initial years (Lau, Qian and Roland, 2000). Starting from a baseline of fully state-controlled in China, a 'dual track' system of energy pricing policy, i.e., 'in-plan' prices and 'out-plan' prices, was adopted in the early 1980s. 'In-plan' energy prices were normally lower than market prices, while 'out-plan' energy prices were typically market prices. However, in-plan energy prices were not always fixed. Most in-plan prices dramatically increased as energy price reform proceeded after 1994 (Wu and Li, 1995). In-plan energy prices were gradually replaced with market-mediated prices (Hang and Tu, 2007). For example, in 1990, approximately 46% of coal and 80% of crude oil was plan allocated (Garbaccio, 1995). However, in 1992 energy price reforms accelerated and a large fraction of coal and oil were moved from plan to market allocation. By 1999 plan allocation of energy had been largely eliminated (Hang and Tu, 2007). However, the market-oriented energy price reforms varied in time and in intensity due partially to their roles in national economic growth and effects on people's lives across energy type. Thus it is necessary to review price reforms and discuss their progress separately.

6.2.2 Evolution of energy price policies

6.2.2.1 Coal price reforms

The 'dual track' pricing system for coal was introduced **in 1985**. Under this policy, CGOMs were given an output quota at low price for unified allocation to those important state-owned downstream industries such as electricity, steel, metallurgy, engineering, chemical and transportation. The LGOMs and TVOMs were also given quota. Coal within quotas was referred to as 'in-plan' and above quotas was referred to as 'out-plan'. The output above the quotas could be priced 50% higher and the output above more could be priced 100% higher than within quotas (Cheng, 1998). As more and more coal was sold on free market, the deliberate low price of 'in-plan' coal was difficult to sustain. It confronted with great pressure to recover to market level, which caused little complain from most of downstream industries because their market and price have been gradually freed. Therefore, price regulation on coal was completely abolished **after 1994**.

However, as electricity tariffs were still tightly controlled, some power plants could not afford coal with market price and some coal enterprises refused to sell coal to power plants at the 'in-plan' prices. As a result, a new policy was established **in 1996** that the prices of coal sold to power plants were guided by central government again and announced at the end of every year. However, this policy could not be implemented perfectly because coal producers did not fully perform their contracts with many excuses (Wang, 2007). In addition, the contracts sometimes aborted due to transportation unavailable, most of which was actually caused by profit-driven incentives because coal producers were not willing to sell their products at the guided prices. Consequently, the electricity industry could not always meet its coal demand under guided prices. Under this circumstance, the disputes and blackout happened frequently between coal producers and power plants.

The bargaining between two parties became even more severe **after 2002** when government-guided price of coal was once announced to be cancelled but electricity tariffs still remained regulated. This means that coal producers were allowed to determine coal price at their will. As a result, only 90 mmt, which was only 37% of total amount of demand for coal, were contracted at 2002 (Wang, 2007). The central government as a mediator was in a dilemma at the first time. Faced with serious power shortage, in April 2003 NDRC gave an order, in which the price was just midpoint between requirements of two parties, and in 2004 government introduced a new coal pricing policy, which was called ‘co-movement’ of prices of both coal and electricity. The co-movement is not a free market adjustment but regulated and determined periodically by the SDRC to avoid extreme price fluctuation. Adjustment will only be made if fluctuation of coal price exceeds 5%, otherwise, the change will be accumulated into the next adjustment period (Ma and He, 2008).

China Taiyuan Coal Trade Exchange (TCTE) was established on 18 June 2007 (TCTE, 2007), which replaces the coal ordering meeting between coal producers and power producers. Since then, more freedom would be given to coal suppliers and consumers, implying that the toughest reform in China's energy industry has been settled and a full competitive energy market was expected to operate in China.

6.2.2.2 Electricity price reforms

Electricity pricing reform is complicated and costly in China, since it affects millions of households. So, the Chinese government has been very cautious in reforms of its electricity industry. As in other countries, electricity prices are not completely deregulated in China. However, the government has made significant progress to reform and raise electricity prices to 'realistic' market levels since the beginning of economic reform.

In 1985, electricity tariffs were raised throughout the country. For the first time, local power producers were allowed to raise tariffs to cover the rising costs of coal and transportation (Hang and Tu, 2007). The State Council also encouraged investment in the power industry and introduced multi-tiers of electricity tariffs. In 1987, the government issued a new policy of *Fuel and Transportation Add-up*. It was used as an adjustable surcharge on the list of prices based on fluctuations in coal and transportation costs. This pricing adjustment procedure was administered and assessed annually by the SDRC.

In 1991, a 'high-in' and 'high-out' policy was introduced, allowing electricity tariffs to fluctuate according to the cost of coal and other factor costs. In 1993, a 'new plant-new price' policy was implemented, which allowed all power plants built after 1992 to sell power to provincial power companies at debt repayment prices in order to provide sufficient revenue for the repayment of loan capital with interest. In the 1990s, a range of surcharges, such as the '*Power Construction Fund*', '*Three Gorge Construction Fund*', were imposed (Ma and He, 2008). With these new policies, electricity tariffs have risen rapidly (Lam, 2004). However, these new policies also resulted in a complicated price structure, leading to high regulatory, supervisory and transaction costs.

To simplify and control prices, a new price scheme, operation-period price and yardstick price, were adopted in 1997. The price under this scheme is based on an average social generation cost and a unified internal rate of return on capital over the remaining operation period. For present plants, this is indeed an operation-period price while for new plants the new scheme actually specifies a unified yardstick price.

Some new policies were introduced post-2002. 'Operation-period price and yardstick price' are still used in regions where competitive regional wholesale market was not established after 2002. For regions where competitive wholesale transaction have been introduced, the price consists of two components: capacity price, which is determined by the government according to the average cost of all generation units in the market, and volume price which is determined competitively in the market.

On the retail side, list of prices was simplified to include: i) a unit price scheme used for residential and agricultural sectors; ii) a two-component price scheme, similar to the counterpart on the generation side, used by the industrial and commercial sectors; iii) the '*tidu'* prices (a kind of variable price)[29] was also introduced after 2004; vi) higher prices charged for energy-intensive industries (Ma

[29] This price is a kind of variable price based on the current quantity consumed and used to encourage or restrain electricity consumption.

and He, 2008). To reflect the rising cost of coal the 'co-movement' price of coal and electricity is used to adjust the list of prices.

6.2.2.3 Petroleum price reforms

Petroleum price regulation has experienced four stages. Pre-1981, petroleum prices were fully state-controlled. From 1981 to 1994, a 'dual track' pricing system was adopted, while from 1994 to 1998 petroleum prices were market-meditated.[30] After 1998, domestic petroleum prices have been set by SDRC in accordance with the international energy market price (Hang and Tu, 2007). Meanwhile, central government sets the regional prices of refined oil products according to the Singaporean oil market and as a result, the 1998 reform sees domestic oil prices closely following international prices (Wu, 2003).

6.3 The changes in energy prices

Over the past three decades, China's energy prices have experienced a series of energy policy adjustments. As a result, the prices of major energy sources have increased significantly and appear to become more sensitive to international market trends (Hang and Tu, 2007; Wu, 2003). However, at the provincial level energy price heterogeneity appears endemic for some forms of energy due to transportation costs.

[30] Since regulated prices cannot reflect real production cost, government allows market to lead energy price rising in order to better regulate energy prices. In other words, this is the way that was used to find real energy market prices.

6.3.1 Historical observations

Table 6-1, shows the energy spot prices and their changes over time for four major fuels in China. As can be seen, energy prices rose slower during the late 1990s. They rose rapidly, however, in the new millennium for example, gasoline and diesel prices were below ¥2500 per ton in the late 1990s, but reached over ¥3600 and ¥3300 per ton, respectively, in 2000. They quickly climbed to over ¥5400 and ¥4500 per ton by 2005. Similar scenarios can be found for coal and electricity. As a result, energy prices almost doubled during the study period for coal, gasoline and diesel. The electricity price also rose by over 50% during the same period.

It is useful to compare Chinese trends in energy price changes with those internationally and to consider the degree of market integration which is an important commitment within the WTO. As coal is the most important energy source in China, we use it for comparative purposes. If we compare the cif price of Japanese steam coal imports (BP, 2008) and China's coal spot price for the period of 1995-2005 (Figure 6-3) we find that post-1998, the coal prices in Japan and China were consistent, unlike earlier years. This illustrates how China's coal price has converged to that of the international energy market.

6.3.2 Observations across provinces

It is perhaps not surprising that the levels of energy price and the patterns of price changes show considerable variation across provinces given cost of long distance transportation. Table 6-2 presents the spot prices in 2005 and the changes from 1995 to 2005 for four major energy types for 31 Provincial (municipal or autonomous regional) capital cities in mainland China. It can be seen that the spot price of coal varies considerably and the patterns of price change are also quite different across cities for example, the spot price of coal is over ¥630 per ton in the East (Shanghai and Nanjing – consuming areas), while it is below ¥200 per ton in the West (Lanzhou and Urumqi – producing areas). The spot price of coal increased by 300% in Chongqing, 200% in Taiyuan, and over 150% in many other places from 1995 to 2005. However, the spot price of coal only increased by 25% in Haikou and Xi'an; and by less than 50% in Nanning, Lhasa and Xining during the same period. The spot price of coal actually declined in Lanzhou and Urumqi.

The patterns of price changes for gasoline and diesel are fairly similar. The spot prices across cities are around ¥5300 and ¥4300 per ton for gasoline and diesel, respectively. Prices almost doubled from 1995 to 2005 and price changes are also similar across cities, which is mostly likely because transportation cost to value ratio for oil is much lower than for coal.

6.4 Reconciling energy reforms and price changes

The market-oriented energy price reforms varied in time and in intensity across energy type. It is likely that energy prices of various fuel sources are not convergent as a whole during the whole study period. We also cannot say that energy prices were convergent under the government perfect regulation even the trends of energy prices statistically look like convergent. It would not be expected that energy prices would be convergent during the transition period. Moreover, statistically, the ADF tests are biased towards the non rejection of a unit root when there are structural breaks in the data (Nelson and Plosser, 1982; Perron, 1989; Enders, 1995). This also urges us to recognize the process of development of a transitional energy economy in China.

In addition, there are significant differences in the characteristics of fuel sources. Some pairs of fuel types, such as coal and electricity[31] and gasoline and diesel, are more likely convergent in their price movement. However, some pairs of fuel types, such as coal and gasoline (or diesel) or electricity and gasoline (or diesel), are less likely to be cointegrated in their price movement due to significant differences in their functions. In this case, we will pay particular attention to the pairs of coal-electricity and gasoline-diesel when we observe the co-movement of their prices.

Identifying the presence of structural breaks is necessary before conducting any statistical tests for fuel price series (Zou and Chau, 2006). The patterns of fuel price changes could mirror the historical energy price reforms. In other words, the historical fuel price reforms should be embodied in the changing patterns of fuel prices. The reason for this section is to identify the changing patterns of fuel prices so as to reconcile them with corresponding historical energy price reforms. In addition, this observation can also provide us rich information on how fuel prices are co-moved.

To show a clearer picture of how the changes of energy prices reconcile corresponding price reforms, we simply transform these highly frequency panel price data sets to four national aggregate level price data series. Figure 6-4 demonstrates

[31] In China, most of electricity is generated from coal.

how prices change over 01/1995-12/2005 for four major fuels in China. As can be seen from Figure 6-4 that energy prices barely change (except for coal) and they seem still regulated in the first two years although 'dual track' pricing system was abandoned for petroleum in May 1994 (but still regulated until June 1998). This is because it was not until June 1998 that China's domestic oil prices were set in accordance with the global price of oil (Hang and Tu, 2007; Wu, 2003), which means that complete oil price deregulation commenced only after June 1998 in China. However, coal prices did rise stably because its price deregulation commenced in 1994.

China's energy prices fluctuated considerably and sometimes apparently irrationally in 1997 and 1998. Therefore, this period might be considered as a transition period. During this period, it seems that each fuel price changed wildly. For example, the coal price jumped from the 12/1996 ¥234 to the 01/1997 ¥260, rising by ¥26 per ton; the diesel price jumped from the 12/1996 ¥2243 to the 01/1997 ¥2693, rising by ¥450 per ton; the gasoline price jumped from the 12/1996 ¥2585 to the 01/1997 ¥2869, rising by ¥284 per ton. The electricity price, with a few months lag, jumped from the 12/1996 ¥355 to the 07/1997 ¥381, continuing to the 01/1998 ¥518, rising by ¥163 per thousand KWh within one year from 12/1996. For electricity and gasoline, their prices jumped seemingly irrationally in 1998 and finally they regressed to their 'normal' trend price. It should be noted during this stage that the coal price remained stable for a long period (until 01/2002) after it suddenly jumped in 12/1996. The reason is not because coal price was regulated again, but because coal supply was redundant in time period so that the government had to close small coal mines and reduce coal output (Wang, 2007).

After 1999, China's energy economy might be treated as a new regime period, during which it seems prices changed smoothly. Reconciling fuel price reforms and features of Figure 6-4, from 1999 to early 2002 may be defined as the early period of the new regime. This period was characterized with the June 1998 complete petroleum price deregulation and without a market-oriented frame of industrial organization (old administrative system still dominated oil market). Two major petroleum companies have been competing for retail market prices since June 1998 (Wu, 2003).

The developing period of the new regime probably commenced in 2002 during which a market-oriented industrial organization was being gradually established. Many key market reforms took place after 2002. For example, it was in 2002 that the government-guided price of coal used in power plants was announced to be cancelled and more freedom has been given to coal producers and buyers (Wang, 2007). The State Power Corporation, a monopoly in the electricity sector, was dismantled on 29 December 2002 and this introduced competition through diversifying the generating entities to lower cost and to improve efficiency (Ma and He, 2008).

It seems unclear whether, when or even if, China's energy market completed its development phase, however, two recent events may suggest that the market-oriented energy economy has fundamentally been setup. Firstly, the China Taiyuan Coal Exchange (TCTE), approved by State Council on 18 June 2007, has been established in Taiyuan to replace the coal ordering meetings between coal producers and power producers (TCTE, 2007). This was probably the toughest reform in China's power industry to be resolved. Secondly, a comprehensive administrative agency, the State Energy Administration (SEA), a division of SDRC, was established in July 2008. Therefore, it is likely that a full competitive energy market system has started to operate in China since then.

Following the major reforms of energy price policies over the last two decades, can we discern evidence of energy prices convergence across markets and cointegration across energy types? The literature, to date, has been unable to address such questions. I will discuss this issue statistically and econometrically in detail in Chapters 9.

Table 6-1. National aggregate energy prices over time

Year	Coal (¥/ton)	Electricity (¥/KWh)	Gasoline (¥/ton)	Diesel (¥/ton)
1995	214	38	2772	2293
1996	231	38	2773	2306
1997	264	40	2876	2612
1998	260	45	3240	2451
1999	247	46	2870	2530
2000	241	48	3640	3305
2001	240	50	3685	3229
2002	261	51	3571	3177
2003	283	54	4154	3516
2004	366	56	4730	3913
2005	414	58	5455	4501
1995-2005:				
% change	93	54	97	96
% growth rate	6.8	4.4	7.0	7.0

Data source: calculated by taking the average of 10-day interval spot price time series published by State Development and Reform Commission of China.

Table 6-2. Energy price changes from 1995 by fuels and cities

City	Coal (¥/ton)		Electricity (¥/KWh)		Gasoline (¥/ton)		Diesel (¥/ton)	
	2005	Δ%	2005	Δ%	2005	Δ%	2005	Δ%
Beijing	408	172	63	87	5345	88	4373	93
Tianjin	370	114	62	56	5486	96	4533	123
Shijiazhuang	387	165	56	33	5469	101	4533	106
Taiyuan	389	227	45	88	5534	116	4549	109
Hohhot	296	104	52	29	5491	96	4539	98
Shenyang	397	61	61	131	5357	103	4556	99
Changchun	475	147	67	86	5270	87	4323	90
Harbin	321	69	56	100	5107	79	4432	94
Shanghai	632	150	71	27	5544	102	4513	94
Nanjing	634	141	68	15	5292	118	4077	90
Hangzhou	501	75	72	30	5502	108	4430	93
Hefei	559	136	57	81	5333	90	4554	94
Fuzhou	523	87	65	6	5592	83	4435	84
Nanchang	374	58	58	95	5297	82	4489	94
Jinan	552	115	56	182	5395	109	4579	112
Zhengzhou	370	123	50	102	5330	85	4566	99
Wuhan	426	106	57	32	5210	81	4406	93
Changsha	490	87	59	36	5367	92	4411	94
Guangzhou	467	69	72	29	5422	102	4361	106
Nanning	369	41	56	135	5476	84	4517	83
Haikou	370	10	60	22	5779	109	4576	86
Chongqing	537	327	57	92	5666	99	4570	74
Chengdu	358	99	58	123	5631	119	4518	116
Guiyang	313	148	49	-32	5614	92	4606	86
Kunming	411	183	50	61	5682	97	4606	93
Lhasa	370	50	56	88	6410	143	5242	129
Xi'an	245	24	52	9	5390	97	4501	100
Lanzhou	168	-17	48	28	5440	96	4556	98
Xining	241	46	42	190	5099	83	4557	102
Yinchuan	270	132	47	12	5404	93	4504	108
Urumqi	135	-24	48	99	5082	99	4360	138

Data source: calculated by taking the average of 10-day interval spot price time series published by State Development and Reform Commission of China.

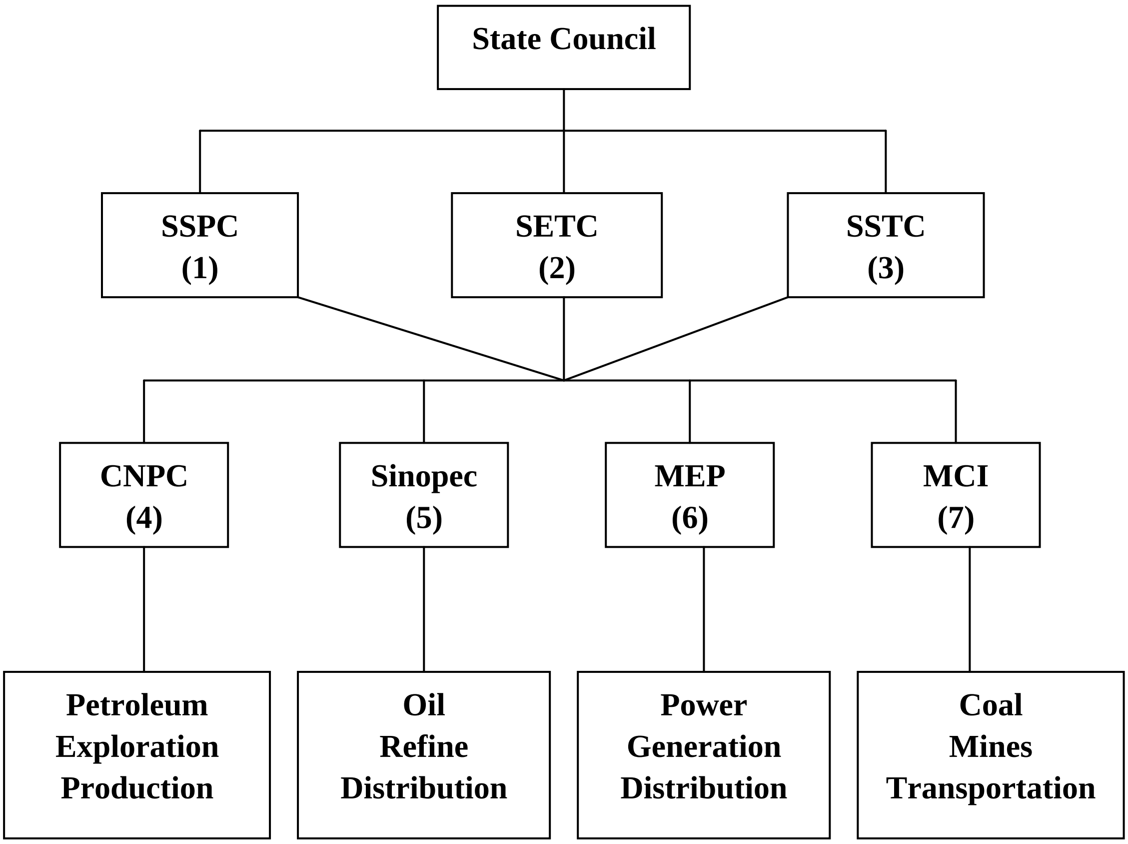


Figure 6-1. Old energy regulatory system set in 1993

Note:
(1) SCSPC - State Planning Commission
(2) SETC - State Economic Trade Commission
(3) SSTC - State Science Technology Commission
(4) CNPC - China National Petroleum Corporation
(5) Sinopec - China Petroleum and Chemical Corporation
(6) MEP - Ministry of Electric Power
(7) MCI - Ministry of Coal Industry

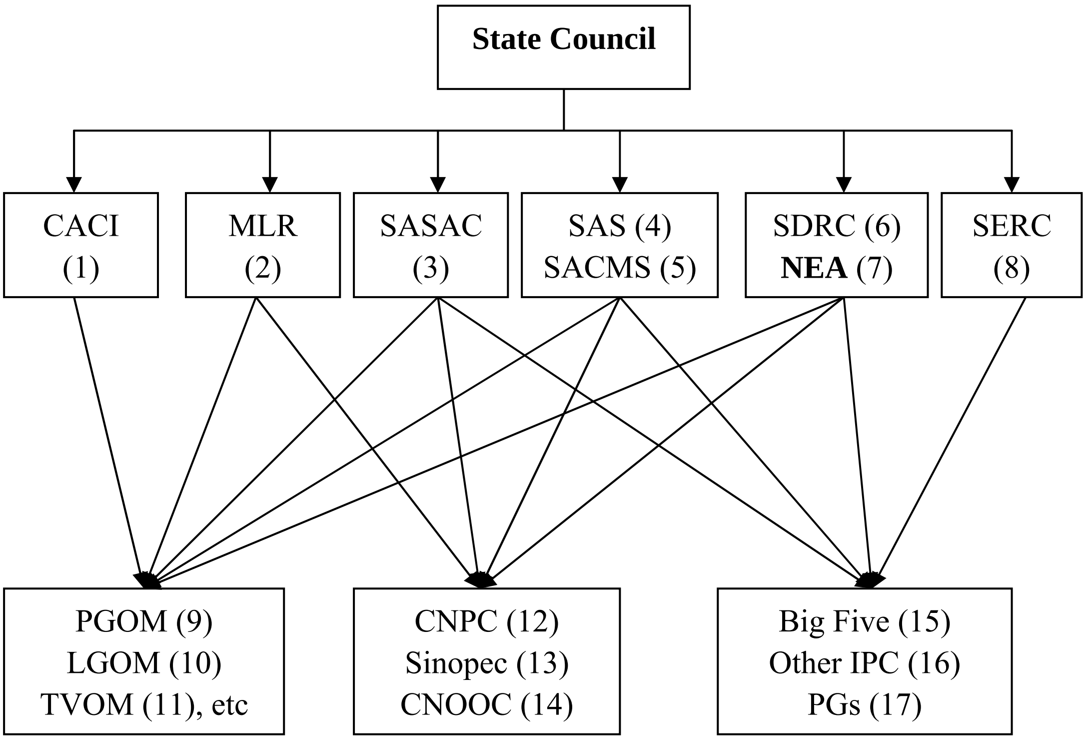


Figure 6-2. New energy regulatory system after 2008

Note:

(1) CACI - China Association of Coal Industry

(2) MLR - Ministry of Land and Resources

(3) SASAC - State-owned Assets Supervision and Administration Commission of State Council

(4) SAWS - State Administration of Work Safety

(5) SACMS - State Administration of Coal Mine Safety

(6) SDRC - State Development and Reform Commission

(7) NEA - National Energy Administration in SDRC set up at August 8, 2008.

(8) SERC - State Electricity Regulatory Commission.

(9) PGOM - Provincial government owned mines

(10) LGOM - Local government owned mines

(11) TVOM - Township and village owned mine enterprises.

(12) CNPC - China National Petroleum Corporation.

(13) Sinopec - China Petroleum and Chemical Corporation.

(14) CNOOC - China National Offshore Oil Corporation.

(15) Big Five - Huaneng Group, Datang Group, Huadian Corporation, Guodian Co. and Power Investment Co.

(16) IPP - Independent Power Plant.

(17) PGs – Power Grids.

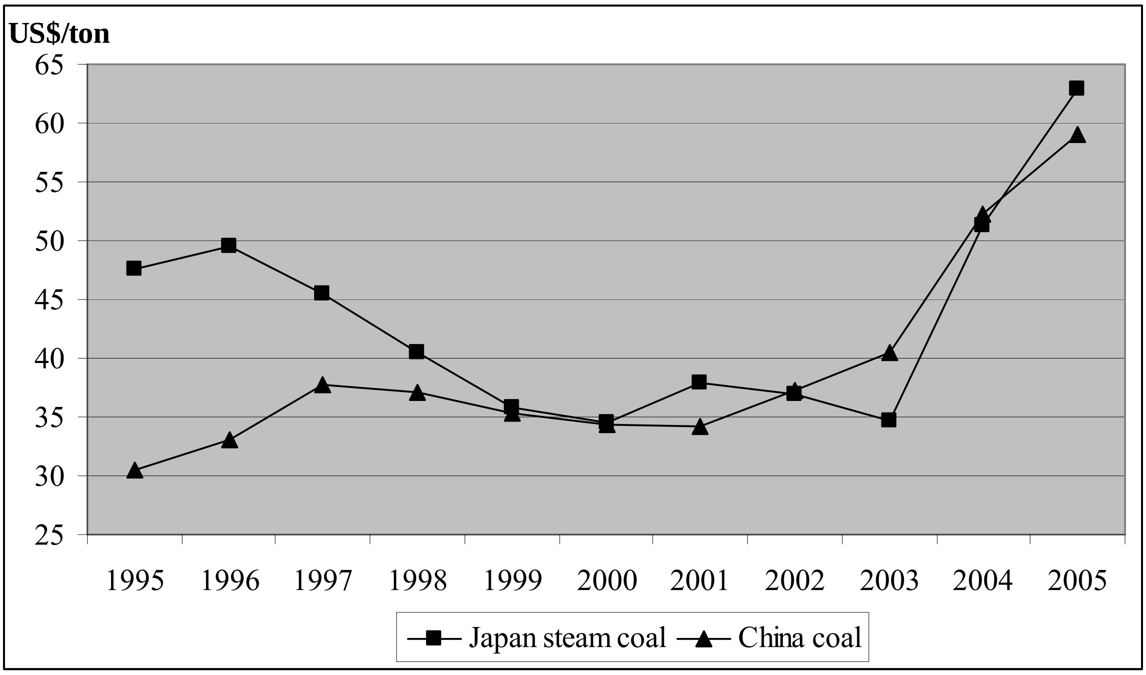


Figure 6-3. Japanese import price and China's domestic prices

Note: Japanese steam coal import cif prices and exchange rate of US$ to ¥ is around to 7.0.
Data source: BP 2008 and State Development and Reform Commission of China.

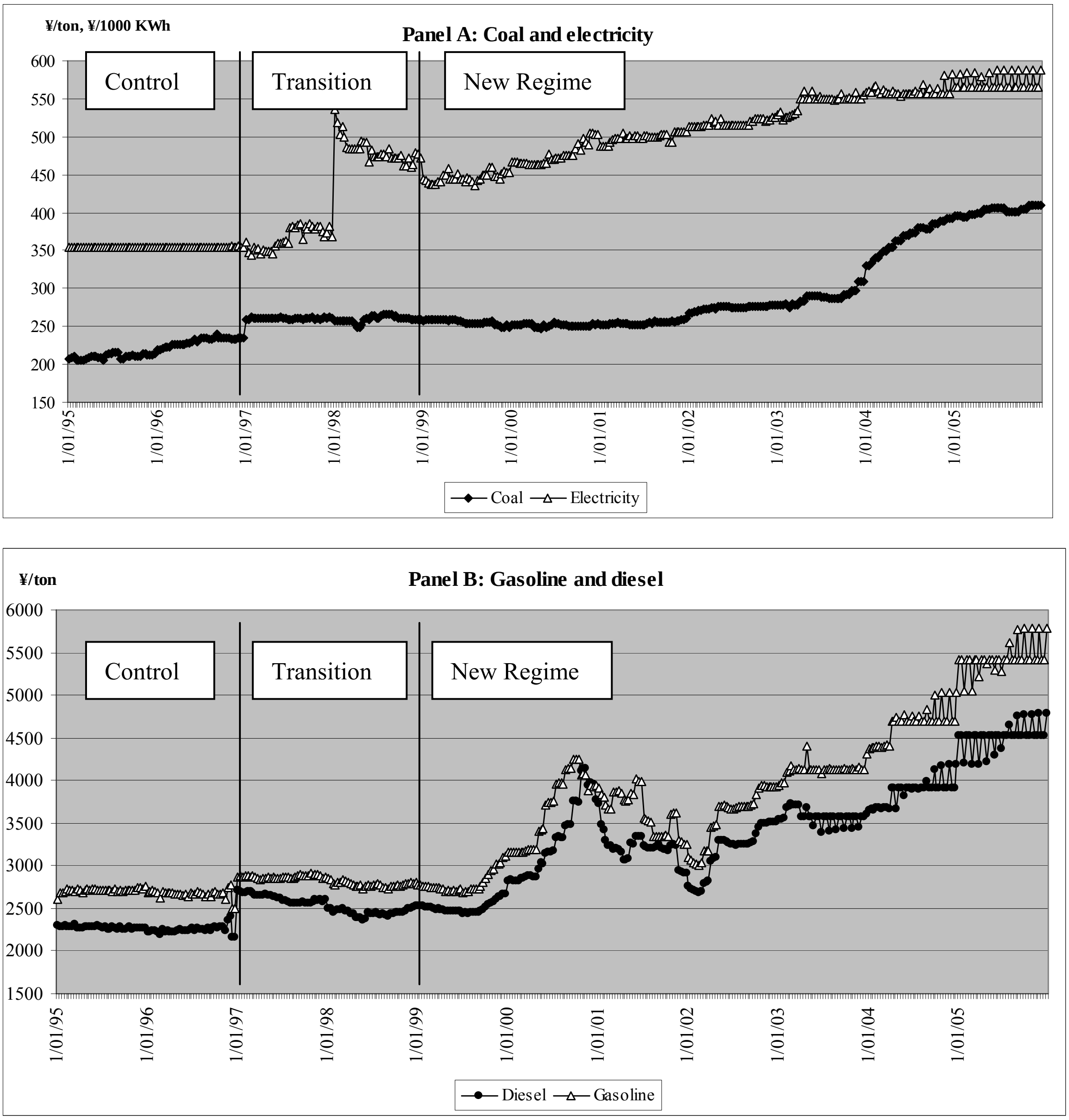


Figure 6-4. Monthly energy price changes over time

Note: Price for coal, gasoline and diesel is ¥/ton and ¥/1000 KWh for electricity over 01/1995-12/2005. Data source: calculated by taking the average of 10-day interval spot prices of 35 major cities published by State Development and Reform Commission of China.

Chapter Seven: Factor Substitution and the Demand for Energy[32]

This chapter will estimate a translog cost function for both the aggregate economy and industrial economy using the methodologies presented in Chapter 4 and the data described in Chapter 5. The estimated elasticities include the substitution of and demand for energy. I will first discuss the estimated results for the aggregate economy followed by results for the regional aggregate economy and national industrial economy. I will then consider the resulting, policy implications of from the results and finally a conclusion for this chapter.

7.1 Estimates for the aggregate economy

To test whether equation (4-34) and equation (4-35) should be chosen as the final functional forms; whether prices are separable; whether consumption behaviors vary across regions; and whether there is significant technological change, we estimate various nested functional forms against equation (4-34) and equation (4-35). It can be seen from Table 7-1 that equation (4-34) and equation (4-35) should be chosen as the final functional forms.

[32] Section 1 of this chapter has appeared in ***Energy Economics*** 2008 (for aggregate economy), Section 2 has appeared in ***Energy Policy*** 2009 (for regional aggregate economy), and Section 3 will appear in ***Environmental Modelling and Software*** 2009 (for national industrial economy).

7.1.1 Inter-factor substitution and demand

Table 7-2 reports the estimated parameters of the translog factor cost function. Recall that the estimation at this stage includes one total factor cost equation and two factor share equations (aggregate energy and capital shares - the labor share equation is dropped from the system due to the adding-up restriction). The conventional R^2 equals 0.99 for the total factor cost equation, 0.97 for the aggregate energy share equation and 0.96 for the capital share equation. The major parameters have the correct sign and more than 50% of parameters are statistically significant. The estimated total factor cost function is well behaved as the input demand function is strictly positive and concave in the input prices (Berndt and Wood, 1975).

Using the estimated parameters reported in Table 7-2 to apply equation (4-20), equation (4-21) and equation (4-22) allows the implied elasticities of substitution (σ_{ij}) and price elasticities (η_{ij}) of factor demand for the interfactor substitution to be calculated. The results of these calculations are shown in Table 7-3, where several important features are apparent.

First, each of the three factors is responsive to a change in their own price, with the magnitude of the elasticities greatest for energy, then capital and then labor. Specifically, the estimated own-price elasticities are η_{EE} = -0.47, η_{KK} = -0.42 and η_{LL} = -0.21. Second, energy and capital appear to be substitutable and the estimated σ_{EK} is 0.80 with cross-price elasticities of η_{EK} = 0.11 and η_{KE} =0.22.

An argument could be made that we might expect energy and capital to be complements. However, the empirical literature to date finds evidence of both complementarity and substitutability. Berndt and Wood (1975), Fuss (1977), and Magnus (1975) find energy and capital to be strong complements. Halvorsen and Ford (1978) and Fuss and Waverman (1975) find 'mixed results' on energy-capital substitutability. Griffin and Gregory (1976) find strong evidence of capital-energy substitutability as does Pindyck (1979). Pindyck (1979) provides two ways to reconcile the capital substitutability and complementarity results. Firstly, some studies may be picking-up short run effects (complementarity) versus long run (substitutability). Secondly, the number of factors in the model may (it seems) affect the results. Berndt and Wood (1977) show that complementarity between two factors in a four-dimensional production space can be consistent with substitutability between the same factors in a three-dimensional space. More recent studies, for example, Caloghirou et al. (1997) for Greece and Cho et. al. (2004) for Korea found a similar degree of substitutability to our results for China (see Table 7-7). Furthermore, in our results, neither the Allen partial elasticity of energy-capital substitution nor the cross-price elasticities η_{EK} and η_{KE} reported here are statistically significant at the 5% level.

The third feature of the results in Table 7-3 is that the substitution possibilities between energy and labor are almost as large as those for capital and energy, and are more statistically significant, with the Allen partial elasticity of substitution, σ_{EL} of 0.61 and the cross-price elasticities, η_{EL} = 0.36 and η_{LE} =0.17. Fourth, capital and labour are only slightly substitutable, with σ_{KL} =0.34 and cross-price elasticities of η_{KL} = 0.20 and η_{LK} =0.05 (all statistically insignificant). Finally, no complementary is found among energy, capital and labor in this study. As in Cho et al. (2004), all the cross-price elasticities are less than one, suggesting that the scope for substituting capital and labor for energy in China is somewhat limited.

There appears to be significant substitution possibilities between energy and labor and they appear quite elastic when compared with international findings. This is potentially good news for China, which is labor abundant, as it suggests that allowing energy prices to rise would tend to reduce energy use and increase labor intensiveness.

Comparing the elasticities of substitution, it is found that they are much larger between energy and capital than between energy and labor. This suggests that capital more easily substitutes for energy than labor does. This finding may reflect the fact that there are more incentives for capital investment and fewer incentives for labor inputs. There has been high capital investment and low unemployment during the recent transition of the economy of China. Most of the regional elasticities of demand for factors are statistically significant, where the elasticities of demand for energy are the largest.

7.1.2 Inter-fuel substitution and demand

Table 7-4 reports the parameters estimates of the fuel share equations for aggregate economy. Only three share equations (coal, gasoline and electricity) are estimated, with the fourth share equation (diesel) dropped from the system due to the adding-up restriction. The conventional R^2 figures are 0.89 for the coal share equation, 0.91 for the gasoline share equation, and 0.98 for the electricity share equation. The major parameters also have the correct sign and are statistically significant. The estimated share equations were also checked and found to be well behaved as all the input demand functions are strictly positive and concave in input price.

Based on the estimated parameters reported in Table 7-4, and again using equation (4-20), equation (4-21) and equation (4-22), the implied elasticities of substitution (σ_{ij}) and price elasticities (η_{ij}) of fuel demand for China are calculated and the results are presented in Table 7-5, from which several important features can be seen:

- Coal and electricity have substantial substitution possibilities – the estimated σ_{CO-EL} =1.49 (with a standard error of 0.19);[33]
- In contrast, coal and diesel appear to be complementary – the estimated σ_{CO-DI} = -1.79 (with a standard error of 0.60) while the complementarity between coal and gasoline is smaller and imprecisely estimated (σ_{CO-GA}= -0.82 with a standard error of 0.53);
- Gasoline and electricity are slightly significantly substitutable – the estimated σ_{GA-EL} =0.60;
- Likewise, electricity and diesel are slightly significantly substitutable – the estimated σ_{EL-DI} =0.68.

At the policy level, these results have potentially important implications. If coal and electricity are substitutes as suggested above, China would have the potential to

[33] There may be a double counting problem since much of the coal consumed in China is used to generate electricity. However, any double counting problem will become less serious over time because large industrial plants increasingly use more electricity from the outside network with coal used only for their boilers. As for power plants, they mainly use coal to generate electricity and use minimal electricity for their own consumption. We thank the referee for pointing out this issue.

switch from the greenhouse-gas emitting coal to electricity, hence retaining the ability to use energy in economic development and reduce the environmental implications.

This finding of substitutability between coal and electricity appears to be consistent with China's changing situation. For example, central heating systems have been constructed in medium and large cities, reducing household reliance on coal. Environmental regulation has also reduced the ability of private companies to directly produce electricity using coal. In fact, annual growth rates of consumption by final users were more than 8% for electricity, but less than 4% for coal according to the 2005 China Statistical Yearbook. Firms are also moving away from self-generation of electricity and instead purchasing electricity from the grid (which is produced more efficiently). We would therefore expect to see some reduction in carbon emissions due to these improvements in the efficiency of generation. There are also possibilities of substitution from gasoline and diesel to electricity, although on a somewhat smaller scale. However, all of these implications could, to some extent, be undermined by the use of coal (and less problematically oil) in the production of electricity, something we cannot measure using the data that we have.

The most elastic substitution between coal and electricity may appear to have implications for environmental taxes, since increasing these could reduce the coal consumption and correspondingly encourage electricity consumption. But since almost 80% of coal consumed in China is used for generation of electricity the net effect of such taxes on greenhouse gas emissions might be smaller than expected. Second, any shift from coal to electricity has implications for investment patterns since it requires transmission lines for electricity rather than (or in addition to) railways for moving coal.

Somewhat unexpectedly, there do not appear to be significant substitution possibilities between gasoline and diesel (σ=-0.01). This may reflect the cost of switching capital in the transport sector (e.g. replacing petrol engines with diesel) and also that there is little movement in the relative prices of these two fuels (e.g., price movements have been almost the same for the two fuels in all regions, refer to in Table 6-2 of Chapter Six).

Looking forward, the estimated substitution parameters and the fact that electricity consumption is growing at twice the rate of coal imply likely changes in the future structure of the Chinese economy. First, since coal is abundant domestically, movement away from this energy source suggests that there will either be even more reliance on imported sources of energy to fuel power stations (noting the limited role of trans-border trade in electricity for China) or a reliance on new sources of generation. Second, because electricity benefits much more from efficient transmission and inter-regional trade than coal, due to the ease of coal storage, growing reliance on electricity can be expected to further advance the integration of the domestic Chinese energy market (See Ma, Oxley and Gibson, 2007).

The computed values of the fuel-price elasticities are displayed in Table 7-5. It can be seen that all the own-price elasticities of fuel demand are negative. It is also obvious that coal and electricity display the highest own-price elasticities (0.535 and 0.405, respectively) and are statistically significant. However, gasoline and diesel show much smaller own-price elasticites (0.214 and 0.108, respectively) and are statistically insignificant.

Total own- and cross-price elasticities of fuel demand are presented in Table 7-6, which provides several notable conclusions:

- The estimated results suggest that some fuel sources are substitutable while others are complementary. For example, coal-gasoline, gasoline-diesel and coal-diesel are all complementary, while electricity-diesel and gasoline-electricity are substitutable;
- The fuel demands of coal and electricity are more sensitive to their own price changes than of gasoline and diesel. In other words, the former are elastic while the later are inelastic;
- Electricity demand is more sensitive to coal-price change than to gasoline- and diesel-price change, η^*_{EI-CO} =0.597 and η^*_{EI-GA} =0.072 and η^*_{EL-DI} =0.123. This finding implies that in the long run, a coal-price change has greater effect on electricity demand rather than a gasoline-price change;
- Diesel demand is more sensitive to coal-price change than to gasoline-price change, η^*_{DI-CO} = -0.314 and η^*_{DI-GA} = - 0.067;

As there is no similar study on China with which to compare our estimated results, Table 7-7 lists similar estimates for South Korea, West Germany, Greek, Portugal and Spain. However, these are for periods ten years older that those of this study. It can be seen from that Table that some estimates are quite similar, while some are quite different, not only the magnitudes, but also the signs.

7.2 Estimates for the regional aggregate economy

7.2.1 Inter-factor substitution and demand

Again using the estimated parameters (Table 7-2) and the factor shares reported in Table 7-8 allows calculation of the implied elasticities of substitution (σ_{ij}) and price elasticities (η_{ij}) of factor demand.[34] Here we only focus on the substitution and demand elasticities of interest. The results of these calculations are shown in Table 7-9. The following observations focus on the substitution and own-price elasticities that are relevant to energy and are statistically significant.

Possible substitution of energy for capital is implied by results for regions 2, 3 and 7. These suggest that the removal of price ceilings on energy would tend to reduce energy use and increase capital intensiveness. The types of substitution possibilities that arise here could involve, for example, manual operation, semi-mechanical and some automated production processes, excavation, etc. As noted by Liao, Fan and Wei (2007), energy consumption is sensitive to capital investment in China. Therefore, reducing energy consumption is closely related to the types of capital investment.

There are substitution possibilities between energy and capital only in regions 2, 3 and 7, with similarly-sized elasticities, ranging from 0.85 to 0.90. This means that substitution possibilities for energy-capital are regional rather than national, mainly

[34]Empirically, Gross Domestic Products (GDP) has four components: compensation of employees, depreciation of fixed assets, net tax on production and operating surplus, which account for 40-50%, 13-15%, 13-15 and 20% of GDP, respectively, from 1996-2006 for China. The compensation of employees accounts for more than 70% of GDP. This means China invests more and consumes less, while USA consumes more and invests less in terms of GDP composition.

located in the center and northern areas (refer to regional classification of Figure 1-4 in Chapter One). In contrast, substitution possibilities between energy and labor arise for all regions as all elasticities are statistically significant. This is an interesting finding given labor abundance and rising energy costs in all regions. However, it should be noted that the elasticities of substitution between energy and labor are inelastic and relatively small.

Comparing the elasticities of substitution, we find that they are much larger between energy and capital than between energy and labor. This suggests that capital more easily substitutes for energy than labor does. This finding may reflect the fact that there are more incentives for capital investment and fewer incentives for labor inputs. There has been high capital investment and low unemployment during the recent transition of the economy of China. Most of the regional elasticities of demand for factors are statistically significant, where the elasticities of demand for energy are the largest, although still inelastic.

7.2.2 Inter-fuel substitution and demand

We follow the same procedure used above, but here we consider interfuel substitution possibilities and the elasticities of demand for fuels. These estimated elasticities are presented as Table 7-10. The follow observations focus only on substitution and own-price elasticities that are statistically significant.

There are statistically significant substitution possibilities between coal and electricity, while there are statistically significant complementaries between coal and diesel for all seven regions. It is also found that their elasticities of both substitution and complementarity are elastic, ranging from 1.38 in region 1 to 1.66 in region 2 for coal and electricity, and from -1.36 in region 3 to -2.68 in region 2 for coal and diesel.

These patterns may reflect several features of China; first the substitutability of coal and electricity is consistent with these two energy sources having nationwide consumption. Second, these findings may be related to regional energy production and preferential policy, in particular, the substitution of coal-electricity is slower in coal producing areas (e.g., region 1), while it is faster in non-coal producing areas (e.g., region 2, including Beijing Tianjin and Shanghai (refer to Table 1-3 of Chapter One) due, in part, to environmental regulation. However, it should be noted that coal and petroleum products are complementary in some regions in China. For example, the largest complementarity of coal-diesel can be found in region 2 (-2.68, Beijing, Tianjin and Shanghai), while the smallest can be found in region 3 (-1.36, three northeast provinces).

Amongst the two fuels with statistically significant own-price elasticities, the inter-regional variation in fuel demand elasticities is smaller than was the inter-regional variation in factor demand elasticities. Hence variation in individual fuel prices may be expected to have less impact on the regional structure of China's economy than will changes in overall energy price levels.

7.3 Estimates for the national industrial economy

To test whether equation (4-34) and equation (4-35) should be considered the final functional forms, prices are of separable, consumption behavior vary across regions, and there is potential technological change, we estimate the nested functional forms (varying based on the particular assumptions made) against equation (4-34) and equation (4-35) and the results are displayed in Table 7-11.

7.3.1 Inter-factor substitution and demand

The translog factor cost function and share equations results are presented as Table 7-12. At this stage, estimation includes one total factor cost equation and two factor share equations (the labor share equation is dropped from the system due to the adding-up restriction). The results show a conventional R^2 of 0.99 for the total factor cost equation, 0.96 for the aggregate energy share equation and 0.98 for the capital share equation. The major parameters have the correct sign and more than 50% of parameters are statistically significant. The estimated total factor cost function is well behaved as the input demand function is strictly positive and concave in the input price (Berndt and Wood, 1975).

Based upon the results from Table 7-12 we apply equation (4-20), equation (4-21) and equation (4-22) from which we calculate the implied elasticities of substitution (σ_{ij}) and price elasticities (η_{ij}) of factor demand for the interfactor substitution. The results of these calculations are presented as Table 7-13 and several points can be drawn:

- That each of the three factors is responsive to a change in their own price where η_{EE} = -0.34, η_{KK} = -0.51 and η_{LL} = -0.38.
- Energy and capital appear to be substitutable; σ_{EK} is 0.67 and the cross-price elasticities are calculated to be η_{EK} = 0.16 and η_{KE} =0.27.[35]
- Substitution possibilities between energy and labour are almost as large as those for capital and energy, and are more statistically significant, with the Allen partial elasticity of substitution, σ_{EL} of 0.51 and the cross-price elasticities, η_{EL} = 0.18 and η_{LE} =0.21.
- Capital and labour are substitutable, with σ_{KL} =0.68 and cross-price elasticities of η_{KL} = 0.23 and η_{LK} =0.17.
- Finally, no complementary is found among energy, capital and labour in this study. As in Cho et al. (2004), all the cross-price elasticities are less than one, suggesting that the scope for substituting capital and labor for energy in China's industrial sector is somewhat limited although they all are statistically significant.

7.3.2 Inter-fuel substitution and demand

Table 7-14 presents the results of the fuel share equations. Three share equations (coal, electricity and oil) are estimated, with the third share equation (oil)[36] dropped from the system due to the adding-up restriction. For the coal share equation the R^2 measure of fit is 0.76; 0.81 for the electricity share equation. The main parameters

[35] One might expect energy and capital to be complements. However, the empirical literature finds evidence both ways. Berndt and Wood (1975), Fuss (1977), and Magnus (1979) find energy and capital to be strong complements. Halvorsen and Ford (1978) and Fuss and Waverman (1975) find 'mixed results' on energy-capital substitutability. Griffin and Gregory (1976) find strong evidence of capital-energy substitutability as does Pindyck (1979).

[36] For industrial economy, we aggregate gasoline and diesel into oil because both of their consumptions are very small.

also have the correct sign and are statistically significant. The estimated share equations were also checked and found to be well behaved as all the input demand functions are strictly positive and concave in input price.

From Table 7-14 and again using equation (4-20), equation (4-21) and equation (4-22), the implied elasticities of substitution (σ_{ij}) and price elasticities (η_{ij}) of fuel demand for the industry sector in China are calculated and the results are presented in Table 7-15 and several points can be drawn:

- Coal and electricity have substitution possibilities – the estimated σ_{CO-EL}=0.90, which closes to one (with a standard error of 0.13);
- Coal and oil appear to be slightly complementary, but insignificant – the estimated σ_{CO-OI}= -0.43 (with a standard error of 0.69);
- Oil and electricity are slightly substitutable but insignificant– the estimated σ_{EL-OI}=0.44 (with a standard error of 0.28).

If coal and electricity are substitutes, China would have the potential to switch from the greenhouse-gas emitting coal to electricity, hence retaining the ability to use energy in economic development and reduce the environmental implications. The main caveat here is the high proportion of electricity is currently produced from coal. However, environmental regulation has reduced the ability of private companies to directly produce electricity using coal leading to firms to move away from self-generation of electricity and instead purchasing electricity from the grid. We would therefore expect to see some reduction in carbon emissions due to these improvements in the efficiency of generation.

Table 7-15 also presents fuel-price elasticities. From those results it can be seen that all the own-price elasticities of fuel demand are negative. It is also clear that coal displays the highest own-price elasticities (0.60) and is also statistically significant. Electricity and oil show similar small own-price elasticites (0.22 and 0.23, respectively) but only the former is statistically significant.

Total own- and cross-price elasticities of fuel demand are presented in Table 7-16 and several points can be drawn:

- Coal-oil and oil-coal are all complementary (negative sign), while coal-electricity and electricity-oil are substitutable (positive sign);
- The fuel demands of coal and electricity are more sensitive to their own price change than of oil.
- Electricity demand is more sensitive to the coal-price change than to the oil-price change, η^*_{EL-CO}=0.39 and η^*_{EL-OI}=0.06. This finding implies that in the long run, a coal-price change has greater effect on electricity demand rather than an oil-price change.

7.4 Further discussion

Factor use varies across regions, with labor's share of total factor cost ranging from (45% in region 2 to 64% in region 1, energy shares ranging from 25% in region 1 to 31% in region 2 and capital shares ranging from 11% (regions 1,5 and 6) to 24% in region 2. These regional differences in substitution of and demand for energy are related to the regional economy and energy production, for example, region 2 has a different pattern of factor costs from others as this region includes Beijing, Tianjin and Shanghai, which are China's three major municipalities so that they enjoy more special regional policies and high investment and economic growth rates which raises their capital and energy shares. Comparing the regional energy production and balance sheet with the energy shares, it can be easily found that energy cost composition is closely related to regional energy resources. The most evident example is coal. For example, region 1 has the largest coal share (20%) because this region is China's major coal production base. Conversely, with more environmental concerns and priority policy, region 2 has the lowest coal share (11%).

Theoretically, regional elasticities of substitution and demand are related to regional cost composition and relative price change. For example, it can be seen from equation (4-20), equation (4-21) and equation (4-22) that if parameters (β_{ij}) are negative, the relations (substitutable or complementary) between factors are dependent upon the product of factor cost shares. The two factors appear to be complementary if the product of their cost shares is small enough to make the absolute value of $\beta_{ij} / S_i S_j$ greater than one, while they become substitutable if the product of their cost shares is large enough to make the absolute value of $\beta_{ij} / S_i S_j$ less than one. If the parameters (β_{ij}) are positive, the factors are substitutable and their elasticities are dependent upon their cost shares. It is clear that the composition of factor cost determines not only the relations (either substitutable or complementary) between factors, but the magnitudes of their elasticities of either substitution or complementarity. In this study, the elasticity of substitution between energy and capital is largest in region 2, the largest (0.90), because the factor cost shares of energy and capital are largest in region 2. The same can be found for the substitution between energy and labor in region 6 and between capital and labor in region 2. The same ideas can be used to understand the substitutability or complementarity between fuels across regions. For example, because the estimated parameters (β_{ij}) are positive and fuel cost shares large, coal and electricity are extremely substitutable for all regions, the largest substitution elasticity (1.66) is found in region 2 where the largest product of coal and electricity cost shares is identified. In contrast, because the estimated parameters (β_{ij}) are negative and their fuel cost shares smaller, coal and diesel are highly complementary for all regions, the largest complementarity elasticity (-2.68) found in region 2 which has the smallest product of coal and diesel cost shares. It is odd not to find any substitutable relation between gasoline and diesel in any region, as the estimated positive parameters (β_{ij}) is insignificant and the estimated elasticities small.

7.5 Conclusions and implications

We calculate the effects of technological change, factor demand and inter-factor and inter-fuel substitutability in China using a new and appropriate dataset and rigorous econometric methods. In particular, we use individual fuel price data and a two-stage approach to estimate total factor cost functions and fuel share equations where the estimated parameters are used to calculate implied elasticities of substitution (σ_{ij}) and price elasticities (η_{ij}) for inter-factor substitution and inter-fuel substitution.

A central issue for energy policy design, planning and analysis is the extent to which other factors can substitute for energy in the economy and the effects of such substitution on future economic growth. Until now, results on Chinese inter-factor and inter-fuel substitution possibilities inputs were unavailable, especially at the regional level. The research presented above helps fill this important gap and contribute to the body of knowledge.

The results suggest that there are significant substitution possibilities between energy and labor. This finding is relevant in a country like China facing labor abundance and rising energy costs. The possibility of substituting energy for capital is identified only locally in regions 2, 3 and 7. The elasticities of substitution between energy and labor are less than those between energy and capital. This suggests that labor is less of a substitute for energy than is capital. Addressing this issue, within a sustainability agenda, is an important task for the Chinese government given the abundance of labor forces. Recalling the results of Hogan and Manne (1977) cited in the Introduction, we found that the elasticity of substitution between energy and aggregate all other non-energy factors is approximately 0.60. This implies that economic growth in China to the year 2010 would be predicted to be only slightly impeded by even dramatic constraints on growth in energy supply. Likewise, regional economic development would not be impeded by constraints on the supply of energy as most of the elasticities of substitution between energy and non-energy are over 0.50.

There are many factors responsible for the inelasticity of demand for energy. However, the levels of energy prices and regional variations appear to be some of the most important causes. Therefore, energy price reform and deregulation remain an important challenge for the Chinese government. However, the estimated small elasticities of demand for fuels mean that rising fuel prices by themselves may not constrain energy consumption at present in China. Therefore, some other energy policies should also be used in order to encourage or depress some certain types of energy consumption.

Although this section has provided some new data on the substitution possibilities between energy and non-energy, it represents work in progress. More research is required to consider questions, such as why are the elasticities of substitution between energy and labor much less than those between energy and capital?

In summary we find that energy is Allen substitutable for all capital and labor. This is a good new for China given present energy situation above, potential labor forces and investment opportunities in energy industry. Some fuel sources are substitutable, while our results suggest that others are complementary. This is most likely consistent with the fact that China is being in its transactional economy. All factor inputs might be desperately needed.

Table 7-1. Maximum likelihood ratio tests for model specification

The assumptions for the nested function forms to be tested	Critical values		# Restrictions	χ^2 Statistics
	5%	1%		
Against equation (4-34):				
1. $\sum D_R \ln P_i = 0$	27.6	33.4	17	344.4***
2. $\sum \ln P_i t = 0$ and $\sum D_R \ln P_i t = 0$	23.7	29.1	14	231.4***
3. $\sum D_R \ln P_i t = 0$	21.0	26.2	12	104.7***
4. $\sum \ln P_i \ln P_j = 0$	7.8	11.3	3	35.0***
5. $\sum D_R \ln Y = 0$ and $\sum D_R (\ln Y)^2 = 0$	21.0	26.2	12	122.3***
6. $\sum D_R t = 0$ and $\sum D_R tt = 0$	21.0	26.2	12	49.7***
7. $\sum D_R t \ln Y = 0$	12.6	16.8	6	48.2***
8. $\sum D_R = 0$	12.6	16.8	6	86.7***
Against equation (4-35):				
9. $\sum D_R = 0$	28.9	34.8	18	116.1***
10. $t = 0$ and $\sum D_R t = 0$	28.9	34.8	18	84.1***
11. $\sum D_R t = 0$	25.0	30.6	15	32.4***
12. $\sum \ln P_j = 0$	12.6	16.8	6	38.4***

Note: The null hypotheses relate to any two of price, output and time variables are separable; the null hypotheses for regional dummy variables are "there are no significant differences in production behavior across regions." The tests for model specification include the separability of prices and incorporation of regional dummy variables for nested functions against equation (4-34) and equation (4-35).

*** denotes significant at the 1% level.

Table 7-2. The estimated coefficients for total factor cost function

Variable	Coeff.	t-stat.	Variable	Coeff.	t-stat.	Variable	Coeff.	t-stat.
P_E	0.287	3.62	P_LD_4	-0.991	-5.42	P_EtD_3	-0.003	-0.79
P_K	0.287	4.54	P_LD_5	0.024	0.09	P_EtD_4	-0.001	-0.42
P_L	0.426	4.38	P_LD_6	-0.004	-0.03	P_EtD_5	0.004	1.28
P_EP_E	0.070	3.62	YD_1	5.359	1.23	P_EtD_6	0.008	2.64
P_EP_K	-0.007	-0.42	YD_2	-8.549	-2.93	P_KtD_1	-0.015	-4.84
P_EP_L	-0.062	-3.70	YD_3	-3.149	-2.39	P_KtD_2	-0.023	-7.59
P_KP_K	0.061	2.48	YD_4	0.434	0.64	P_KtD_3	-0.006	-2.20
P_KP_L	-0.054	-3.31	YD_5	-4.762	-5.46	P_KtD_4	0.003	1.24
P_LP_L	0.116	5.20	YD_6	1.853	1.44	P_KtD_5	-0.002	-0.94
Y	0.628	0.96	tD_1	-0.541	-1.41	P_KtD_6	-0.003	-1.28
YY	0.025	0.29	tD_2	0.651	2.31	P_LtD_1	0.014	2.92
P_EY	-0.009	-0.87	tD_3	0.190	1.18	P_LtD_2	0.018	3.88
P_KY	-0.021	-2.60	tD_4	0.002	0.02	P_LtD_3	0.008	2.08
P_LY	0.030	2.40	tD_5	0.370	3.61	P_LtD_4	-0.002	-0.46
T	0.050	0.60	tD_6	-0.136	-0.99	P_LtD_5	-0.002	-0.44
Tt	0.003	0.81	P_EYD_1	0.040	1.90	P_LtD_6	-0.005	-1.33
P_Et	0.010	4.59	P_EYD_2	-0.035	-1.60	YYD_1	-0.769	-1.25
P_Kt	-0.001	-0.38	P_EYD_3	0.091	5.89	YYD_2	1.201	2.99
P_Lt	-0.009	-3.54	P_EYD_4	0.049	4.06	YYD_3	0.411	2.35
Yt	-0.013	-1.18	P_EYD_5	-0.052	-3.61	YYD_4	-0.038	-0.42
P_ED_1	-0.233	-1.56	P_EYD_6	-0.032	-2.52	YYD_5	0.667	5.52
P_ED_2	0.269	1.63	P_KYD_1	0.049	2.96	YYD_6	-0.324	-1.51
P_ED_3	-0.704	-5.88	P_KYD_2	0.195	11.0	ttD_1	-0.004	-0.48
P_ED_4	-0.360	-3.93	P_KYD_3	0.052	4.21	ttD_2	0.008	1.14
P_ED_5	0.358	3.43	P_KYD_4	-0.022	-2.29	ttD_3	0.012	1.95
P_ED_6	0.189	2.09	P_KYD_5	0.029	2.49	ttD_4	-0.002	-0.46
P_KD_1	-0.168	-1.41	P_KYD_6	0.017	1.72	ttD_5	0.007	1.46
P_KD_2	-1.327	-10.1	P_LYD_1	-0.089	-3.48	ttD_6	-0.007	-1.22
P_KD_3	-0.377	-3.96	P_LYD_2	-0.159	-5.88	YTD_1	0.079	1.48
P_KD_4	0.150	2.07	P_LYD_3	-0.143	-7.56	YtD_2	-0.096	-2.47
P_KD_5	-0.212	-2.54	P_LYD_4	-0.027	-1.83	YtD_3	-0.036	-1.62
P_KD_6	-0.075	-1.04	P_LYD_5	0.023	1.32	YtD_4	0.005	0.38
P_LD_1	-0.117	-0.34	P_LYD_6	0.015	0.94	YtD_5	-0.055	-3.81
P_LD_2	1.229	5.37	P_EtD_1	0.001	0.33	YtD_6	0.027	1.22
P_LD_3	2.350	7.15	P_EtD_2	0.005	1.31			

Note: All variables are measured in natural logarithms, P and Y represent price and output, and D represents regional dummy variables. Regional dummy variables and constant term are not shown in the table.

Table 7-3. The elasticities of factor substitution and demand from total factor cost function

Substitution/demand	Elasticities	Standard Error
σ_{EE}	-1.7229**	0.2574
σ_{EK}	0.8034	0.5102
σ_{EL}	0.6130**	0.1198
σ_{KK}	-3.0342**	0.9237
σ_{KL}	0.3384	0.2168
σ_{LL}	-0.3646**	0.0645
η_{EE}	-0.4715**	0.0704
η_{EK}	0.1109	0.0643
η_{EL}	0.3606**	0.0615
η_{KE}	0.2199	0.1275
η_{KK}	-0.4189**	0.1784
η_{KL}	0.1991	0.1177
η_{LE}	0.1678**	0.0286
η_{LK}	0.0467	0.0276
η_{LL}	-0.2145**	0.0380

Note: E denotes aggregate energy, K denotes capital and L denotes labor. These elasticities are estimated based on equations 4-20, 4-21 and 4-22 and the mean of each factor share. S_E=0.2727, S_K=0.1381 and S_L=0.5882.
** Denotes significant at the 5% level.

Table 7-4. The estimated coefficients of fuel shares from aggregate energy price function

Coal			Gasoline			Electricity			Diesel		
Variable	Coeff.	t-stat.	Variable	Coeff.	t-stat.	Variable	Coeff.	t-stat.	Variable	Coeff.	t-stat.
Cons	0.278	26.70	Cons	0.080	12.59	Cons	0.574	44.41	Cons	0.068	7.71
D_1	-0.081	-3.85	D_1	0.026	2.04	D_1	0.022	0.84	D_1	0.033	1.83
D_2	0.004	0.18	D_2	0.048	3.73	D_2	-0.101	-3.83	D_2	0.050	2.77
D_3	-0.056	-2.93	D_3	0.008	0.71	D_3	0.004	0.18	D_3	0.043	2.68
D_4	-0.086	-4.87	D_4	0.028	2.66	D_4	-0.009	-0.42	D_4	0.066	4.46
D_5	0.004	0.21	D_5	0.019	1.89	D_5	-0.029	-1.39	D_5	0.006	0.45
D_6	-0.090	-4.75	D_6	0.071	6.11	D_6	-0.010	-0.43	D_6	0.030	1.83
P_1	0.051	2.74	P_1	-0.035	-3.41	P_1	0.046	2.65	P_1	-0.062	-4.62
P_2	-0.035	-3.41	P_2	0.079	3.42	P_2	-0.028	-1.97	P_2	-0.017	-0.80
P_3	0.046	2.65	P_3	-0.028	-1.97	P_3	0.007	0.24	P_3	-0.026	-1.35
P_4	-0.062	-4.62	P_4	-0.017	-0.80	P_4	-0.026	-1.35	P_4	0.104	4.40
T	-0.011	-6.17	t	-0.001	-0.87	t	0.010	5.07	t	0.002	1.06
tD_1	0.000	0.03	tD_1	0.002	1.11	tD_1	-0.001	-0.22	tD_1	-0.001	-0.50
tD_2	-0.009	-2.49	tD_2	0.001	0.55	tD_2	0.009	1.93	tD_2	-0.001	-0.34
tD_3	0.000	0.11	tD_3	0.000	0.13	tD_3	-0.001	-0.22	tD_3	0.000	0.09
tD_4	0.001	0.39	tD_4	0.001	0.63	tD_4	-0.002	-0.50	tD_4	0.000	-0.17
tD_5	-0.003	-0.99	tD_5	0.001	0.93	tD_5	-0.001	-0.42	tD_5	0.003	1.12
tD_6	0.010	3.22	tD_6	-0.006	-3.37	tD_6	-0.004	-0.97	tD_6	0.000	0.06

Note: Coefficients for the diesel share are calculated based on the adding-up restriction. Prices are measured in terms of logarithms.

Table 7-5. The elasticities of substitution and demand from aggregate energy price function

Substitution	Elasticities	Standard Error	Demand	Elasticities	Standard Error
σ_{CO-CO}	-3.2666**	0.7140	η_{CO-CO}	-0.5249**	0.1147
σ_{CO-GA}	-0.8175	0.5338	η_{CO-GA}	-0.1314**	0.0632
σ_{CO-EL}	1.4948**	0.1869	η_{CO-EL}	0.2402**	0.1088
σ_{CO-DI}	-1.7908**	0.6043	η_{CO-DI}	-0.2878**	0.0838
σ_{GA-GA}	-1.8035	1.6485	η_{GA-CO}	-0.0968	0.0858
σ_{GA-EL}	0.5951**	0.2052	η_{GA-GA}	-0.2137	0.1953
σ_{GA-DI}	-0.0099	1.2603	η_{GA-EL}	0.0705	0.1195
σ_{EL-EL}	-0.6964**	0.0896	η_{GA-DI}	-0.0012	0.1748
σ_{EL-DI}	0.6826**	0.2346	η_{EL-CO}	0.8702**	0.0300
σ_{DI-DI}	-0.7814	1.2348	η_{EL-GA}	0.3464**	0.0243
			η_{EL-EL}	-0.4054**	0.0522
			η_{EL-DI}	0.3973**	0.0326
			η_{DI-CO}	-0.2484**	0.0971
			η_{DI-GA}	-0.0014	0.1493
			η_{DI-EL}	0.0947	0.1366
			η_{DI-DI}	-0.1084	0.1713

Note: CO, GA, EL and DI denote coal, gasoline, electricity and diesel, respectively; The elasticities are estimated based on equations 4-20, 4-21 and 4-22 and the mean of each fuel share. S_C=0.1607, S_G=0.1185, S_E=0.5821 and S_D=0.1387.
** denotes significant at the 5% level.

Table 7-6. Total elasticities of demand for fuels from aggregate energy price function

Demand	Elasticities	Demand	Elasticities
η^*_{CO-CO}	-0.6007	η^*_{EL-CO}	0.5956
η^*_{CO-GA}	-0.2072	η^*_{EL-GA}	0.0718
η^*_{CO-EL}	0.1644	η^*_{EL-EL}	-0.6800
η^*_{CO-DI}	-0.3635	η^*_{EL-DI}	0.1228
η^*_{GA-CO}	-0.1527	η^*_{DI-CO}	-0.3139
η^*_{GA-GA}	-0.2695	η^*_{DI-GA}	-0.0668
η^*_{GA-EL}	0.0146	η^*_{DI-EL}	0.0293
η^*_{GA-DI}	-0.0571	η^*_{DI-DI}	-0.1738

Note: CO, GA, EL and DI denote coal, gasoline, electricity and diesel, respectively. The elasticities are estimated based on equations 4-20, 4-21 and 4-22 and the mean of each fuel share. S_C=0.1607, S_G=0.1185, S_E=0.5821 and S_D=0.1387.

Table 7-7. Comparison of elasticities of factor substitution and demand

Elasticity	China (1995-04)	South Korea (1981-97)	West Germany (1976-94)	Greece (1970-90)	Portugal (1980-96)	Spain (1980-96)
σ_{EE}	-1.723	4.850	-	-	-3.73	-0.729
σ_{EK}	0.803	0.783	-0.399	0.972	0.893	-0.012
σ_{EL}	0.613	-1.418	-0.075	0.976	0.812	0.300
σ_{KK}	-3.034	-1.111	-	-	-0.299	-0.275
σ_{KL}	0.338	0.867	-	1.061	-0.134	0.952
σ_{LL}	-0.365	-0.556	-		-0.219	-1.043
η_{EE}	-0.472	0.356	-	-0.845	-0.689	-0.122
η_{EK}	0.111	0.341	-0.320	0.361	0.301	-0.005
η_{EL}	0.361	-0.697	0.867	0.236	0.388	0.127
η_{KE}	0.220	0.058	-0.133	0.060	0.165	-0.002
η_{KK}	-0.419	-0.484	-	-0.436	-0.101	-0.400
η_{KL}	0.199	0.426	-	0.386	-0.064	0.402
η_{LE}	0.168	-0.104	0.191	0.058	0.150	0.050
η_{LK}	0.047	0.377	-	0.565	-0.045	0.391
η_{LL}	-0.215	-0.277	-	-0.604	-0.105	-0.441

Note: E denotes aggregate energy, K denotes capital and L denotes labor; the figures in parentheses are the standard errors; the elasticities for South Korea are from Cho, Nam and Pagan (2004), for West Germany from Welsch and Ochsen (2005); for Greece are from Christopoulos and Tsionas (2002), for Portugal and Spain are from Vega-Cervera and Medina (2000).

Table 7-8. Composition of factor cost and aggregate energy price

Factor	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7
Mean of share of factor cost (1995-2004):							
Energy [a]	0.25	0.31	0.27	0.27	0.26	0.27	0.30
Capital	0.11	0.24	0.18	0.12	0.11	0.11	0.16
Labor	0.64	0.45	0.55	0.61	0.63	0.62	0.54
Mean of share of aggregate energy cost (1995-2004):							
Coal	0.20	0.11	0.17	0.15	0.12	0.19	0.15
Gasoline	0.09	0.13	0.15	0.10	0.13	0.12	0.13
Electricity	0.60	0.61	0.54	0.60	0.58	0.57	0.57
Diesel	0.12	0.15	0.16	0.15	0.17	0.13	0.14

Note: regional classification refers to Table 1-2 of Chapter One.
[a] The energy cost share is higher in China compared to that of other developed countries. For example, the energy cost share was 33.7% for China in 2004, while for the USA it was only 11.8% in 1971 (see Berndt and Wood, 1975) and 10.1% for West Germany in 1994 (see Welsch and Ochsen, 2005). There are two main reasons for the differences. Firstly, energy intensity (the ratio of energy consumption to GDP) is extremely high in China while it is lower in comparable developed countries. For example, energy intensity was 0.91 for China in 2005 while it was only 0.21 for USA in the same year (CESY, 2007). This means that the energy cost share in China would be almost five times that of the energy cost share in the USA, holding other factors constant. However, the energy cost share (33.7%) for China in 2004 was three times that of the USA (11.8%) in 1971. Secondly, labor costs are much lower in China than in developed countries. Cheap labor in China mean that the labor cost share is low and the energy cost share relatively high, while expensive labor means the labor cost share is high and the energy cost share relatively low in developed countries. For example, the labor cost share was 55.5% for China in 2004 while it was 76.0% for USA in 1971 (see Berndt and Wood, 1975).

Table 7-9. The elasticities of factor substitution and demand for regional aggregate economy

Elasticity [a]	Region 1 [b]	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7
σ_{EK}	0.72 (1.0)	0.90 (3.4)	0.85 (2.2)	0.77 (1.3)	0.74 (1.1)	0.75 (1.1)	0.85 (2.2)
σ_{EL}	0.61 (5.2)	0.56 (4.0)	0.58 (4.4)	0.62 (5.3)	0.62 (5.3)	0.63 (5.4)	0.61 (5.1)
σ_{KL}	0.21 (0.8)	0.50 (3.1)	0.46 (2.6)	0.27 (1.1)	0.23 (0.9)	0.21 (0.8)	0.39 (1.9)
η_{EE}	-0.47 (-6.2)	-0.46 (-7.5)	-0.47 (-6.6)	-0.47 (-6.7)	-0.47 (-6.4)	-0.48 (-6.6)	-0.47 (-7.3)
η_{KK}	-0.32 (-1.4)	-0.50 (-4.9)	-0.48 (-3.6)	-0.37 (-1.8)	-0.34 (-1.5)	-0.33 (-1.5)	-0.46 (-3.1)
η_{LL}	-0.18 (-5.1)	-0.29 (-5.9)	-0.24 (-5.9)	-0.20 (-5.5)	-0.19 (-5.3)	-0.19 (-5.3)	-0.25 (-5.9)

Note: The elasticities are estimated based on equations 4-20, 4-21 and 4-22 and the mean of each factor share.

[a] E denotes aggregate energy, K denotes capital and L denotes labor; the numbers in parenthesis are t-values.

[b] Regional classification refers to Table 1-2 of Chapter One.

Table 7-10. The elasticities of fuel substitution and demand for regional aggregate economy

Elasticities [a]	Region 1 [b]	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7
σ_{CO-GA}	-0.89 (-1.6)	-1.32 (-1.9)	-0.43 (-1.0)	-1.28 (-1.9)	-1.26 (-1.9)	-0.51 (-1.2)	-0.72 (-1.4)
σ_{CO-EL}	1.38 (9.6)	1.66 (6.7)	1.52 (7.7)	1.52 (7.7)	1.65 (6.7)	1.43 (8.9)	1.52 (7.7)
σ_{CO-DI}	-1.51 (-2.8)	-2.68 (-3.4)	-1.36 (-2.7)	-1.80 (-3.0)	-2.03 (-3.1)	-1.42 (-2.7)	-1.79 (-3.0)
σ_{GA-EL}	0.49 (1.9)	0.65 (3.7)	0.64 (3.5)	0.55 (2.4)	0.62 (3.2)	0.59 (2.8)	0.63 (3.3)
σ_{GA-DI}	-0.49 (-0.3)	0.14 (0.1)	0.28 (0.3)	-0.06 (0.0)	0.21 (0.2)	-0.04 (0.0)	0.12 (0.1)
σ_{EL-DI}	0.65 (2.5)	0.72 (3.4)	0.70 (3.1)	0.72 (3.5)	0.74 (3.8)	0.66 (2.7)	0.69 (3.0)
η_{CO-CO}	-0.55 (-6.0)	-0.44(-2.7)	-0.53 (-4.8)	-0.51 (-4.1)	-0.46 (-3.1)	-0.54 (-5.7)	-0.52 (-4.4)
η_{GA-GA}	-0.04 (-0.1)	-0.26 (-1.5)	-0.31 (-1.9)	-0.13 (-0.6)	-0.24 (-1.3)	-0.22 (-1.1)	-0.26 (-1.5)
η_{EL-EL}	-0.39 (-7.7)	-0.37 (-7.6)	-0.45 (-8.0)	-0.39 (-7.7)	-0.40 (-7.8)	-0.42 (-7.8)	-0.41 (-7.8)
η_{DI-DI}	-0.03 [c]	-0.15 [b]	-0.18 [b]	-0.16 [b]	-0.21 [b]	-0.09 [b]	-0.13 [b]

Note: The elasticities are estimated based on equations 4-20, 4-21 and 4-22 and the mean of each fuel share.
[a] CO, GA, EL and DI denote coal, gasoline, electricity and diesel; σ and η denote the elasticities of substitution and demand; the numbers in parenthesis are t-values.
[b] Regional classification refers to Table 1-2 of Chapter One.
[c] Due to adding up, t-values are not provided.

Table 7-11. Maximum likelihood ratio tests for model specification of industry economy

The assumptions for the nested function forms to be tested	Critical values		# Restrictions	χ^2 Statistics
	5%	1%		
Against equation (4-34):				
1. $\sum D_R \ln P_i = 0$	27.6	33.4	17	292.3**
2. $\sum \ln P_i t = 0$ and $\sum D_R \ln P_i t = 0$	23.7	29.1	14	202.1**
3. $\sum D_R \ln P_i t = 0$	21.0	26.2	12	90.2**
4. $\sum \ln P_i \ln P_j = 0$	7.8	11.3	3	39.4**
5. $\sum D_R \ln Y = 0$ and $\sum D_R (\ln Y)^2 = 0$	21.0	26.2	12	149.7**
6. $\sum D_R t = 0$ and $\sum D_R tt = 0$	21.0	26.2	12	104.8**
7. $\sum D_R t \ln Y = 0$	12.6	16.8	6	104.0**
8. $\sum D_R = 0$	12.6	16.8	6	141.7**
Against equation (4-35):				
9. $\sum D_R = 0$	28.9	34.8	18	50.2**
10. $t = 0$ and $\sum D_R t = 0$	28.9	34.8	18	60.3**
11. $\sum D_R t = 0$	25.0	30.6	15	19.0
12. $\sum \ln P_j = 0$	12.6	16.8	6	11.6**

Note: The null hypotheses related to any two of price, output and time variables are the separability; the null hypotheses for regional dummy variables are there are no significant differences in production behavior across regions; tests for model specification include the separability and incorporation of regional dummy variables assumed for the nested models against equations 4-34 and 4-35.

** and *** denote significant at the 5% level and 1% level.

Table 7-12. The estimated coefficients of total factor cost function for industry economy

Variable	Coeff.	t-stat.	Variable	Coeff.	t-stat.	Variable	Coeff.	t-stat.
P_E	0.276	2.96	P_LD4	-0.464	-2.85	P_ETD3	-0.002	-0.39
P_K	0.302	3.49	P_LD5	0.288	1.15	P_ETD4	-0.004	-1.04
P_L	0.422	6.94	P_LD6	-1.543	-6.66	P_ETD5	0.006	1.45
P_EP_E	0.102	4.02	YD1	-9.565	-2.77	P_ETD6	0.017	4.15
P_EP_K	-0.033	-1.53	YD2	-24.072	-8.62	P_KTD1	-0.002	-0.46
P_EP_L	-0.069	-4.51	YD3	1.757	1.86	P_KTD2	-0.011	-2.49
P_KP_K	0.060	2.36	YD4	3.052	4.10	P_KTD3	-0.001	-0.27
P_KP_L	-0.027	-1.63	YD5	-1.182	-1.26	P_KTD4	0.009	2.39
P_LP_L	0.096	5.24	YD6	2.554	2.29	P_KTD5	-0.002	-0.53
Y	-2.717	-3.68	TD1	0.676	2.18	P_KTD6	-0.004	-1.05
YY	0.497	4.62	TD2	2.094	7.61	P_LTD1	0.009	2.73
P_EY	0.013	0.98	TD3	-0.326	-2.49	P_LTD2	0.002	0.63
P_KY	-0.006	-0.51	TD4	-0.344	-3.24	P_LTD3	0.003	1.00
P_LY	-0.007	-0.78	TD5	0.056	0.47	P_LTD4	-0.004	-1.80
T	0.256	2.52	TD6	-0.038	-0.27	P_LTD5	-0.004	-1.51
TT	0.014	2.97	P_EYD1	0.031	1.31	P_LTD6	-0.013	-4.94
P_ET	0.013	4.44	P_EYD2	-0.095	-4.07	YYD1	1.495	2.86
P_KT	-0.010	-3.34	P_EYD3	0.040	2.32	YYD2	3.758	8.78
P_LT	-0.004	-1.89	P_EYD4	0.039	2.72	YYD3	-0.247	-1.78
YT	-0.050	-3.30	P_EYD5	-0.080	-4.32	YYD4	-0.431	-3.96
P_ED1	-0.276	-1.74	P_EYD6	-0.067	-3.99	YYD5	0.235	1.64
P_ED2	0.584	3.67	P_KYD1	0.007	0.30	YYD6	-0.302	-1.45
P_ED3	-0.287	-2.34	P_KYD2	0.121	5.62	TTD1	0.006	0.65
P_ED4	-0.222	-2.22	P_KYD3	-0.019	-1.19	TTD2	0.042	4.72
P_ED5	0.502	4.15	P_KYD4	-0.081	-6.06	TTD3	0.006	0.82
P_ED6	0.317	3.00	P_KYD5	0.033	1.96	TTD4	-0.003	-0.45
P_KD1	0.046	0.32	P_KYD6	0.019	1.21	TTD5	0.002	0.39
P_KD2	-0.709	-4.83	P_LYD1	-0.038	-2.45	TTD6	-0.003	-0.46
P_KD3	0.173	1.53	P_LYD2	-0.026	-1.73	YTD1	-0.113	-2.34
P_KD4	0.515	5.56	P_LYD3	-0.021	-1.93	YTD2	-0.345	-8.11
P_KD5	-0.194	-1.75	P_LYD4	0.042	4.41	YTD3	0.039	2.00
P_KD6	-0.015	-0.16	P_LYD5	0.047	3.94	YTD4	0.051	3.25
P_LD1	0.617	1.83	P_LYD6	0.048	4.48	YTD5	-0.019	-1.02
P_LD2	0.509	1.40	P_ETD1	-0.007	-1.40	YTD6	0.012	0.47
P_LD3	0.158	0.79	P_ETD2	0.009	1.89			

Note: All indices are measured in term of natural logarithm, P and Y represent price and output, and D represents regions. Regional dummy variables and constant term are not shown in the table.

Table 7-13. The elasticities of factor substitution and demand for industry economy

Substitution/demand	Elasticities	Standard Error
σ_{EE}	-0.8367**	0.1512
σ_{EK}	0.6706**	0.2522
σ_{EL}	0.5144**	0.1789
σ_{KK}	-2.0753**	0.3596
σ_{KL}	0.6786**	0.2551
σ_{LL}	-1.0900**	0.1532
η_{EE}	-0.3423**	0.0619
η_{EK}	0.1644**	0.0529
η_{EL}	0.1778**	0.0372
η_{KE}	0.2743**	0.0882
η_{KK}	-0.5089**	0.1041
η_{KL}	0.2346**	0.0681
η_{LE}	0.2104**	0.0440
η_{LK}	0.1664**	0.0483
η_{LL}	-0.3768**	0.0530

Note: E stands for aggregate energy, K stands for capital and L stands for labor. Elasticities are estimated based on equations 4-20, 4-21 and 4-22 and the mean of each factor share. S_E=0.4091, S_K=0.2452 and S_L=0.3457.

Table 7-14. The estimated coefficient of fuel share equations for industry economy

Coal			Electricity			Oil		
Variable	Coeff.	t-stat.	Variable	Coeff.	t-stat.	Variable	Coeff.	t-stat.
Cons	0.269	22.42	Cons	0.639	49.15	Cons	0.092	11.50
D1	-0.081	-3.24	D1	0.088	3.26	D1	-0.007	-0.41
D2	0.004	0.16	D2	-0.022	-0.81	D2	0.018	1.06
D3	-0.025	-1.09	D3	0.008	0.33	D3	0.016	1.07
D4	-0.036	-1.71	D4	0.030	1.36	D4	0.007	0.50
D5	-0.030	-1.50	D5	0.037	1.76	D5	-0.007	-0.54
D6	-0.140	-6.09	D6	0.098	4.08	D6	0.043	2.87
P1	0.039	2.17	P1	-0.013	-0.72	P1	-0.026	-2.17
P2	-0.013	-0.72	P2	0.051	2.13	P2	-0.037	-2.06
P3	-0.026	-2.17	P3	-0.037	-2.06	P3	0.063	2.86
T	-0.008	-4.00	T	0.011	5.50	T	-0.004	-4.00
TD1	0.000	0.00	TD1	-0.002	-0.50	TD1	0.002	0.67
TD2	-0.007	-1.75	TD2	0.006	1.20	TD2	0.001	0.33
TD3	-0.003	-0.75	TD3	0.006	1.50	TD3	-0.003	-1.50
TD4	-0.003	-1.00	TD4	0.000	0.00	TD4	0.003	1.50
TD5	0.000	0.00	TD5	-0.001	-0.33	TD5	0.001	0.50
TD6	0.014	3.50	TD6	-0.009	-2.25	TD6	-0.005	-2.50

Note: Coefficients for oil share are calculated based on adding-up restriction. Prices are measured in term of logarithm.

Table 7-15. The elasticities of fuel substitution and demand for industry economy

Substitute	Elasticities	Standard Error	Demand	Elasticities	Standard Error
σ_{CO-CO}	-3.1360***	0.4866	η_{CO-CO}	-0.6046***	0.0938
σ_{CO-EL}	0.9030***	0.1273	η_{CO-EL}	0.1741*	0.0909
σ_{CO-OI}	-0.4283	0.6925	η_{CO-OI}	-0.0826	0.0647
σ_{EL-EL}	-0.3013***	0.0473	η_{EL-CO}	0.6446***	0.0245
σ_{EL-OI}	0.4383	0.2774	η_{EL-EL}	-0.2150***	0.0337
σ_{OI-OI}	-2.4646	2.5169	η_{EL-OI}	0.3128***	0.0259
			η_{OI-CO}	-0.0400	0.1335
			η_{OI-EL}	0.0409	0.1980
			η_{OI-OI}	-0.2303	0.2352

Note: CO stands for coal, EL stands for electricity and OI stands for oil. The elasticities are estimated based on equations 4-20, 4-21 and 4-22 and mean of each fuel share. S_{CO}=0.1928, S_{EL}=0.7138 and S_{OI}=0.0934.
* and *** denote significant at the 10% level and 1% level.

Table 7-16. Total elasticities of demand for fuel for industry economy

Own- and cross-price	Elasticities
η^*_{CO-CO}	-0.6730
η^*_{CO-EL}	0.1057
η^*_{CO-OI}	-0.1510
η^*_{EL-CO}	0.3913
η^*_{EL-EL}	-0.4683
η^*_{EL-OI}	0.0595
η^*_{OI-CO}	-0.0732
η^*_{OI-EL}	0.0078
η^*_{OI-OI}	-0.2634

Note: CO stands for coal, EL stands for electricity and OI stands for oil. The elasticities are estimated based on equations 4-20, 4-21 and 4-22 and the mean of each fuel share. S_{CO}=0.1928, S_{EL}=0.7138 and S_{OI}=0.0934.

Chapter Eight: Technological Changes and Decomposition of Energy Intensity[37]

This Chapter is organized as follows: Section One presents the estimated decompositions of energy intensity for firstly, the aggregate economy, followed by the industrial economy (Section Two). Section Three compares the aggregate economy and industry economy results in order to uncover the differences driving energy intensity in practice. Section Four provides further discuss of these results and what can be learnt from them by providing more empirical background information. The final Section Five presents some implications and conclusions.

8.1 Decomposition for the aggregate economy

We employ a new parametric method (see Chapter 4), rather than the traditional index number decomposition approach, to decompose the changes in energy intensity into several components. This allows us to ascertain the actual driving forces of energy intensity in China. As can be seen from Table 8-1 we have decomposed the changes in energy intensity into budget, technology, substitution and output effects. The general pattern of the changes in energy intensity are similar across regions and show that "budget" and technological change are the two major drivers. However, regional

[37] Parts of this chapter have appeared in ***Energy Economics*** 2008 and ***Energy Policy*** 2009 together with Chapter 7 and will appear on ***Environmental Modelling and Software*** 2009 with Chapter 7.

variations are also apparent. For example, the estimated energy intensity of China at the national level increased by about 7.3% over the period 2000-2004, which is mainly the net effect of rising energy price and adopting energy intensive technology. The 'budget-effect' is –19.3%, which means that due to 'energy budget constraints', the increasing energy price forces enterprises to reduce energy use, which reduces energy intensity by approximately 20%. For example, aggregate energy prices increased by 50% for electricity and 100% for coal and petroleum products during the study period (see Table 1-4 of Chapter One). The larger effect, however, comes from technological change, which increased energy intensity by 23.7% over the period. The aggregate effects of factor substitution are small and tend to offset each other

The same pattern of driving forces can be found in the regional level decomposition, but variations in these components are also evident across regions. For example, all regions increased their energy intensity except for region 3 (the old industrial heartland in the northeast) where energy intensity declined by 4.29% during the study period. Noticeable differences in the 'budget effect' occur across regions, for example, energy intensity fell by 36% due to the 'budget effect' in region 3, while it fell by only 11% in regions 4 and 6. Substitution effects also differ across regions for example, increasing labor inputs (in other words, falling labor cost) would reduce energy intensity by 12% in region 2, but this effect would be only 3.2% in region 1. Moreover, increasing energy inputs (or reducing energy prices) would still increase energy intensity by 9.2% in region 3, while the energy price effect was only 4.1% in region 4. The same pattern can be found for output effects, but the technological effects are largely similar across regions.

8.2 Decomposition in the industrial economy

Similarly, I decompose the change in energy intensity into 'budget', 'substitution', 'technology' and 'output' effects for the industrial economy. The results are displayed in Table 8-2. It can be seen that the estimated energy intensity of China's industrial economy at the national level increased by about 6.9%, which is mainly due to a rising energy price and adopting energy intensive technologies, as the effects of substitution and production are small and are offsetting. The 'budget-effect' is –10.1%, which suggests that, due to 'budget constraints', the increases in energy price force firms to reduce energy use. This reduces energy intensity by about 10%. During the estimation period, energy prices increased by 25% which should lead to a reduction in energy use, however, a larger effect comes from technological change, which increased energy intensity by 19.6% over the period. This finding suggests that China's industrial economy is adopting energy intensive technology, which is embodied in capital investment. The total substitution effect of energy intensity is negligible - the price of labor suggests it falls by about 6.9%, which is almost offset by the effect of the energy price (5.4%). The capital price effect is close to zero.

Although there is a similar pattern of decomposition in energy intensity changes across regions, the driving forces behind energy intensity seem to vary by region. For example, energy intensity declined by 21.8% in region 3, but it only decreased by about 4.4% in regions 4 and 7.9% in region 2 due to the budget effect. Energy intensity increased by 8.6% in region 3, but it only increased by 3.0% in region 4 due to the substitution of energy. Likewise, the effect of the substitution of labor also varies across regions. For instance, energy intensity decreased by about 10.2% in region 2 but it only declined by 5.1% in regions 1 due to the substitution of labor. These findings suggest that the effects of energy price (budget effect) and substitution are extremely different across regions.

8.3 A comparison of decomposition between two economies

It is interesting and useful to compare the estimated pattern of decomposition of energy intensity between the aggregate economy and the industrial economy, because although industry accounts for nearly half of economic output (GDP) the industrial structure is really dynamic in China (see Table 8-3). For example, the agricultural share of GDP sharply declined by 50% during the last decade and the industrial share of GDP also declined by 4 percentages during the same period. Even more dynamism can be found across regions. Several evident differences can be seen in the decomposition of energy intensity between the aggregate economy and industrial economy by careful comparisons of Table 8-1 and Table 8-2.

Firstly, in particular, it seems there is little difference in the increase of energy intensity between the industrial economy and the aggregate economy during the last five years (6.85% and 7.27%, respectively). However, increasing growth of energy intensity for other industries is much faster than the industrial sector. For example, energy intensity increased by 15% for agriculture, 61.5% for the construction sector, and 17.6% for the commercial sector from 2000 to 2004, while it only rose by 6.0% for the industrial sector over the same period (see Table 3-4 of Chapter Three).

Secondly, there is a significant difference in the 'budget effect' between the aggregate economy and the industrial economy. For example, the 'budget effect' only reduces energy intensity by about 10% for the industrial economy, but it reduces energy intensity by nearly 20% for the aggregate economy. This means that the 'budget effect' for the aggregate economy is only 50% of aggregate economy. Recall the definition and explanation of the 'budget effect' in Chapter 4, it means that industrial sector can afford the maximum reduction in energy intensity (or energy consumption hold output constant) if the energy prices increase is much less than in other sectors. This clearly means that rising energy prices hinder industrial economic growth.

Thirdly, both the industrial economy and the aggregate economy adopted energy-using technology, but comparably, the aggregate economy adopted more energy-using technology than the industrial economy. For example, technological change made the energy intensity increase by 23.7% for the aggregate economy, while it made energy intensity only increase by 19.6% for the industrial economy.

Finally, expansion of production reduced energy intensity by 1.24% in the industrial economy, while production expansion increased energy intensity by 2.51% for the aggregate economy as a whole.

It is clear that the effects of production on the change of energy intensity are completely opposite. To explain this, we need to know the shares of the industrial economy in both energy consumption and production. As can be seen the share of aggregate energy consumption is about 71% in 2006 (refer to Table 3-8 of Chapter Three) while GDP's share is only 44% (Table 8-3) for the industrial sector in the same year. Given these, the results probably suggest that there is more surplus productivity in the industrial economy.

Turning to regional decompositions, it can be seen that it almost follows the same pattern of decomposition of energy intensity, but apparent differences can be found across regions. For example, the changes in energy intensity in regions 4 and 7 are almost the same between the industrial economy and the aggregate economy for some regions. For example, they are 13.15% vs. 13.36% in region 4, and 6.39% vs. 6.02% in region 7, respectively. However, there are significant differences in the change of energy intensity between the industrial economy and aggregate economy for other regions. For example, they are 2.31% vs. 7.02% in region 1, -9.54% vs. -4.29% in region 3, and 6.85% vs. 13.45% in region 6, respectively.

Also, the most evident reverse effects of production can be found in the change of energy intensity between two economies. For example, region 3 has the minimum effect of production (-5.22%) for its industrial economy and maximum effect of production (6.47%) in its aggregate economy. This probably means that there are more surplus productivities in this region. In fact, this is an old industrial area (heavy industry and military industries) and is located in the northeast of China. Restructuring old industrial system is still a challenge faced by the northeast region.

The largest effect of substitution can be found in region 2, -4.65% for the industrial economy and -5.81% for the aggregate economy, most of which results from labor use.

This means this region is very sensitive to changes in factor prices. This region includes Beijing, Tianjin and Shanghai, which are some of the most developed areas in China.

8.4 Further discussion

In this chapter we focused only on the decomposition of the changes in energy intensity and tried to explain the major driving forces for change. Attempts to provide detailed reasons for energy intensity changes across regions is beyond the scope of this chapter since these changes are the result of many factors. However, we will try, below, to reconcile our findings with the results from existing studies of China's energy intensity.

Technological change and innovative activities can be embodied in capital investment, specialized labor and exported goods. These changes and activities typically create increasing energy intensive use, as has been well documented by Qi and Chen, 2006; Gao and Wang, 2007; Ma and Stern, 2008; Zhang and Ding, 2007; Zhou and Li, 2006; Shi Fu, 2007. These authors show that technological change has increased energy intensity in China by 40-70%. However, what kinds of technical activities have increased China's energy intensity? This issue has been extensively investigated by, for example, Liao, Fan and Wei (2007) who investigate the factors that they believe have led China's energy intensity to increase between 1997 and 2006. They conclude that; i) a one percentage increase in the investment (capital) ratio may result in a 1.14% increase in energy consumption; ii) energy-intensive sub-sectors or products have expanded rapidly and this is only partly offset by the energy efficiency improvement. Approximately 84% of the increased industrial energy consumption resulted from seven sub-sectors with the iron and steel sector alone accounting for more than 30%; iii) accelerating industrialization and urbanization in China requires more energy-intensive products; vi) China's local authority performance appraisal and official promotion systems have induced high levels of energy-consuming investment activities. Kahrl and Roland-Holst (2008) further conclude that China's energy-intensive exports have significantly increased domestic energy consumption. They found that net exports accounted for 15-22% of China's total energy consumption which has significantly contributed to the increase in China's measured energy intensity implies that the energy intensity of exports is higher than that of non exports. Their calculations show that the energy intensity of exports rose 8% annually, almost the same rate as national economic growth. Wang and Yang (2006) estimate that a given one percentage increase in energy efficiency would lead to a decline of energy intensity of 31.4% for petroleum processing and coking industry; 25.1% for chemical industry; 23.6% for nonmetal mineral products industry; 41.6% for ferrous metals processing industry and 26.6% for nonferrous metals processing industry. Therefore, there is the potential for China to reduce its energy consumption.

Energy laws and regulation can also be responsible for the recently rising energy intensity and technological adoption. Although energy laws and regulation have also assumed a higher profile in China, energy-saving was not given much attention until recently. For example, the Energy-Saving Law was drafted in 1997, issued in 1998, revised in 2007, reissued in 2008. This means that it is not until 2008 that China had a complete Energy-Saving Law. Renewable Energy Law and Circular Economic Promotion Law are even later (for details, refer to Chapter 3).

Similar patterns of decomposition of energy intensity are also likely rooted in the homogeneous industrial structure of the aggregate economy across regions. It can be seen that there is little difference in regional production structures apart from region 2 (including Beijing, Tianjin and Shanghai). For example, the GDP shares range from 40-48% for industry, 5.0-8.0% for construction 6.0-7.0% for transportation and 20-27% for other sectors in 2006 based on the China Statistical Yearbook. This probably implies that the production technologies are homogenous across regions in China.

However, factor use varies across regions (see Table 7-8 of Chapter Seven), with labor's share of total factor cost ranging from (45% in region 2 to 64% in region 1, energy shares ranging from 25% in region 1 to 31% in region 2 and capital shares ranging from 11% (regions 1,5 and 6) to 24% in region 2. These regional differences are related to the regional economy and energy production, for example, region 2 has a different pattern of factor costs from others as this region includes Beijing, Tianjin and Shanghai, which are China's three major municipalities so that they enjoy more special regional policies and high investment and economic growth rates which raises their capital and energy shares. Comparing the regional energy production and balance sheet (Table 1-3 of Chapter One) with the energy shares in the bottom section of the Table 7-8 of Chapter Seven, it can be easily seen that energy cost composition is closely related to regional energy resources. The most evident example is coal. For example, region 1 has a largest coal share (20%) because this region is China's major coal production base. Conversely, with more environmental concern and priority policy, region 2 has the lowest coal share (11%).

As for why there are significant differences in the 'budget effect' on the change in energy intensity, this might be dependent upon regional economic growth, natural resources and industrial structure. It is possible that the larger the industry GDP share, the larger the 'budget effect' for example, the largest 'budget effect' (-35.9%) and the largest industry sector GDP share (45.1%) are found in region 3 (refer to Table 8-1); while, the smallest 'budget effect' (-11.6%) and a smallest industry sector GDP share (38.1%) are found in region 6. It also seems that the lower per capital GDP, the smaller the 'budget effect' for example, regions 4 and 6 (except for region 1) have the lowest per capital GDP and the lowest 'budget effect' (around -11%, see Table 8-1). These interpretations are only suggestive and further econometric analysis is required to investigate why 'budget effects' differ significantly across region.

8.5 Conclusions and implications

We decomposed the changes in energy intensity to identify the driving forces behind the recent national increases in energy intensity. Taken together, the new results presented here provide the inputs necessary to inform analysis of the potential for governments to adapt to the rising dependency on energy in a situation of rising fuel prices while, at the same time, attempting to minimize the effects on the environment of policies to stimulate economic growth.

From the research we conclude that, after decomposing energy intensity, the 'budget effect' and technological changes are the two major driving forces of the changes in energy intensity nationally. The variations in 'budget effect' across regions are most likely related to the differences in regional economic growth and industrial structure. Technological changes, or innovative activities, can be embodied in capital investment, equipped labor, export goods and sectoral shifts. These changes and activities involve intensive energy consumption during the transition of the Chinese economy. Whether this trend of increasing energy intensity continues or declines will be significant and important for China and the rest of the World.

Other studies have demonstrated that technological activities have increased energy intensity since 2000 in China. Therefore, reducing exports of energy-using commodities, depressing the high-level energy-using sectors, lowering capital investment and reducing imports of second-hand or old vintage equipment, would help to reduce growth in energy intensity in China, if this were the only target.

Although this chapter has provided some new data on the driving forces of energy intensity, it represents work in progress. More research is required to consider questions such as what kinds of technical activities increase China's energy intensity and in which industry? And the reasons why such technologies are employed?

Table 8-1. Decomposing the changes in energy intensity for aggregate economy

Region	$\Delta\hat{e}/\hat{e}$	Budget	Tech.	Substitution				Output
				Sum	Energy	Capital	Labor	
National	0.0727	-0.1934	0.2368	0.0043	0.0619	-0.0017	-0.0559	0.0251
Region 1	0.0702	-0.2387	0.2340	0.0363	0.0701	-0.0014	-0.0324	0.0387
Region 2	0.0550	-0.1540	0.2517	-0.0581	0.0641	-0.0010	-0.1212	0.0153
Region 3	-0.0429	-0.3589	0.2299	0.0214	0.0916	-0.0019	-0.0683	0.0647
Region 4	0.1336	-0.1123	0.2487	-0.0099	0.0409	-0.0014	-0.0494	0.0071
Region 5	0.0638	-0.2242	0.2343	0.0195	0.0594	-0.0008	-0.0391	0.0341
Region 6	0.1345	-0.1161	0.2342	0.0069	0.0523	-0.0026	-0.0428	0.0095
Region 7	0.0602	-0.1686	0.2318	-0.0143	0.0656	-0.0027	-0.0771	0.0113

Note: To make the estimate more stable and reliable, we take three year averages of 1999-2001 and 2002-2004 for the base year and reporting year to calculate the growth rate of energy intensity. Regional classification refers to Table 1-2 of Chapter One.

Table 8-2. Decomposing the changes in energy intensity for industry economy

Region	$\Delta\hat{e}/\hat{e}$	Budget	Tech.	Substitution				GDP
				Sum	Energy	Capital	Labor	
National	0.0685	-0.1012	0.1961	-0.0140	0.0539	0.0009	-0.0689	-0.0124
Region 1	0.0231	-0.1455	0.1842	0.0152	0.0639	0.0018	-0.0505	-0.0308
Region 2	0.0720	-0.0791	0.2037	-0.0465	0.0523	0.0032	-0.1021	-0.0061
Region 3	-0.0954	-0.2176	0.1877	-0.0132	0.0857	0.0002	-0.0991	-0.0522
Region 4	0.1315	-0.0436	0.1968	-0.0263	0.0295	0.0020	-0.0578	0.0047
Region 5	0.0861	-0.0887	0.1969	-0.0146	0.0399	0.0037	-0.0582	-0.0075
Region 6	0.0685	-0.1012	0.1961	-0.0140	0.0539	0.0009	-0.0689	-0.0124
Region 7	0.0639	-0.1238	0.2034	-0.0088	0.0721	-0.0021	-0.0788	-0.0069

Note: To make the estimate more stable and reliable, we take three year averages of 1999-2001 and 2002-2004 for the base year and reporting year to calculate the growth rate of energy intensity. Regional classification refers to Table 1-2 of Chapter One.

Table 8-3. The changes of industrial structure by GDP over time

Region	Agriculture	Industry	Construction	Transportation	Commerce	Others	Sum
In 2006 (%):							
National	10.7	44.4	5.7	5.7	8.2	25.4	100.0
Region 1	8.2	42.1	5.4	7.5	7.7	29.2	100.0
Region 2	12.1	45.1	5.7	5.7	9.2	22.2	100.0
Region 3	5.4	48.9	5.1	4.7	9.2	26.8	100.0
Region 4	12.0	46.6	6.4	6.1	7.5	21.4	100.0
Region 5	12.2	43.9	4.8	5.1	8.3	25.8	100.0
Region 6	18.0	34.8	7.4	5.6	7.3	26.9	100.0
Region 7	13.4	42.5	7.7	6.3	6.5	23.6	100.0
In 1996 (%):							
National	20.4	40.6	5.9	6.1	9.6	17.4	100.0
Region 1	22.2	42.4	5.2	6.1	8.1	16.0	100.0
Region 2	4.0	44.6	6.1	7.4	10.7	27.2	100.0
Region 3	19.1	43.6	5.1	5.6	10.2	16.4	100.0
Region 4	18.7	43.9	5.4	5.4	10.9	15.8	100.0
Region 5	21.5	37.4	6.5	7.5	10.2	16.9	100.0
Region 6	26.7	35.4	6.6	4.6	8.8	17.9	100.0
Region 7	28.7	29.4	8.5	7.6	8.6	17.2	100.0

Data source: China Statistical Yearbook 2007. Beijing: China Statistical Publisher 2007. Regional classification refers to Table 1-2 of Chapter One.

Chapter Nine: Gradual Reforms and the Emergence of Energy Market: Evidence from Tests for Convergence of Energy Prices

This Chapter is organized as follows: I first use maps and graphs of spatial energy prices and then statistically test using both conventional unit root tests and panel unit root tests. Next, I compare my results and finding with other's and finally provide some conclusions.

9.1 Spatial price trends

Given the likely importance of transport costs when attempting to interpret the evidence on market integration, it is useful to identify which of China's provinces are energy producers and which are energy consumers. Table 3-9 reports energy outputs and deficits (consumption) for coal, electricity, gasoline and diesel. It can be seen that the major coal producers, ordered by volume, are Taiyuan (581 mmt), Hohhot (298 mmt), Zhengzhou (195 mmt), Xi'an (183 mmt), Jinan (141 mmt), Guiyang (118 mmt), Harbin (103 mmt); The major coal importers, ordered by volume, are Nanjing (153 mmt), Jinan (149 mmt), Shijiazhuang (130 mmt), Hangzhou (113 mmt), and Guangzhou (111 mmt), and major coal exporters, ordered by volume, are Taiyuan (298 mmt), Xi'an (143 mmt), Hohhot (136 mmt), Lanzhou (30 mmt) and Guiyang (19 mmt).

Figure 3-4 of Chapter Three shows the distribution of major cities across China. Juxtaposing Figure 3-4 against Table 3-9 in Chapter Three, we see a general picture of how energy is transported in China. Based on the assumption that energy prices are lower in the producing areas and higher in the consuming areas due to transportation costs, to understand whether there is an energy market in China, we need to observe the spatial price series ordered from producing to consuming areas. Likewise, the consuming areas can show price differentials caused by transportation costs if ordered by their distances to the producing areas. To simplify our analysis, we choose major energy producers and major energy consumers to compare the price trends and spatial patterns.

9.1.1 Coal

Consider, firstly, the spatial observations and comparisons of coal prices. Recall that coal is mainly produced in the north and the main transport routes are from west to east and from north to south. Note the spatial coal price trends of Figure 9-1 to Figure 9-3, of which six are spatial coal price trends ordered from producing areas to consuming areas and one is from three southeast consuming areas ordered by their distances to major producing areas. There are several points that can be made based on these data on spatial coal price trends. Firstly, all spatial coal price trends demonstrate some evidence of the Law of One Price (LOP), which suggests that price differentials are mainly caused by transportation costs. Secondly, the spatial price trends do not illustrate consistent evidence of the LOP over the whole sample period as price differentials are not consistent over time for example, the price differentials were small from 1999 to 2001 for some changes (e.g., Panel A and Panel B of Figure 9-1, Panel B of Figure 9-2 and Figure 9-3). Finally, some price differential display the LOP relation only late in the sample and in an irregular fashion for example, the spatial coal price trend from Xi'an via Wuhan to Changsha does not show a LOP relation during 1997-1999 and 2003-2004 (Panel A of Figure 9-2). This finding probably indicates that the coal price deregulations may be heterogeneous across the country. It is noted that coal prices in consuming areas are divergent from in producing areas after 2002 (Panel A and Panel C of Figure 9-1, Figure 9-2), see the next section for an explanation.

9.1.2 Gasoline

Figures 9-4 and 9-5 present the spatial price trends for gasoline from producing to consuming areas (Figure 9-4), along consuming areas (Panel A and Panel B of Figures 9-5) and along ports areas (Panel C of Figure 9-5). It is notable that the spatial gasoline price trends are very consistent for not only 'from gasoline producing areas to consuming areas', but for 'all consuming areas' as well. Secondly, although spatial gasoline prices are very similar, the averaged statistics still show some spatial price differentials caused by transportation distance for example, Panel A of Figure 9-4 shows the price differentials from producing areas, Shenyang where the gasoline average price is ¥4182 per ton from 2000 to 2005, to consuming areas by distance, Hohhot where the gasoline average price is ¥4244 per ton and Wuhan where the gasoline average price is ¥4364 per ton during the same period. Likewise, Panel B and Panel C of Figure 9-4 also clearly shows the transportation costs from producing areas, Xi'an and Lanzhou where average gasoline prices are ¥4169 and ¥4174 per ton from 2000 to 2005, respectively, to consuming areas, via Chengdu where average gasoline price is ¥4258 per ton to Xining where average gasoline price is ¥4285 during the same period. Thirdly, gasoline spot prices are similar in the consuming areas, while price differentials can be still clearly be seen due to their different distances to the producing areas for example, along the east coastal areas, Nanjing is closer to gasoline producing areas (e.g., Shenyang, Xi'an and Lanzhou) so that its gasoline spot price is lowest among the east coastal areas of Nanjing, Shanghai, Hangzhou and Fuzhou (Panel B of Figure 9-5, also refer to Figure 3-4 Chapter Three). Note that Panel A of Figure 9-5 shows Guangdong as having the lowest gasoline spot price even though it is the most southern, which may reflect oil smuggling in southern China and if so, Guangzhou might be taken as a gasoline producing area. Fourthly, gasoline spot prices are homogeneous around port areas (e.g., Shanghai, Tianjin, Qingdao and Dalian, Panel C of Figure 9-5), which might reflect similar oil import prices. Finally, it seems that there are two different periods of price differentials, separated around 1999-2000. This may indicate that government intervention played a more important role in energy price formation during the first sub-period, while market forces were more powerful during the second sub-period.

9.1.3 Diesel

Figures 9-6 and 9-7 present the spatial price trends from producing areas to consuming areas (Figure 9-6), along the east coastal consuming areas (Panel A of Figure 9-7), along southern consuming areas (Panel B of Figure 9-7), and along northern consuming areas (Panel C of Figure 9-7). There are several points that can be made. Firstly we observe that the spatial diesel spot price trends are consistent for not only the producing areas to consuming areas, but for all consuming areas, although there is still some variation in time and space. Secondly, diesel spot prices appear homogeneous, while the data support the hypothesis that spatial price differentials are due to transport costs for example, Panel

A of Figure 9-6 shows that between 2000 and 2005 the average diesel price was ¥3659 per ton from producing areas (Shenyang) to ¥3725 per ton to consuming areas (Hohhot). Likewise, Panel B of Figure 9-6 shows the 2000-2005 average prices from producing areas (Urumqi, ¥3469 per ton) to consuming areas via Chengdu (¥3606 per ton) to Guiyang (¥3646 per ton). Panel C of Figure 9-6 presents the 2000-2005 average spot prices from producing area (Xi'an, ¥3580 per ton) to consuming areas via Chengdu (¥3606 per ton) to Kunming (¥3651 per ton). Thirdly, diesel spot prices appear homogeneous in the consuming areas and it seems there is an oil importing centre in the south for example, along the east coastal areas and the south areas, both Panel A and Panel B of Figure 9-7 shows that Guangdong acts like a producing area. Similarly, we suspect that there might be large quantity of oil smuggling in southern China. If so, Guangzhou might be taken as a producing area. Fourthly, it seems that there are two different periods of price differential trends. The first period up to 2000 shows spot prices as flat with little variation. However, the second period from 2000 shows much more variability.

9.1.4 Electricity

Finally, we look at changes in electricity spot prices in China. Figures 9-8 and 9-9 display the spatial price trends from producing areas to consuming areas (Figure 9-8), along east coastal consuming areas (Panel A of Figure 9-9), and along northern major consuming areas (Panel B of Figure 9-9). The first three figures allow us to observe whether the LOP exists for spatial electricity spot prices in China, while the second two figures allow us to observe the possibility of convergence of electricity spot prices given similar transmission distance. Several points can be made for the spatial electricity spot prices. Firstly, it can be seen from Figure 9-8 that electricity spot prices are lower in producing areas, rising with increasing transmission distance for example, Panel A of Figure 9-8 shows that electricity spot prices are lower in two producing areas (Kunming and Guiyang) than in a major consuming area (Guangdong). It also shows that spot prices tend to become more convergent in two producing areas when they are very close in location using hydropower. The same can be observed for coal-burning power plants, Panel B and Panel C of Figure 9-8 (for hydroelectricity mainly located along the Yangzi River). Next, the electricity spot prices in major consuming areas tend to converge given similar distances to producers, for example, Panel A of Figure 9-9 shows that electricity spot price differentials along the east coastal major consuming cities converge in the later periods, particularly after 2002. A clearer convergent scenario of electricity spot prices can be seen from Panel B of Figure 9-9 based on northern major consuming cities (Shijiazhuang, Jinan, Nanjing and Zhengzhou). It is apparent that more stable (flat) price trends can be seen in the early periods while more volatile price patterns emerge in the later years. Again, this finding suggests that market forces have been playing a more important role in electricity price formation in China. Finally, it should be noted, however, that electricity spot prices appear to involve more government intervention than other energy types. This suggests that the emergence of an electricity market in China may be a more recent and embryonic process.

In summary, although we are unable to draw hard conclusions based on our descriptive statistics, the patterns of energy price movements would seem to indicate the potential convergence of spatial energy prices and provide support for the emergence of an energy market. The alternative would be to suggest that a 'central planner' is generating an observationally equivalent set of integrated, spatially determined, energy prices whose variation is determined solely by the distance of consumption from production.

9.2 Unit root tests

The previous section used 'ocular tests' for convergence based upon time series graphs and patterns. In this section we use parametric time-series based tests for convergence. We first briefly, introduce the methods used and then present the empirical results. Given the apparent changes in price regimes identified above, we will consider several sub-periods.

A powerful approach used to investigate price convergence applies unit root tests to examine whether price differentials are stationary (see for example, Bernard and Durlauf, 1996 and Greasley and Oxley, 1997). Rejection of the unit root hypothesis implies that the time series of relative prices are stationary, such that relative prices will converge in the long run. Otherwise, if the tests fail to reject the null hypothesis, the relative price series will follow a random walk (Fan and Wei, 2006).

9.2.1 The ADF unit root tests

The methodology used here commences with the ADF unit root tests on the raw price data. The individual ADF unit root test results are displayed in Table 9-1 for the price level series and Table 9-2 for the first differenced price series for the raw data series during the whole sample period (1995-2005). The ADF unit root tests show that each of the 35 city raw price data series exhibits unit roots for all four energy sources. All the tests suggest that the first differences of the series are stationary and therefore that all series are integrated of order 1 or I (1).

However, the ADF test statistics are biased toward the non-rejection of a unit root when there are structural breaks in the data (Nelson and Plosser, 1982; Perron, 1989; Enders, 1995). Thus, testing for the presence of the structural break is important, although the approach taken here is to consider sub-periods where breaks are imposed based upon our prior expectations informed by known changes in regimes where, energy economic reforms have been carried out since the early 1990s. Therefore, energy reform would likely produce some structural changes of price series and at worse, spurious breaks would lead only to a reduction in the power of the test (Nelson and Plosser, 1982; Perron, 1989; Enders, 1995). We therefore split the whole sample into two sub-periods (1995-1999 and 2000-2005) based on the previous analysis of price trend figures and our understanding of China's energy price reforms. The ADF unit root tests are displayed in Table 9-3 for the period of 1995-1999 and in Table 9-4 for the period of 2000-2005, which suggests that the first differences of the series are stationary and therefore that all series are integrated of order 1 or I (1). This means that, even if there are structural breaks in the series, their time series properties are not affected.

Table 9-5 presents unit root tests of price convergence for the whole sample period and Table 9-6 for the two sub-periods (1995-1999 and 2000-2005) for 35 provincial capital city markets using the group averages of all 35 markets as a benchmark. It can be seen from Table 9-5 that of the 35 relative price series there are five instances of convergence for coal, two for electricity, 13 for gasoline and 14 suggest convergence for diesel. The general results suggest that there are fewer instances of convergence for coal and electricity than for gasoline and diesel. From these simple tests we cannot conclude that China's energy markets are integrated. To test the proposition further consider the results in Table 9-6, which show the number of rejections of the null for each of the four energy types and each of the 35 markets during the two sub-periods. Based on these results it appears that there are no apparent differences in the number of rejects across the two sub-periods except for coal. This suggests that not all market prices are convergent to the national average prices and that national aggregated markets might not exist, but instead regional markets exist. However, there is some evidence that market forces are gradually having some effect in determining energy price formation as there are more instances supporting convergence in the second sub-period than the first sub-period, except in the case of coal. The most obvious example of this can be found for the case of diesel where there are only 15 pairs of convergent relative price series in the first sub-period (1995-1999), but 20 pairs of convergent relative price series in the second sub-period (2000-2005).

To analyze more deeply the role of the market mechanism in determining the formation of energy prices, we undertake 'city-by-city' based unit root tests for all four fuel types. The results are presented in Table 9-7, which displays the number of the city-by-city based relative price series that reject the null for each of the 35 city markets and each of the three periods (1995-2005, 1995-1999 and 2000-2005). We firstly observe that the number of pairs of relative price series rejecting the null from the first sub-period to the second sub-period increases (except for coal). For example, in the case of gasoline, the number of pairs of relative price series rejecting the null was 242 in the first subsample period, but this rises to 478 in the second subsample period Similarly, for diesel, there were 164 in the first subsample, this rising to 484 in the second period. As a result, a total of 630 pairs of city-by-city based relative price series the percentage rejecting the null hypothesis increased from 19% in the first subsample period (1995-1999) to 38% in the second subsample period (2000-2005) for gasoline and from 13% in the first subsample period (1995-1999) to 39% in the second subsample period (2000-2005) for diesel. For electricity, the numbers of pairs of relative price series rejecting the null are 42 in the first subsample period (1995-1999), but 70 in the second subsample period (2000-2005).

In the case of coal there are more pairs of convergent relative price series in the first sub-period than the second sub-period, 148 and 64, respectively. However, several points should be noted. Firstly, the price of coal varies significantly spatially due to the extremely unbalanced distribution of reserves and the high long distance transport costs, which may comprise a large percentage of final user prices. Secondly, final user prices of coal may be significantly distorted if the transportation sector (especially rail) is itself not market-oriented. Thirdly, transport costs apparently increased substantially in the second subsample period, especially after 2002, from the major producing areas to the major consuming areas (refer to Figure 9-1 and Figure 9-2). Finally and also potentially most importantly, major coal consumers (e.g., power plants) used to pay a lower price to coal producers before 2002 due to coal price regulation. However, with coal market deregulation, they had to offer higher prices to coal producers after 2002. Given these points, it is dangerous to conclude that the market mechanism deteriorated in the second sub-period.

There are significant variations in the number of pairs of convergent relative price series across cities and fuels in the whole sample period. For example, there are six city markets (Taiyuan, Changchun, Harbin, Chongqing, Qingdao and Xiamen) that are integrated with more than 20 other city markets for diesel; and Chongqing and Qingdao are integrated with almost every other city (30 and 29, respectively). For gasoline, there are eight city markets (Shanghai, Fuzhou, Nanchang, Guiyang, Kunming, Qingdao and Xiamen) that are integrated with more than 20 other city markets. But fewer city markets are convergent with many other city markets for electricity and coal for example, four cities are convergent with only 5-6 other city markets for electricity. Nanning and Shijiazhuang are integrated with 17 and 11 other city markets, respectively, and four city markets (Hefei, Guangzhou, Xi’an and Xiamen) are integrated with 7-9 other city markets for coal. Based on these observations, it might be concluded that there are more regional energy markets in China.

Compared with the ADF tests based on a group as the benchmark (Table 9-6), there are many more pairs of relative price series that reject the null hypothesis based on the city-by-city ADF unit root tests (Table 9-7) for example, the numbers of pairs of convergent electricity relative price series are 70 for 2000-2005 and 42 for 1995-1999 based on the city-by-city ADF unit root tests (Table 9-7), but correspondingly, only 2 and 3 based on group as a benchmark (Table 9-6). Similarly, the numbers of pairs of convergent gasoline relative price series are 478 for 2000-2005 and 242 for 1995-1999 based on the city-by-city ADF unit root tests (Table 9-7), but only 14 and 13 based on group as benchmark (Table 9-6), correspondingly.

The numbers of pairs of convergent diesel relative price series are 484 for 2000-2005 and 164 for 1995-1999 based on the city-by-city ADF unit root tests (Table 9-7), but only 20 and 15 based on group as benchmark (Table 9-6), correspondingly. The same can be observed for coal.

9.2.2 Panel unit root tests

9.2.2.1 National panel unit root tests

Using the same procedure, we next conduct panel unit root tests to ascertain whether there is a national integrated energy market in China. Similarly, we conduct panel unit root tests on the raw data series to ascertain their order of integration. These results are presented as Table 9-8, which display tests for the raw data in both levels and the first difference for three sample periods. The results show some variation, but in general the evidence is in favour of an order of integration of 1 or I (1).

Panel unit root tests for the relative price series for 35 city markets based on the group average as benchmark are presented as Table 9-9, which displays three periods and five types of tests for all four types of energy. Several points can be made based on the panel unit root test results from Table 9-9. Firstly, it should be noted that most of the LLC panel unit root tests fail to reject the null hypothesis, which might be due to the assumption of a common unit root process. Secondly, most of the remaining panel unit root tests reject the null hypothesis of a unit root, which suggests that energy prices are convergent as a whole. Thirdly, there are more tests that reject the null in the second subsample period than in the first, suggesting that it is more likely that relative energy prices are convergent in the second subsample period than in the first. Finally, fewer panel unit root tests reject the null for coal and electricity than for gasoline and diesel, suggesting that gasoline and diesel are more likely to be market-oriented than coal and electricity.

9.2.2.2 Regional panel unit root tests

Here we conduct regional panel unit root tests only with exogenous variables of individual effects and a linear trend in the test equation because most of price series seem to contain a trend, especially in the second sub-period, either deterministic or stochastic (Hamilton, 1994). Firstly, we conduct various regional panel unit root tests for the raw data, which are presented in Appendix Table 9-1 to Appendix Table 9-7 for regions 1-7 respectively. Then we conduct various regional panel unit root tests for relative price series using regional average price as a benchmark. These regional panel unit root test results for relative prices are present in Appendix Table 8 to Appendix Table 14. Similarly, most of the LLC panel unit root tests fail to reject the null hypothesis, which might be due to the assumption of a common unit root process, but note the bold numbers.

To better consider the regional panel unit root test results, we just abstract the IPS test for an example, which is provided as Table 9-10. Clearly, some general results can be now seen for the tests for all markets, but variations in test results obviously do exist across regions.

Several regional specific conclusions can be drawn based on the regional panel unit root test results. Firstly, more tests are in favour of price convergence for gasoline and diesel than for coal and electricity, which suggests that the former is likely more market integrated than the later. Secondly, more tests are in favour of price convergence during the second sub-period than during the first sub-period, suggesting that energy market integration was a gradual process in China, which coincides with the institutional evolution and gradual price reforms of China's energy industry. Thirdly, it seems that diesel markets are more integrated than gasoline markets in some regions, for example, more tests are in favour of price convergence for diesel markets than for gasoline markets in region 2. There may be two reasons for this. The first is that urban areas typically consume more gasoline while rural areas use more diesel. The second is that urban residents might receive more subsidies than rural residents. Fourthly, fewer tests are in favour of price convergence in the case of coal in some regions during the second sub-period than during the first sub-period. Please see the previous section for further explanation of this point. Finally, certain types of energy market seem more integrated in some regions than in other regions. This is likely caused by the variations in the regional energy distribution and economic growth, for example, the coal market is more integrated while the electricity market is the least integrated in Region 2 (Beijing, Tianjin and Shanghai) because coal is not a major determinant of regional economic growth while electricity is.

9.3 Inter-fuel price trends and cointegration tests

9.3.1 Inter-fuel price trends

In this section, we use our price data to sketch a descriptive picture of the emergence of China's energy market cointegration. To do so, we plot the price data and examine how various fuel prices move together in the same geographical regions or markets. Sub-periods will be distinguished and determined by the historical events of important energy reforms as presented in the previous section. The analysis takes place at national, regional and city levels and for two sub-periods of transition (1997-1998) and the new regime (after 1999). We will also pay particular attention to the price co-movement of coal-electricity and gasoline-diesel because these two pairs of fuel price series are most likely to be cointegrated.

9.3.1.1 National inter-fuel price trends

Panel A of Figure 6-4 shows the price co-movement of coal and electricity for three sub-periods. It can be seen that the electricity price suddenly jumped to a higher level from 1997 to 1998, from ¥360 per thousand KWh in 1997 to ¥475 per thousand KWh in 1998, while coal price almost remained unchanged for the whole transition period. Government control played an important role in price formation during this transition period. By contrast, the third sub-period shows a likely more market-oriented period where electricity prices have increased, particularly after 2004 while coal prices also began to increase, especially after 2004. It seems that an apparent convergence of coal and electricity prices occurred after 2002, which needs to be investigated further.

Turning to gasoline and diesel. During the transition period (01/1997-12/1998), the prices of gasoline and diesel were low and their trends were flat and 'parallel' (Panel B of Figure 6-4). Recall that during this period 1994 to 1998[38] retail price levels were much lower than international market prices. Petroleum prices have been set according to the international market since 1999, as can be seen with prices increasing, especially since 2002.

9.3.1.2 Regional inter-fuel price trends

As discussed previously, each region might have its own energy regulation policy due to unbalanced economic growth and unbalanced energy reserves across regions. Under these conditions, even if fuel prices are cointegrated at the national levels, it doesn't necessarily mean that they are cointegrated in each region. To observe price trends of pairs of fuels for each region and compare whether there are any differences in these price trends of pairs of fuels during the whole study period (01/1995-12/2005), we present Figures 9-10 to 9-16. According to these figures, all regional price trends of coal-electricity are generally similar to that at the national level. Secondly, some variations are still evident in price trends across pairs of fuels. The most evident example is that the price trends of gasoline and diesel are more likely cointegrated than those of coal and electricity for each region. Thirdly, the price trends of coal and electricity are more likely inclined to be cointegrated as energy policy reforms progressed. The most likely cointegration for price trends of coal and electricity can be seen after 2003 where coal prices show a strong rising trend, approaching the electricity price trend. Fourthly, the price trends of gasoline and

[38] There are likely two reasons for the low prices of petroleum products. The first is low domestic production cost of petroleum products. The second is low quality of both domestically processed and imported petroleum products.

diesel are more similar to those at the national level than the price trends of pairs of coal and electricity. This is because the prices of petroleum products are more likely homogeneous across the country than coal and electricity prices are. Fifthly, the price trends of gasoline and diesel look homogeneously cointegrated during the whole study period for all regions. However, similar to those at the national level, the price trends of gasoline and diesel appear to diverge since 2002 for all regions.

Having compared the variations over region, we then have the following observations for specific regions:

Firstly, the prices trends of coal and electricity demonstrate the least likely emergence of an energy market in Region Two (Figure 9-11) and in Region Three (Figure 9-12) for example, during the transition period, electricity prices remain flat, jump to a new level and remain flat until 2000, and then jump and remain flat again roughly until 2003 in Region Two compared to Beijing, Shanghai and Tianjin). Correspondingly, however, during the transition period, coal prices remained flat, decline to a new level in 1998 and decline three times until the mid of 2000, and then slowly rise until early 2003 when they accelerate until mid of 2004 in Region Two (Figurer 9-11). This probably reflected political concerns that stability and the tensions created by 'reforms' in this region (Beijing, Shanghai and Tianjin).

Secondly, having compared the trends of electricity and coal prices, we found that electricity prices appeared to be adjusted more frequently and probably responded more sensitively to demand than coal prices in Region Five (Figure 9-14, including Fuzhou, Changsha, Guangzhou, Nanning and Haikou). This also can be seen in Region One

(Figure 9-10, which includes Shijiazhuang, Taiyuan, Hefei, Jinan and Zhengzhou) and probably in Region Six (Figure 9-15, which includes Chongqing, Chengdu, Xi'an, Lanzhou, Guiyang and Kunming).

Thirdly, although the price trends of gasoline and diesel have shown a consistent co-movement for most of regions since the transition period (01/1997, see Panel B of Figure 9-10 to Figure 9-16), Region Two (including Beijing, Shanghai and Tianjin) seemingly demonstrates the apparent regulated price trends of gasoline and diesel during the late 1998 to the late 1999 (Panel B of Figure 9-11).

9.3.1.3 City inter-fuel price trends

Whether inter-fuel price trends at city level are similar to those at the national and regional levels, needs to be further examined since aggregation might obscure the real relations between pairs of fuel prices at the city market level. To save space, only selected major cities are discussed here, specifically: Harbin, Beijing, Shijiazhuang, Taiyuan, Jinan, Zhengzhou, Wuhan, Nanjing, Shanghai, Hangzhou, Guangzhou, Xi'an, Chengdu, and Urumqi. These cities are evenly located cross the country, and are either important energy production bases or important economic growth zones or both. The GDP in the 14 provinces and the sample cities accounts for almost 70% of the national GDP in 2006. Therefore, these 14 provincial capital city markets should be fairly representative for national energy reforms.

Price trends for pairs of fuel sources are presented in order from the northeast (Harbin) to South (Guangzhou) and to West (Xinjiang) and Southwest (Chengdu) in Appendix Figure 9-1 to Appendix Figure 9-14. The price trends of inter-fuels at the city market level are fundamentally similar to those at both national and regional aggregate levels. The price trends fluctuate more and also more ‘flat’ price trends can be found at the single city market level for pairs of coal and electricity. In contrast, the price trends fluctuate less and price trends are steeper at the single city market level for pairs of gasoline and diesel. This means that markets are more likely to be cointegrated for pairs of gasoline and diesel than for pairs of coal and electricity.

The potential emergence of energy price cointegration appeared one year later at the city market level. This may be explained by data aggregation. As observed at both the national and regional aggregate levels, the new regime of energy economic development began in early 1999. However, the city level price data show that the new regime of energy economy emerged in the mid or late 1999 for example, in Beijing (Panel B of Appendix Figure 9-2), Jinan (Panel B of Appendix Figure 9-5), Zhengzhou (Panel B of Appendix Figure 9-6), Wuhan (Panel B of Appendix Figure 9-7) and Nanjing (Panel B of Appendix Figure 9-8), gasoline and diesel prices started to display rising and changing trends in late 1999.

The emergence of a potentially cointegrated energy market for coal and electricity seems later than for petroleum products. It seems that coal and electricity prices show a potential cointegrated relationship for most of the cities after 2002. The prices of coal and electricity have also changed more frequently since then. Therefore, we might tentatively propose that the real emergence of coal and electricity cointegration was after 2002.

Finally, a strange phenomenon can be found between the price trends of coal and electricity for most provincial city markets during the transition and new regime, which varies across city market. Namely, electricity prices increase while coal price decline for example, during the early 1998 to the late 2001, electricity prices jumped twice, while coal prices correspondingly dropped twice in Harbin (Panel A of Appendix Figure 9-1). During the whole of 2000, electricity prices jumped dramatically, while coal prices declined slightly in Beijing (Panel A of Appendix Figure 9-2). The reasons for this are unclear, but large surpluses of coal may be one of the most important factors that significantly depressed the coal price during this period (Wang, 2007).

In summary, we have the following primary assumptions for the emergence of energy price cointegration in China to be statistically tested in the next section. Firstly, the emergence of price cointegraton across homogeneous pairs of fuels is apparent though the intensities of price cointegration vary across homogeneous pairs of fuels. Secondly, the descriptive pictures of fuel price trends indicate that the same co-movement of prices occurs in the case of different petroleum products in the whole study period (01/01/1995-31/12/2005). When reconciling energy price reforms and price co-movement trends, however, we may conclude that it is most likely since 2000 that the emergence of price cointegration across petroleum products has occurred because only since then the prices of petroleum products began to increase and change strongly for most of city markets according to our observations above and price reform time table. Actually, the emergence of energy price cointegration appears to be one year later at city level (which is 2000) than at the regional or national aggregate level (which is 1999). This may be the result of price aggregation. Thirdly, the descriptive pictures of fuel price trends also demonstrate that the same co-movement of prices has most likely occurred in the case of pairs of coal and electricity since 2003 when the prices of coal and electricity began to climb and change significantly for most city markets. Similarly, the potential emergence of price cointegration is several years later at city level (which is 2003) than observed at regional or national aggregate level (which is 1999). As can be seen, the emergence of price cointegration is three years earlier for gasoline and diesel than for coal and electricity, where price reforms for gasoline and diesel markets are earlier and complete compared to those for the coal and electricity markets. In the next section, we consider formal statistical tests of the existence of price cointegration to consider, among other issues the last two assumptions above.

9.3.2 Panel cointegration tests

Given the potential for different pricing periods and reform effects, in the subsequent analysis we test for the existence of inter-fuel price cointegration first for the whole period and then for sub-periods whose dates are informed by institutional and historical changes. The tests also consider national and regional level markets.

We utilise all seven panel cointegration statistics discussed in Chapter 4 for specific inter-fuel price series and specific time periods of interest. The panel cointegration statistics are presented as Appendix Table 9-15 for the national panel and Appendix Tables 9-16 to 9-22 for the panel of Regions 1-7, respectively.

If all tests reject or all tests do not reject, the conclusion is clear, however, as is common when using such a battery of tests, the results are potentially ambiguous and care must be exercised in choosing which results to emphasize and why. As discussed in Pedroni (2004), in terms of monthly data, with fewer than 20 years of data it may be possible to distinguish even the most extreme cases from the null of no cointegration when the data are pooled across members of panels with these dimensions. This condition has been met in our case since we have 36 observations each year or 3 observations each month. Furthermore, if the panel is fairly large so that size distortion is less of an issue, the panel υ-statistic tends to have the best power relative to the other statistics. In very small panels, however, if the group-rho statistic rejects the null of no cointegration, we can be relatively confident of the conclusion as it is slightly undersized and empirically the most conservative of the tests. The other statistics tend to lie somewhere in between these two extremes and have minor comparative advantages over different ranges of the sample size. The panel-υ statistic is the strongest panel cointegration test and therefore the next discussions will be focused on this test.

9.3.2.1 National panel cointegration tests

Table 9-11 presents the national panel cointegration tests for the inter-fuels of all four fuels, electricity and coal, and diesel and gasoline during one whole period (1997-2005) and two sub-periods (1997-1999 and 2000-2005). For the full sample period the national panel cointegration tests suggest that all four price series move together in the long-run given the assumption of no deterministic trend (Table 9-11). *A priori,* however, we would find this result unlikely since we know that for some years and some fuels energy prices were independently controlled and their time series paths appear to vary. If we consider the three sub-period tests, most of the panel υ-statistic tests do not reject the null of no cointegration. The lack of cointegration for all fuels at the national level is also as we might expect as coal and electricity appear to move, over time, differently to gasoline and diesel prices. Such an expectation is supported in the results. However, it is clear that that all four fuel prices are more cointegrated in the second sub-period than in the first sub-period since one of panel υ-statistic tests rejects the null hypothesis in the second sub-period.

Secondly, for coal and electricity, the national panel cointegration tests provide some weak evidence of cointegration for the full sample period. However, these weak results are not supported when we consider the two sub-periods where the results suggest that the coal and electricity price series did not move together in a long-run during 1997-1999, while the coal and electricity price series may have moved together during 2000-2005. These results are consistent with our previous observations.

Thirdly, the national panel cointegration tests show a different scenario for gasoline and diesel price series. The national panel cointegration tests suggest that gasoline and diesel price series have moved together in a long-run during both for the full sample period and the two sub-periods.

9.3.2.2 Regional panel cointegration tests

Table 9-12 provides regional panel cointegration tests of inter-fuel price series. Based upon similar analysis, we can make the follow conclusions for the regional-based panel cointegration tests:

Firstly, some regional panel tests reject the null of no cointegration for coal, electricity, gasoline and diesel prices during the second sub-period (2000-2005), suggesting that inter-fuel prices are cointegrated in some regions even during the transitional energy economy. Given the assumption of no deterministic trend, there are four of seven panel-υ statistic tests that reject the null of no integration in the second sub-period.

Secondly, of the majority of the regional panel tests do not reject the null hypothesis of no cointegration for coal and electricity prices during both sub-periods, especially in the second sub-period. Although most of the previous results display some cointegration for coal and electricity prices after 2000, the regional panel statistical tests do not confirm these results. However, there seem to be two exceptions; Regions 1, 5 and 6 for the sub-period 2000-2005, for which the strongest panel υ-statistic seemingly tends to reject the null hypothesis of no cointegration. It may appear strange for coal and electricity prices to move together during the earlier period (1997-1999), but not during the latest period (2000-2005), however, this was a period of state controlled prices where some common movements would be expected. One might therefore expect this regulated link to disappear as a consequence of the gradualist reforms.

Thirdly, all regional panel tests reject the null hypothesis of no cointegration for gasoline and diesel prices during the latest sub-period of 2000-2005, which suggests that gasoline and diesel prices move together in the long-run after 2000 in all regions. However, the regional panel tests for the 1997-1999 sub-period (equivalent to the period of transition) suggest that gasoline and diesel prices move together in a long-run in some regions for example, four regional panel tests reject the null hypothesis of no cointegration for gasoline and diesel prices in Regions 1, 2, 4 and 5 while three regional panel tests do not reject the null hypothesis of no cointegration for gasoline and diesel prices in Regions 3, 6 and 7. There are several points to be drawn here. Firstly, geographically, gasoline and diesel prices appear to move together even during the transition period for those regions located in the center, east and south, but not for those regions located in the remote areas, such as northeast, west, and southwest. Secondly, regional petroleum products markets are evident in China. Thirdly, gasoline and diesel prices have moved together since 1997 in relatively developed areas which are circled by Shijiazhuang, Taiyuan, Xi'an, Wuhan, Changsha, and east coastal areas.

At this stage, it is potentially interesting to ask why the price series of gasoline and diesel are more cointegrated than those of coal and electricity, both statistically and economically. There may be many answers to this, but the following may be the most important:

- Gasoline and diesel are more homogeneous energy products than coal and electricity. In this case, it is expected that the former price series are more likely cointegrated than the latter.
- The intensity and time of reforms are different over the two groups of energy sources. According our review of the energy policy reform in China, the prices of petroleum products and coal were deregulated earlier than that of electricity.
- The price reforms were almost simultaneous for gasoline and diesel while they were not synchronous for coal and electricity. Typically, price deregulation was earlier for the coal industry than for the electricity industry. One might expect that the non synchronous price reforms in the coal industry and electricity industry would not likely lead to observed cointegration and probably contributed to the later emergence of cointegration of the price series of coal and electricity in China.

- Coal and electricity are categorized in the same energy group in this study, but they are a homogeneous commodity although most electricity is generated from coal. Especially, most of electricity is generated from coal in China.
- Substitutability is significantly different between gasoline and diesel and coal and electricity though they are both substitutable. Gasoline and diesel may be easily substitutable while coal and electricity may be complements.
- Differences in price deregulation over energy types are closely related to their effects on the national economic growth and consumer consequences. Typically, changes in electricity price appear more related to the cost of living than input costs. Hence, electricity price deregulation was deferred in China. Correspondingly, price reforms for other commodities closely related to electricity production might be also delayed or overdue. This is particularly true for reform of coal prices where most of it is used to generate electricity.

9.4 Comparisons with other studies

Whether China is a market economy has attracted attention from both domestic and international scholars, however, few have focused empirically on this question and even fewer are focused on China's energy market. As the early economic reforms were initiated in crop production, Huang and Rozelle (2004) have shown empirically the emergence of an agricultural commodity markets in China during the past decade. They have also claimed that the power of markets to continue to integrate perhaps, more than anything, shows the power of China's gradual method of transition. Park et al. (2002)

demonstrate that China's grain markets have grown dramatically over time. As China rejoined the WTO, however, Poncet (2003 and 2005) investigate the determinants of inter-provincial trade barriers and conclude in favor of a disintegrated domestic market in China. It should be noted that her studies are not based on the formal unit root tests of price data. Fan and Wei (2006) conduct a detailed investigation using unit root tests for spot price series for China. For the energy market, they consider only gasoline and diesel price tests. They only provide a general picture of market integration. This study not only provides more robust tests, but demonstrates that the market mechanism is playing an increasing role in determining energy prices.

Although there are many studies on the emergence of China's agricultural commodity markets (e.g., Huang and Rozelle, 2006), there are few studies on inter-fuel price panel cointegration tests. Therefore, it is difficult for us to compare our finding with others.

9.5 Conclusions and implications

In this chapter, we have shown, in a number of ways, the steady emergence of energy commodity markets that have occurred in China during the study period. Regardless of whether we use descriptive statistics or more formal techniques, our results are consistent with the emergence of markets for coal, electricity, gasoline and diesel. Moreover, energy markets are robust when viewed across space and time.

Although those who visit China are not surprised, such a picture of integrated energy markets may be surprising when juxtaposed against the policy background. Even during the first subsample period, China took a gradualist approach to reforming its energy markets. Our results show that despite the gradualist policy, the operation of energy markets have steadily strengthened in China.

China's market reforms have really been based on entry-driven competition. In the case of China entry has come from both the dismantlement of the state-own enterprises and the emergence of more energy companies. While this has produced an increase in integration and fall in transaction costs that has been documented in the chapter, it is also eroded the power of the state to control the energy markets with traditional command methods. Our results suggest that if policymakers actually want to control energy markets in the future, they need to devise new ways to intervene in the energy sector, otherwise the reforms they have introduced have clearly led to a more market oriented energy sector. However, if they want the market to function freely, it appears that the reforms to date have moved somewhat in this direction.

Although we have tested for energy price convergence, our results suggest China's energy economy is still in a state of transition. However, as the market economy is more efficient in resource distribution, one would expect that China's high energy intensity will be affected by energy market reforms despite the fact that other factors still play an important role in improving a firm's performance and reducing energy consumption. This suggests that further energy market reforms can reduce China's energy intensity and in turn energy imports and the impact of China's energy import on the world energy supply and prices.

It should be noted that although energy prices are convergent across markets, the market process is apparently different across energy types. The results show that gasoline and diesel are more likely market-oriented than coal and electricity. The price reforms of electricity and coal relevant to electricity generation were late and slow. Therefore, how to speed-up price reforms of electricity and coal relevant electricity generation is a great challenge China has to face.

Panel tests demonstrate the convergence of energy prices, however, univariate ADF unit root tests clearly display there are still many regional markets in China for certain types of fuel. This is likely related to the unbalanced distribution of energy reserves, especially for coal. As a result, transportation plays an important role in final user price formation of coal due to huge long distance transportation cost. Reforms of the transportation sector, therefore, particularly the railway, may become a major determinant in the process of price convergence for coal prices across markets and regions.

Finally, it is surprising that the unit root tests that panel cointegration tests accept the null of no cointegration for all four fuel prices at the national level and so do for electricity and coal prices. However, the tests do suggest some clues to the emergence of some developing areas of inter-fuel prices cointegration in China. It also seems that as energy reforms take place, inter-fuel prices are becoming more cointegrated with oil prices apparently cointegrated even during the transition period in some areas.

Table 9-1. The ADF unit root tests for raw prices (level, 1995-2005)

City market	Coal		Electricity		Gasoline		Diesel	
	t-stat.	p-values	t-stat.	p-values	t-stat.	p-values	t-stat.	p-values
Beijing	-1.45	0.845	-2.06	0.564	-1.45	0.844	-2.82	0.190
Tianjin	-2.26	0.453	-3.08	0.111	-2.13	0.526	-2.97	0.141
Shijiazhuang	-2.29	0.436	-1.87	0.666	-1.67	0.761	-3.00	0.133
Taiyuan	-1.49	0.829	-1.65	0.771	-1.35	0.874	-2.06	0.565
Hohhot	-1.04	0.936	-2.54	0.309	-1.37	0.869	-2.69	0.239
Shenyang	-2.52	0.320	-1.96	0.620	-2.28	0.441	-2.79	0.200
Changchun	-1.82	0.693	-1.29	0.889	-2.52	0.317	-3.09	0.111
Harbin	-1.59	0.792	-1.38	0.866	-2.02	0.591	-3.47	0.044
Shanghai	-0.97	0.946	-1.52	0.820	-2.28	0.443	-2.28	0.444
Nanjing	-1.76	0.720	-1.73	0.735	-1.89	0.659	-2.66	0.253
Hangzhou	-1.01	0.940	-2.99	0.134	-1.99	0.603	-2.49	0.331
Hefei	-1.21	0.906	-1.97	0.615	-1.32	0.882	-2.48	0.337
Fuzhou	-0.77	0.966	-1.20	0.908	-1.50	0.827	-3.01	0.132
Nanchang	-1.86	0.672	-2.83	0.187	-1.97	0.616	-2.37	0.393
Jinan	-1.52	0.822	-1.71	0.746	-1.69	0.754	-2.18	0.499
Zhengzhou	-1.44	0.899	-3.25	0.077	-1.86	0.672	-2.31	0.424
Wuhan	-0.79	0.964	-2.69	0.240	-1.52	0.822	-2.56	0.298
Changsha	-0.51	0.983	-1.91	0.649	-1.84	0.685	-2.93	0.155
Guangzhou	-1.34	0.876	-1.13	0.922	-2.05	0.569	-2.83	0.188
Nanning	-1.13	0.922	-2.39	0.384	-1.93	0.638	-2.62	0.270
Haikou	-1.73	0.736	-1.44	0.849	-1.62	0.784	-2.44	0.359
Chongqing	-2.13	0.531	-2.53	0.315	-2.09	0.545	-2.12	0.530
Chengdu	-1.47	0.838	-2.88	0.170	-1.75	0.728	-2.52	0.321
Guiyang	-1.48	0.836	-1.86	0.673	-2.56	0.301	-2.25	0.458
Kunming	-1.49	0.829	-2.75	0.216	-2.19	0.493	-2.68	0.246
Lhasa	-	-	-2.23	0.469	-2.84	0.186	-2.97	0.143
Xi'an	-2.54	0.308	-3.19	0.087	-1.36	0.870	-3.34	0.061
Lanzhou	-2.81	0.196	-3.09	0.110	-1.84	0.683	-3.12	0.104
Xining	-0.43	0.986	-2.27	0.449	-1.55	0.811	-2.47	0.343
Yinchuan	-0.84	0.960	-1.51	0.824	-1.78	0.714	-3.06	0.118
Urumqi	-1.37	0.867	-2.53	0.315	-1.48	0.834	-3.25	0.077
Qingdao	-	-	-2.39	0.382	-2.08	0.555	-2.52	0.320
Dalian	-1.73	0.738	-1.81	0.697	-2.21	0.485	-2.58	0.289
Xiamen	-1.98	0.612	-1.65	0.770	-2.17	0.507	-3.01	0.129
Ningbo	-1.70	0.749	-1.73	0.738	-1.99	0.602	-2.17	0.503

Note: Null hypothesis is that each series contains a unit root; ADF is the Augmented Dickey-Fuller test; MacKinnon (1996) one-sided p-values; lag length chosen via Hannan-Quinn Information Criteria..

Table 9-2. The ADF unit root tests for 1st difference (1995-2005)

City market	Coal		Electricity		Gasoline		Diesel	
	t-stat.	p-values	t-stat.	p-values	t-stat.	p-values	t-stat.	p-values
Beijing	-4.93	0.000	-29.65	0.000	-28.40	0.000	-6.99	0.000
Tianjin	-19.77	0.000	-32.86	0.000	-25.44	0.000	-26.61	0.000
Shijiazhuang	-14.06	0.000	-9.83	0.000	-25.81	0.000	-7.35	0.000
Taiyuan	-22.06	0.000	-33.22	0.000	-27.10	0.000	-27.33	0.000
Hohhot	-9.20	0.000	-30.45	0.000	-24.22	0.000	-7.73	0.000
Shenyang	-11.37	0.000	-11.13	0.000	-24.91	0.000	-7.25	0.000
Changchun	-4.52	0.002	-33.52	0.000	-26.60	0.000	-26.06	0.000
Harbin	-21.36	0.000	-27.74	0.000	-25.58	0.000	-23.36	0.000
Shanghai	-21.06	0.000	-31.29	0.000	-25.64	0.000	-25.30	0.000
Nanjing	-20.89	0.000	-29.63	0.000	-28.30	0.000	-30.88	0.000
Hangzhou	-5.70	0.000	-30.50	0.000	-26.21	0.000	-28.14	0.000
Hefei	-18.47	0.000	-33.14	0.000	-26.31	0.000	-28.35	0.000
Fuzhou	-10.03	0.000	-32.61	0.000	-28.73	0.000	-24.90	0.000
Nanchang	-23.39	0.000	-11.51	0.000	-27.44	0.000	-28.51	0.000
Jinan	-5.53	0.000	-27.18	0.000	-25.82	0.000	-23.26	0.000
Zhengzhou	-19.86	0.000	-6.98	0.000	-26.99	0.000	-28.32	0.000
Wuhan	-8.10	0.000	-28.84	0.000	-27.21	0.000	-26.96	0.000
Changsha	-12.11	0.000	-23.62	0.000	-24.48	0.000	-27.74	0.000
Guangzhou	-19.44	0.000	-29.34	0.000	-26.46	0.000	-27.79	0.000
Nanning	-20.47	0.000	-26.90	0.000	-30.71	0.000	-9.01	0.000
Haikou	-10.93	0.000	-32.77	0.000	-27.64	0.000	-25.48	0.000
Chongqing	-7.88	0.000	-10.91	0.000	-30.11	0.000	-25.47	0.000
Chengdu	-6.93	0.000	-32.20	0.000	-5.54	0.000	-6.74	0.000
Guiyang	-6.73	0.000	-28.91	0.000	-28.20	0.000	-26.16	0.000
Kunming	-14.13	0.000	-26.04	0.000	-28.50	0.000	-26.50	0.000
Lhasa	-	-	-11.28	0.000	-33.41	0.000	-31.73	0.000
Xi'an	-26.18	0.000	-34.10	0.000	-28.69	0.000	-9.29	0.000
Lanzhou	-6.66	0.000	-30.67	0.000	-26.42	0.000	-6.27	0.000
Xining	-19.20	0.000	-35.04	0.000	-27.34	0.000	-26.52	0.000
Yinchuan	-8.13	0.000	-21.56	0.000	-25.29	0.000	-26.12	0.000
Urumqi	-27.73	0.000	-31.08	0.000	-28.49	0.000	-28.34	0.000
Qingdao	-	-	-19.80	0.000	-20.01	0.000	-19.52	0.000
Dalian	-7.78	0.000	-30.61	0.000	-25.20	0.000	-7.12	0.000
Xiamen	-10.09	0.000	-28.34	0.000	-27.68	0.000	-9.10	0.000
Ningbo	-21.20	0.000	-31.29	0.000	-25.83	0.000	-26.63	0.000

Note: Null hypothesis is that each series contains a unit root; ADF is the Augmented Dickey-Fuller test; MacKinnon (1996) one-sided p-values; lag length chosen via Hannan-Quinn Information Criteria..

Table 9-3. The ADF unit root tests for raw prices (p-values, 1995-1999)

City market	Level				First difference			
	Coal	Electricity	Gasoline	Diesel	Coal	Electricity	Gasoline	Diesel
Beijing	0.858	0.591	0.053	0.591	0.000	0.000	0.000	0.000
Tianjin	0.844	0.275	0.611	0.275	0.000	0.000	0.000	0.000
Shijiazhuang	0.932	0.564	0.408	0.564	0.000	0.000	0.000	0.000
Taiyuan	0.855	0.630	0.516	0.630	0.000	0.000	0.000	0.000
Hohhot	0.540	0.453	0.362	0.453	0.000	0.000	0.000	0.000
Shenyang	0.239	0.265	0.044	0.265	0.000	0.000	0.000	0.000
Changchun	0.913	0.650	0.664	0.650	0.000	0.000	0.000	0.000
Harbin	0.897	0.764	0.046	0.764	0.000	0.000	0.000	0.000
Shanghai	0.691	0.475	0.008	0.475	0.000	0.000	0.000	0.000
Nanjing	0.803	0.582	0.854	0.582	0.000	0.041	0.000	0.041
Hangzhou	0.619	0.608	0.940	0.608	0.000	0.001	0.258	0.001
Hefei	0.407	0.403	0.319	0.403	0.000	0.000	0.000	0.000
Fuzhou	0.894	0.710	0.162	0.710	0.000	0.000	0.000	0.000
Nanchang	0.879	0.289	0.117	0.289	0.000	0.000	0.000	0.000
Jinan	0.011	0.624	0.756	0.624	0.000	0.000	0.000	0.000
Zhengzhou	0.646	0.253	0.000	0.253	0.000	0.002	0.000	0.002
Wuhan	0.984	0.901	0.894	0.901	0.000	0.000	0.729	0.000
Changsha	0.652	0.083	0.156	0.083	0.000	0.000	0.000	0.000
Guangzhou	0.990	0.605	0.592	0.605	0.000	0.000	0.000	0.000
Nanning	0.635	0.801	0.928	0.801	0.000	0.000	0.000	0.000
Haikou	0.903	0.480	0.088	0.480	0.000	0.000	0.000	0.000
Chongqing	0.721	0.652	0.326	0.652	0.000	0.000	0.000	0.000
Chengdu	0.727	0.783	0.665	0.783	0.000	0.000	0.171	0.000
Guiyang	0.626	0.895	0.466	0.895	0.000	0.000	0.000	0.000
Kunming	0.902	0.494	0.034	0.494	0.000	0.000	0.000	0.000
Lhasa	-	0.652	0.395	0.652	-	0.000	0.000	0.000
Xi'an	0.354	0.397	0.038	0.397	0.000	0.000	0.000	0.000
Lanzhou	0.124	0.001	0.235	0.001	0.002	0.000	0.000	0.000
Xining	0.000	0.840	0.529	0.840	0.000	0.000	0.000	0.000
Yinchuan	0.442	0.193	0.454	0.193	0.000	0.000	0.000	0.000
Urumqi	0.913	0.870	0.645	0.870	0.000	0.104	0.000	0.104
Qingdao	-	0.652	0.840	0.652	-	0.000	0.000	0.000
Dalian	0.238	0.932	0.651	0.932	0.000	0.000	0.000	0.000
Xiamen	0.397	0.617	0.073	0.617	0.000	0.000	0.000	0.000
Ningbo	0.847	0.719	0.868	0.719	0.000	0.000	0.000	0.000

Note: Null hypothesis is that each series contains a unit root; ADF is the Augmented Dickey-Fuller test; lag length chosen via Hannan-Quinn Information Criteria..

Table 9-4. The ADF unit root tests for raw prices (p-values, 2000-2005)

City market	Level				First difference			
	Coal	Electricity	Gasoline	Diesel	Coal	Electricity	Gasoline	Diesel
Beijing	0.762	0.000	0.881	0.416	0.141	0.000	0.000	0.001
Tianjin	0.192	0.252	0.711	0.269	0.000	0.000	0.000	0.000
Shijiazhuang	0.271	0.554	0.659	0.287	0.000	0.000	0.000	0.000
Taiyuan	0.572	0.450	0.908	0.631	0.000	0.000	0.000	0.000
Hohhot	0.891	0.320	0.789	0.595	0.000	0.000	0.000	0.000
Shenyang	0.820	0.578	0.686	0.383	0.153	0.000	0.000	0.000
Changchun	0.846	0.099	0.702	0.431	0.004	0.000	0.000	0.000
Harbin	0.522	0.164	0.718	0.258	0.000	0.000	0.000	0.000
Shanghai	0.608	0.125	0.663	0.541	0.035	0.000	0.000	0.000
Nanjing	0.053	0.242	0.683	0.502	0.000	0.000	0.000	0.000
Hangzhou	0.971	0.369	0.614	0.212	0.001	0.000	0.000	0.000
Hefei	0.612	0.166	0.764	0.586	0.098	0.000	0.000	0.000
Fuzhou	0.936	0.225	0.698	0.707	0.112	0.000	0.000	0.000
Nanchang	0.593	0.003	0.694	0.388	0.000	0.000	0.000	0.000
Jinan	0.360	0.810	0.847	0.301	0.008	0.000	0.000	0.000
Zhengzhou	0.764	0.476	0.602	0.594	0.000	0.000	0.000	0.000
Wuhan	0.484	0.003	0.852	0.333	0.000	0.000	0.013	0.000
Changsha	0.913	0.065	0.582	0.350	0.000	0.000	0.000	0.000
Guangzhou	0.658	0.719	0.841	0.420	0.000	0.000	0.000	0.000
Nanning	0.884	0.239	0.586	0.590	0.000	0.000	0.000	0.000
Haikou	-	0.052	0.667	0.302	-	0.000	0.000	0.000
Chongqing	0.783	0.319	0.711	0.685	0.000	0.000	0.000	0.000
Chengdu	0.722	0.607	0.741	0.560	0.000	0.000	0.012	0.002
Guiyang	0.588	0.460	0.678	0.604	0.000	0.000	0.000	0.000
Kunming	0.552	0.233	0.516	0.366	0.000	0.000	0.000	0.000
Lhasa	0.767	0.172	0.647	0.377	0.236	0.000	0.000	0.000
Xi’an	0.484	0.381	0.668	0.175	0.000	0.000	0.000	0.000
Lanzhou	0.481	0.187	0.699	0.334	0.000	0.000	0.000	0.000
Xining	0.670	0.378	0.780	0.676	0.000	0.000	0.000	0.000
Yinchuan	0.604	0.751	0.678	0.152	0.000	0.000	0.000	0.000
Urumqi	0.620	0.328	0.729	0.215	0.033	0.000	0.000	0.003
Qingdao	0.767	0.459	0.331	0.522	0.236	0.000	0.000	0.000
Dalian	0.507	0.386	0.751	0.356	0.000	0.000	0.000	0.000
Xiamen	0.430	0.609	0.744	0.451	0.000	0.000	0.000	0.000
Ningbo	0.425	0.604	0.548	0.592	0.155	0.000	0.000	0.000

Note: Null hypothesis is that each series contains a unit root; ADF is the Augmented Dickey-Fuller test; lag length chosen via Hannan-Quinn Information Criteria.

Table 9-5. The ADF unit root tests for relative prices (p-values, 1995-2005)

City market	Coal	Electricity	Gasoline	Diesel
Beijing	0.334	0.598	0.130	0.085
Tianjin	0.711	0.694	0.402	0.221
Shijiazhuang	0.011	0.047	0.040	0.096
Taiyuan	0.662	0.863	0.186	0.001
Hohhot	0.085	0.197	0.008	0.102
Shenyang	0.323	0.576	0.212	0.002
Changchun	0.728	0.915	0.146	0.000
Harbin	0.401	0.893	0.099	0.004
Shanghai	0.429	0.866	0.000	0.004
Nanjing	0.750	0.511	0.044	0.236
Hangzhou	0.040	0.187	0.466	0.180
Hefei	0.056	0.758	0.557	0.866
Fuzhou	0.124	0.880	0.005	0.056
Nanchang	0.800	0.369	0.000	0.065
Jinan	0.378	0.642	0.148	0.156
Zhengzhou	0.088	0.025	0.035	0.055
Wuhan	0.328	0.271	0.207	0.004
Changsha	0.635	0.077	0.018	0.055
Guangzhou	0.630	0.721	0.218	0.335
Nanning	0.000	0.534	0.553	0.340
Haikou	0.761	0.633	0.346	0.570
Chongqing	0.190	0.356	0.398	0.005
Chengdu	0.383	0.076	0.123	0.356
Guiyang	0.966	0.799	0.033	0.267
Kunming	0.489	0.439	0.000	0.002
Lhasa	0.981	0.532	0.678	0.345
Xi’an	0.090	0.418	0.061	0.017
Lanzhou	0.253	0.341	0.070	0.050
Xining	0.060	0.727	0.366	0.247
Yinchuan	0.680	0.883	0.000	0.088
Urumqi	0.749	0.462	0.378	0.512
Qingdao	0.981	0.417	0.035	0.002
Dalian	0.355	0.721	0.091	0.140
Xiamen	0.037	0.557	0.001	0.012
Ningbo	0.110	0.523	0.219	0.174
Number of rejecting null	5	2	13	14

Note: Null hypothesis is that each relative price series contains a unit root. ADF is the Augmented Dickey-Fuller test; MacKinnon (1996) one-sided p-values; group is used a benchmark; lag length chosen via Hannan-Quinn Information Criteria.

Table 9-6. The ADF unit root tests for relative price (p-value)

City market	Coal		Electricity		Gasoline		Diesel	
	00-05	95-99	00-05	95-99	00-05	95-99	00-05	95-99
Beijing	0.446	0.334	0.591	0.598	0.592	0.130	0.127	0.085
Tianjin	0.618	0.711	0.282	0.694	0.409	0.402	0.021	0.221
Shijiazhuang	0.415	0.011	0.271	0.047	0.001	0.040	0.002	0.096
Taiyuan	0.385	0.662	0.443	0.863	0.596	0.186	0.034	0.001
Hohhot	0.215	0.085	0.271	0.197	0.440	0.008	0.099	0.102
Shenyang	0.082	0.323	0.589	0.576	0.208	0.212	0.011	0.002
Changchun	0.450	0.728	0.230	0.915	0.292	0.146	0.015	0.000
Harbin	0.731	0.401	0.155	0.893	0.269	0.099	0.005	0.004
Shanghai	0.165	0.429	0.533	0.866	0.215	0.000	0.320	0.004
Nanjing	0.872	0.750	0.412	0.511	0.433	0.044	0.192	0.236
Hangzhou	0.844	0.040	0.702	0.187	0.002	0.466	0.004	0.180
Hefei	0.679	0.056	0.214	0.758	0.116	0.557	0.644	0.866
Fuzhou	0.860	0.124	0.530	0.880	0.001	0.005	0.000	0.056
Nanchang	0.122	0.800	0.198	0.369	0.045	0.000	0.300	0.065
Jinan	0.383	0.378	0.967	0.642	0.003	0.148	0.382	0.156
Zhengzhou	0.335	0.088	0.363	0.025	0.242	0.035	0.012	0.055
Wuhan	0.116	0.328	0.033	0.271	0.719	0.207	0.000	0.004
Changsha	0.685	0.635	0.047	0.077	0.001	0.018	0.194	0.055
Guangzhou	0.945	0.630	0.836	0.721	0.068	0.218	0.002	0.335
Nanning	0.117	0.000	0.400	0.534	0.000	0.553	0.005	0.340
Haikou	0.675	0.761	0.184	0.633	0.158	0.346	0.252	0.570
Chongqing	0.448	0.190	0.322	0.356	0.266	0.398	0.058	0.005
Chengdu	0.478	0.383	0.513	0.076	0.327	0.123	0.250	0.356
Guiyang	0.623	0.966	0.552	0.799	0.088	0.033	0.252	0.267
Kunming	0.674	0.489	0.095	0.439	0.002	0.000	0.001	0.002
Lhasa	0.675	0.981	0.035	0.532	0.465	0.678	0.043	0.345
Xi'an	0.000	0.090	0.447	0.418	0.472	0.061	0.033	0.017
Lanzhou	0.593	0.253	0.144	0.341	0.170	0.070	0.019	0.050
Xining	0.591	0.060	0.486	0.727	0.000	0.366	0.414	0.247
Yinchuan	0.636	0.680	0.681	0.883	0.005	0.000	0.003	0.088
Urumqi	0.553	0.749	0.278	0.462	0.043	0.378	0.540	0.512
Qingdao	0.675	0.981	0.414	0.417	0.070	0.035	0.064	0.002
Dalian	0.027	0.355	0.388	0.721	0.003	0.091	0.004	0.140
Xiamen	0.611	0.037	0.686	0.557	0.000	0.001	0.015	0.012
Ningbo	0.130	0.110	0.437	0.523	0.000	0.219	0.455	0.174
Number of rejecting null	2 [a]	6	3	2	14	13	20	15

Note: Null hypothesis is that each relative price series contains a unit root; ADF is the Augmented Dickey-Fuller test; MacKinnon (1996) one-sided p-values; lag length chosen via Hannan-Quinn Information Criteria.

[a] See text for explanation why the number is smaller in the second sub-period than in the first sub-period.

Table 9-7. Numbers of rejecting the null based on city-by-city ADF unit root tests for relative prices

Benchmark city	Coal		Electricity		Gasoline		Diesel	
	2000-05	1995-99	2000-05	1995-99	2000-05	1995-99	2000-05	1995-99
Beijing	1	7	7	1	0	9	8	4
Tianjin	6	3	3	2	15	0	17	4
Shijiazhuang	0	5	2	1	23	7	19	10
Taiyuan	3	0	0	1	1	9	16	7
Hohhot	3	6	1	0	9	7	7	2
Shenyang	1	8	0	0	12	16	17	4
Changchun	1	6	3	0	20	0	19	17
Harbin	1	10	2	2	13	8	14	3
Shanghai	2	7	3	0	10	12	10	2
Nanjing	0	6	2	1	6	7	8	0
Hangzhou	1	3	4	2	23	2	18	4
Hefei	2	9	1	1	10	5	6	2
Fuzhou	0	5	1	1	20	13	20	0
Nanchang	3	10	4	2	16	7	5	2
Jinan	0	3	0	0	15	0	3	3
Zhengzhou	1	4	1	2	10	11	27	4
Wuhan	1	8	6	1	0	8	23	6
Changsha	0	1	3	1	26	11	16	4
Guangzhou	0	11	0	0	17	15	13	7
Nanning	3	1	0	3	17	2	19	7
Haikou	0	1	7	1	21	8	12	5
Chongqing	1	1	2	0	18	2	5	7
Chengdu	2	3	1	2	5	1	7	2
Guiyang	2	0	1	1	3	4	14	7
Kunming	0	4	7	2	27	16	20	4
Lhasa	2	1	2	0	0	1	15	2
Xi'an	12	5	1	0	13	14	10	5
Lanzhou	1	2	2	12	18	12	18	6
Xining	1	3	1	1	13	4	16	1
Yinchuan	0	6	0	1	25	10	24	12
Urumqi	0	0	1	0	19	10	10	7
Qingdao	2	1	0	0	4	0	10	3
Dalian	5	2	0	1	20	1	19	2
Xiamen	4	2	0	0	12	8	17	6
Ningbo	3	4	2	0	17	2	2	3
Sum	64	148	70	42	478	242	484	164
Percentage of rejecting null	**5** [a]	12	**6**	3	**38**	19	**38**	13

Note: Null hypothesis is that each relative price series contains a unit root; ADF is the Augmented Dickey-Fuller test; MacKinnon (1996) one-sided p-values; lag length chosen via Hannan-Quinn Information Criteria.

[a] See text for explanation why the number is smaller in the second sub-period than in the first sub-period.

Table 9-8. Panel unit root tests of raw data for all 35 city markets

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-1999:								
Level:								
LLC	7.62	0.995	1.48	0.931	4.38	1.000	4.81	0.998
Breitung	-2.10	0.078	-3.69	0.000	3.73	1.000	1.23	0.891
IPS	0.85	0.803	-1.51	0.085	-3.54	0.000	-0.99	0.160
1st difference:								
LLC	-100.69	0.000	-128.57	0.000	-122.34	0.000	-120.97	0.000
Breitung	-47.04	0.000	-76.67	0.000	-22.64	0.000	-27.22	0.000
IPS	-77.04	0.000	-96.73	0.000	-97.01	0.000	-99.99	0.000
2000-2005:								
Level:								
LLC	-0.64	0.260	4.83	1.000	4.67	0.998	2.60	0.995
Breitung	0.14	0.557	-3.12	0.001	-1.95	0.026	-4.59	0.000
IPS	1.10	0.865	-3.48	0.000	2.13	0.983	-1.51	0.066
1st difference:								
LLC	-83.52	0.000	-189.13	0.000	-169.78	0.000	-104.97	0.000
Breitung	-12.19	0.000	-43.87	0.000	-44.11	0.000	-30.64	0.000
IPS	-52.22	0.000	-143.93	0.000	-136.05	0.000	-71.64	0.000

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS. Exogenous variables include Individual effect and individual linear trend.

Table 9-9. Panel unit root tests of relative price data for all 35 city markets

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-2005:								
LLC	4.97	0.99	0.62	0.73	-3.45	**0.00**	-4.74	**0.00**
Breitung	-1.79	**0.04**	-4.73	**0.00**	-6.72	**0.00**	-9.86	**0.00**
IPS	-2.26	**0.01**	-0.29	0.39	-8.69	**0.00**	-8.83	**0.00**
Fisher ADF	100.61	**0.01**	61.42	0.76	226.67	**0.00**	221.77	**0.00**
Fisher PP	302.93	**0.00**	951.95	**0.00**	1728.9	**0.00**	1403.0	**0.00**
2000-2005:								
LLC	-1.41	**0.08**	5.22	0.99	-2.65	**0.00**	-2.89	**0.00**
Breitung	-2.57	**0.01**	-3.93	**0.00**	-5.05	**0.00**	-4.72	**0.00**
IPS	-2.01	**0.02**	-2.24	**0.01**	-11.40	**0.00**	-10.05	**0.00**
Fisher ADF	103.76	**0.01**	82.31	0.15	343.16	**0.00**	249.23	**0.00**
Fisher PP	160.99	**0.00**	2123.1	**0.00**	1950.4	**0.00**	1292.7	**0.00**
1995-1999:								
LLC	9.05	0.99	2.97	0.99	3.94	0.99	4.32	0.99
Breitung	-2.90	**0.00**	-3.66	**0.00**	-0.12	0.45	-0.83	0.20
IPS	-0.38	0.35	-0.13	0.45	-4.26	**0.00**	-2.48	**0.01**
Fisher ADF	78.21	0.23	64.03	0.68	148.33	**0.00**	106.62	**0.00**
Fisher PP	306.25	**0.00**	407.42	**0.00**	792.52	**0.00**	602.41	**0.00**

Note: Null hypothesis is common unit root for LLC and Breitung tests, and individual unit root for IPS. Fisher ADF and Fisher PP tests. Exogenous variables include Individual effect and individual linear trend.

Table 9-10. Panel IPS unit root tests of relative prices by region

Region	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-2005:								
Region 1	0.09	0.54	-0.59	0.28	-1.46	**0.07**	-2.10	**0.02**
Region 2	-2.18	**0.01**	0.57	0.71	-3.00	**0.00**	-2.87	**0.00**
Region 3	1.03	0.85	0.14	0.56	-1.47	**0.07**	-2.79	**0.00**
Region 4	-0.15	0.44	0.28	0.61	-2.37	**0.01**	-4.09	**0.00**
Region 5	-0.26	0.40	0.26	0.60	-2.33	**0.01**	-2.65	**0.00**
Region 6	-1.33	0.09	-0.38	0.35	-3.06	**0.00**	-3.82	**0.00**
Region 7	-2.65	**0.00**	-2.06	**0.02**	-6.46	**0.00**	-2.75	**0.00**
2000-2005:								
Region 1	-0.10	0.46	-2.49	**0.01**	-1.94	**0.03**	-3.01	**0.00**
Region 2	-2.61	**0.00**	-0.28	0.39	-0.62	0.27	-2.20	**0.01**
Region 3	0.24	0.59	-0.96	0.17	-2.42	**0.01**	-2.02	**0.02**
Region 4	0.72	0.77	-1.06	0.15	-3.85	**0.00**	-4.11	**0.00**
Region 5	-0.09	0.47	-0.89	0.19	-7.12	**0.00**	-5.88	**0.00**
Region 6	-1.23	0.11	-2.18	**0.01**	-6.42	**0.00**	-3.99	**0.00**
Region 7	-1.32	0.09	-0.53	0.30	-3.04	**0.00**	-3.38	**0.00**
1995-1999:								
Region 1	-0.10	0.46	0.18	0.57	0.35	0.64	-0.54	0.29
Region 2	-0.99	0.16	-0.25	0.40	-1.89	**0.03**	-1.14	0.13
Region 3	2.09	0.98	0.76	0.78	-0.19	0.42	0.23	0.59
Region 4	-3.47	**0.00**	-0.32	0.37	-1.45	**0.07**	-3.64	**0.00**
Region 5	1.29	0.90	-0.13	0.45	-0.34	0.37	-0.92	0.18
Region 6	0.19	0.58	-1.08	0.14	-1.77	**0.04**	-0.63	0.27
Region 7	-1.24	0.11	-1.03	0.15	-3.30	**0.00**	-2.63	**0.00**

Note: Null hypothesis is individual unit root. Group is used as a benchmark. Individual effect and linear trend are included. Regional classification is referred to Table 1-2 of Chapter One.

Table 9-11. Panel cointegration tests for all 35 markets (p values)

Test statistics	All four fuels 1997-2005	1997-1999	2000-2005	Electricity and coal 1997-2005	1997-1999	2000-2005	Diesel and gasoline 1997-2005	1997-1999	2000-2005
No deterministic trend:									
Panel v -statistic	**0.399**	**0.305**	**0.386**	**0.229**	**0.345**	**0.075**	**0.000**	**0.000**	**0.000**
Panel ρ -statistic	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel t -statistic [a]	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000
Panel t -statistic [b]	0.394	0.204	0.005	0.001	0.260	0.011	0.000	0.000	0.000
Group ρ -statistic	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Group t -statistic [a]	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Group t -statistic [b]	0.344	0.258	0.051	0.000	0.240	0.000	0.000	0.000	0.000
Deterministic intercept and trend:									
Panel v -statistic	**0.004**	**0.374**	**0.057**	**0.014**	**0.393**	**0.100**	**0.000**	**0.000**	**0.000**
Panel ρ -statistic	0.000	0.000	0.127	0.000	0.000	0.279	0.000	0.000	0.000
Panel t -statistic [a]	0.000	0.000	0.036	0.000	0.000	0.182	0.000	0.000	0.000
Panel t -statistic [b]	0.047	0.000	0.139	0.090	0.000	0.385	0.000	0.000	0.000
Group ρ -statistic	0.000	0.000	0.011	0.000	0.000	0.079	0.000	0.000	0.000
Group t -statistic [a]	0.000	0.000	0.008	0.000	0.000	0.227	0.000	0.000	0.000
Group t -statistic [b]	0.008	0.000	0.398	0.011	0.000	0.240	0.000	0.000	0.000

Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is based Engle-Granger. Pedroni (1999) shows that the panel-ADF and group-ADF statistics have better small sample properties than the other statistics, and hence they are more reliable.
[a] Non-parametric and [b] parametric.

Table 9-12. Panel v -statistic cointegration tests by Region

Region	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Region 1	0.481	0.355	0.458	0.359	0.863	0.275	2.028	**0.051**	3.344	**0.002**	12.178	**0.000**
Region 2	2.360	**0.025**	1.315	0.168	1.959	**0.059**	0.348	0.376	3.959	**0.000**	11.675	**0.000**
Region 3	-0.457	0.359	0.600	0.333	-0.811	0.287	0.945	0.255	-0.202	0.391	6.815	**0.000**
Region 4	0.799	0.290	1.990	**0.055**	2.537	**0.016**	1.209	0.192	3.985	**0.000**	9.478	**0.000**
Region 5	-0.221	0.389	5.762	**0.000**	2.316	**0.027**	2.444	**0.020**	4.862	**0.000**	14.336	**0.000**
Region 6	1.638	0.104	9.793	**0.000**	5.247	**0.000**	2.545	**0.016**	1.496	0.130	13.313	**0.000**
Region 7	2.698	**0.011**	2.889	**0.006**	4.374	**0.000**	0.927	0.260	1.298	0.172	8.249	**0.000**
Deterministic intercept and trend:												
Region 1	0.527	0.347	1.191	0.196	1.008	0.240	2.262	**0.031**	1.611	0.109	7.511	**0.000**
Region 2	1.141	0.208	1.027	0.236	0.003	0.399	-0.490	0.354	1.764	0.084	7.702	**0.000**
Region 3	-1.518	0.126	0.297	0.382	-2.201	**0.035**	0.679	0.317	-0.797	0.290	4.370	**0.000**
Region 4	0.587	0.336	1.592	0.112	1.782	0.082	0.026	0.399	1.739	0.088	5.773	**0.000**
Region 5	-1.235	0.186	5.241	**0.000**	0.293	0.382	0.346	0.376	2.290	**0.029**	9.333	**0.000**
Region 6	1.038	0.233	9.169	**0.000**	3.747	**0.000**	1.855	**0.071**	0.207	0.391	8.693	**0.000**
Region 7	1.487	0.132	2.103	**0.044**	1.933	**0.062**	-0.319	0.379	0.276	0.384	5.711	**0.000**

Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Regional classification is referred to Table 1-2 of Chapter One.

Panel A: From Harbin to Shanghai and Guangzhou

Panel B: From Taiyuan to Wuhan and Guangzhou

Panel C: From Xi'an to Jinan and Shanghai

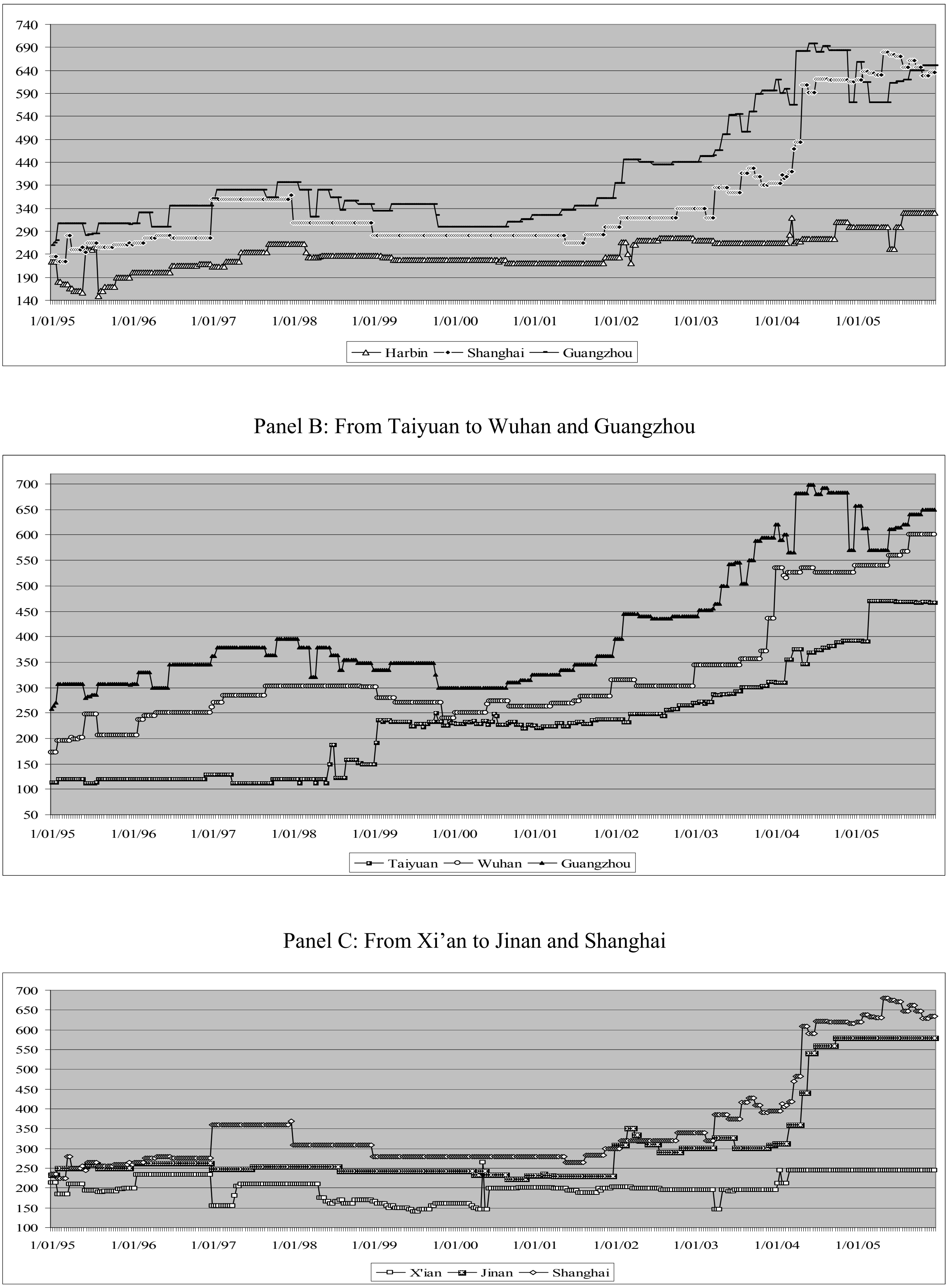
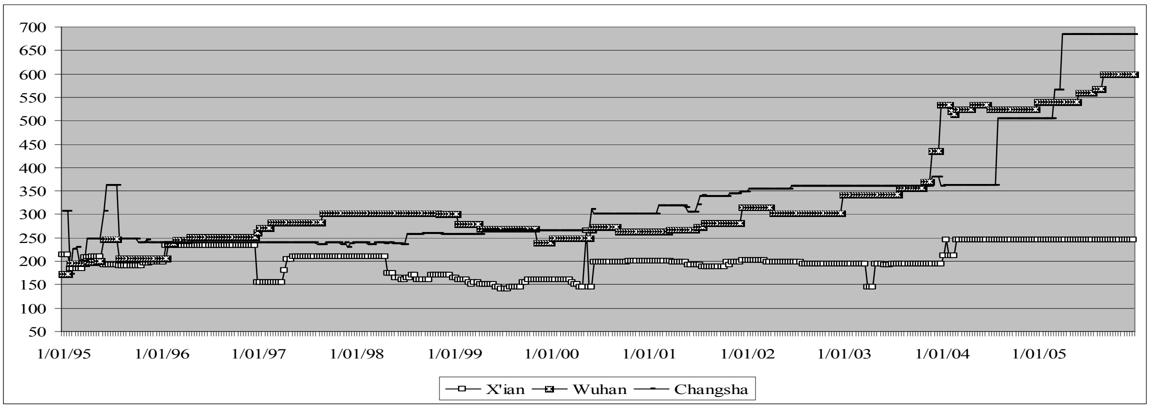


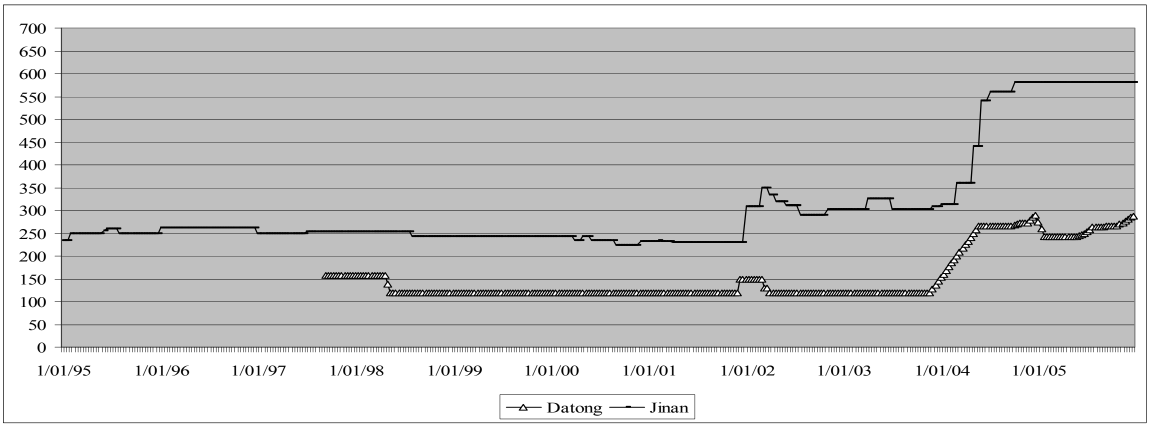
Figure 9-1. The trends of coal spot prices from major producing to consuming areas

Note: Unit is ¥/ton

Panel A: From Xi'an to Wuhan and Changsha



Panel B: From Datong to Jinan



Panel C: From Hohhot to Wuhan and Guangzhou

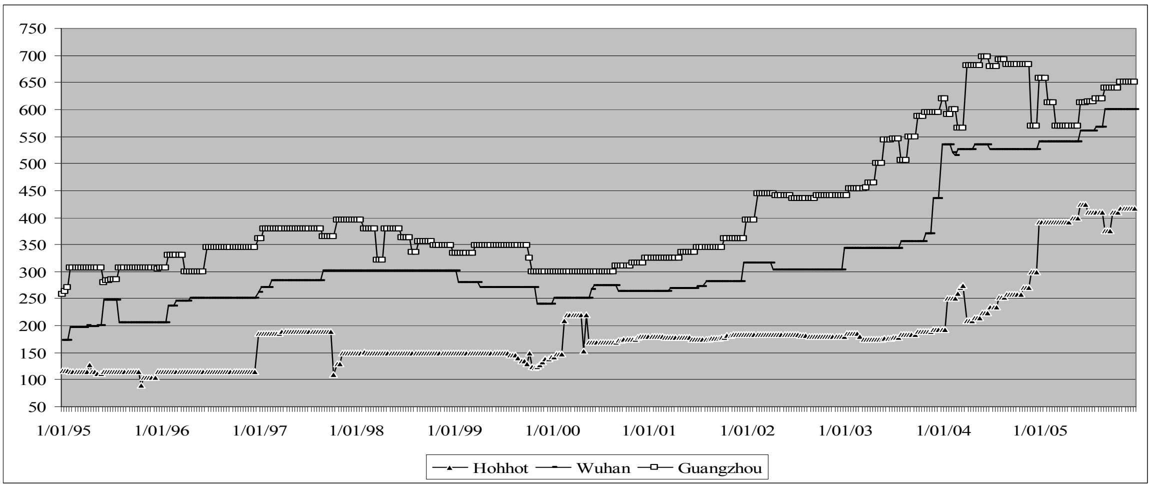


Figure 9-2. The trends of coal spot prices from major producing areas to consuming areas

Note: Unit is ¥/ton

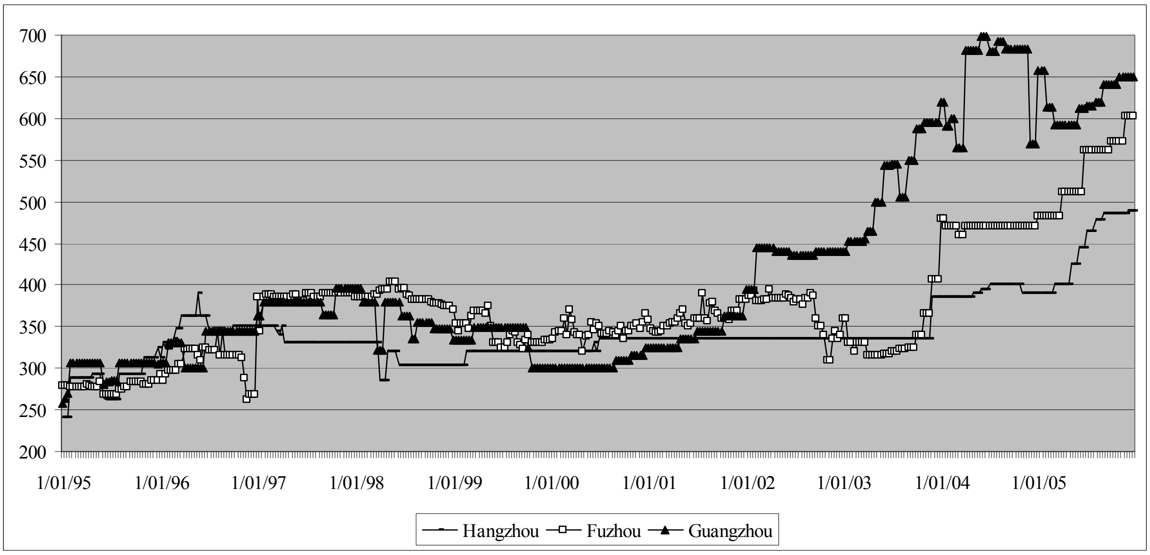
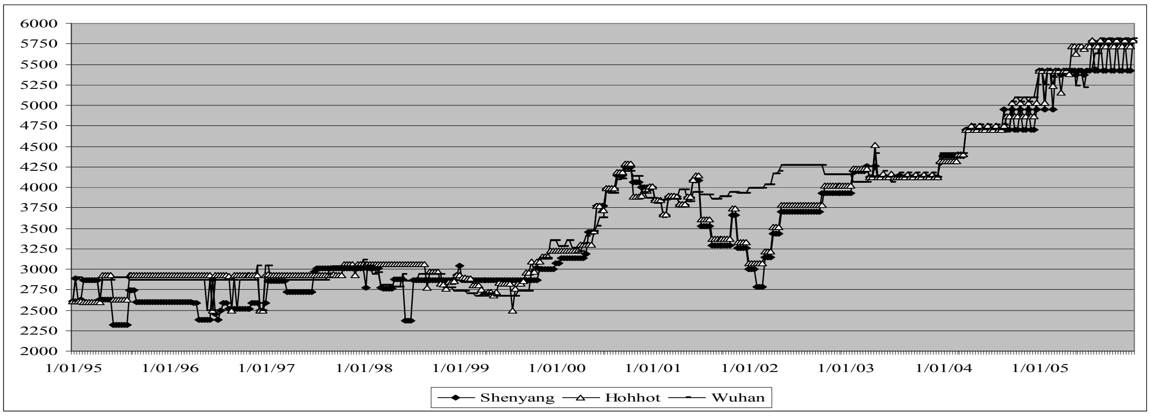


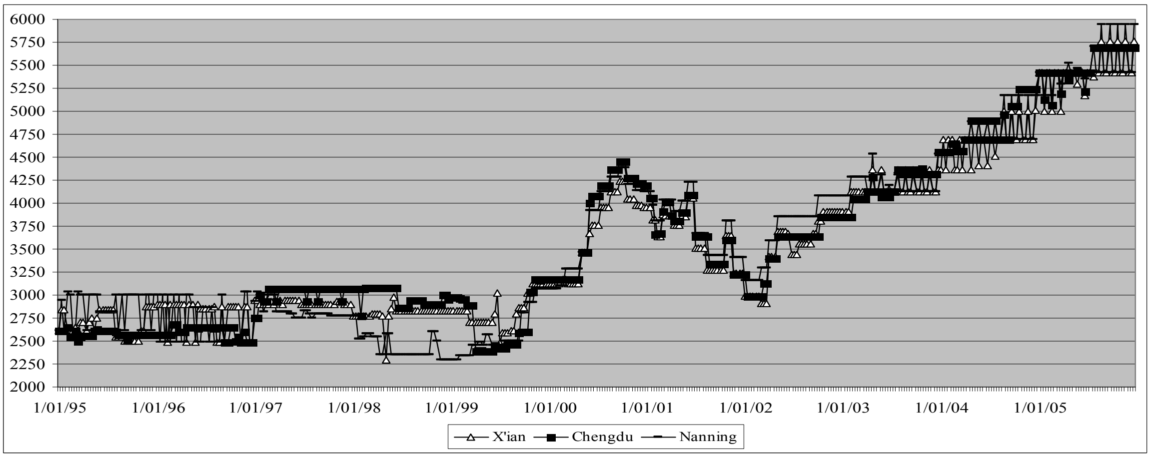
Figure 9-3. The trends of coal spot prices along southeast coastal major consuming areas

Note: Hangzhou, Fuzhou and Guangzhou ordered by distance to major producing areas (¥/ton)

Panel A: From Shenyang to Hohhot and Wuhan



Panel B: From Xi'an to Chengdu and Nanning



Panel C: From Lanzhou to Chengdu and Nanning

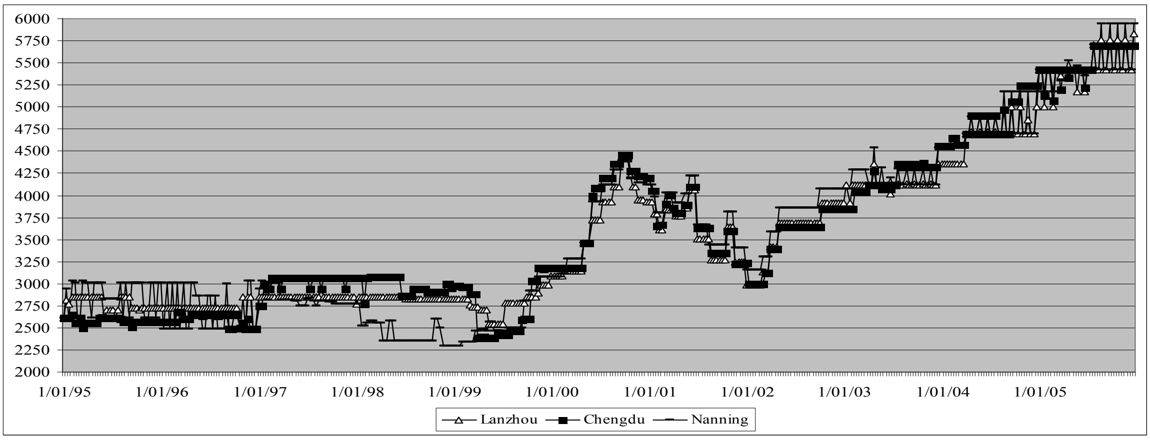
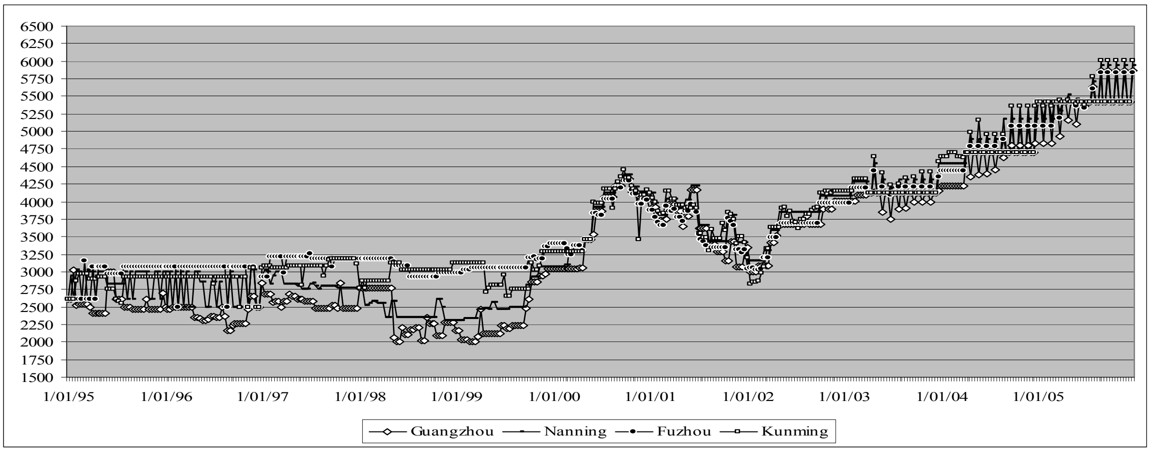


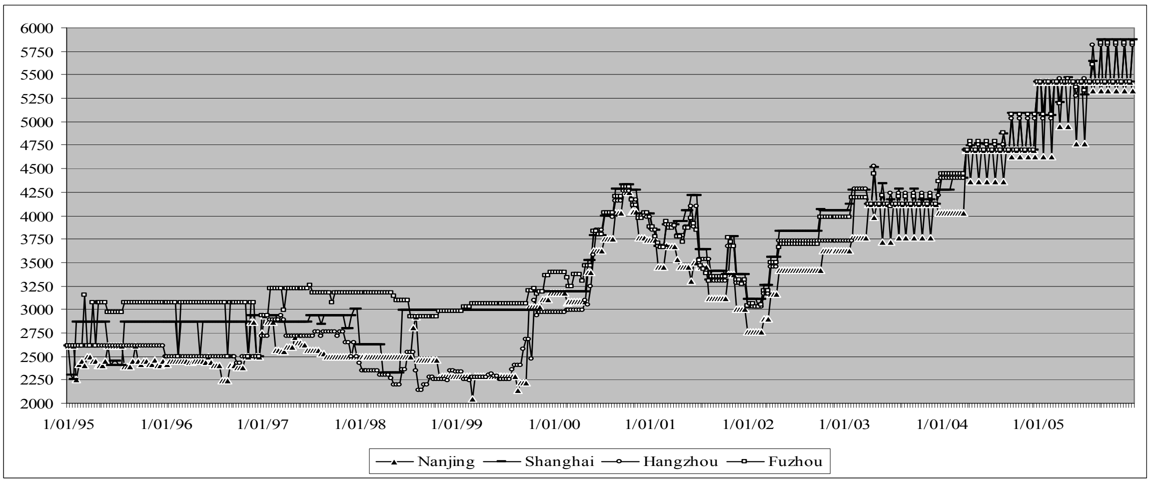
Figure 9-4. The trends of gasoline spot prices from major producing to consuming areas

Note: Unit is ¥/ton

Panel A: Along southern Guangzhou, Nanning, Fuzhou and Kunming



Panel B: Along east coastal Nanjing, Shanghai, Hangzhou and Fuzhou



Panel C: Around major port, Shanghai, Tianjin, Qingdao and Dalian

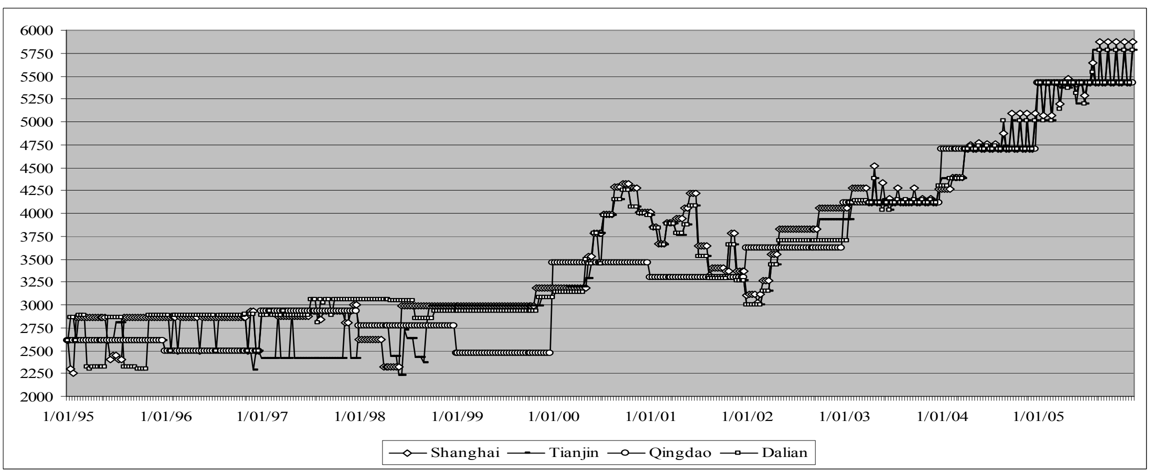
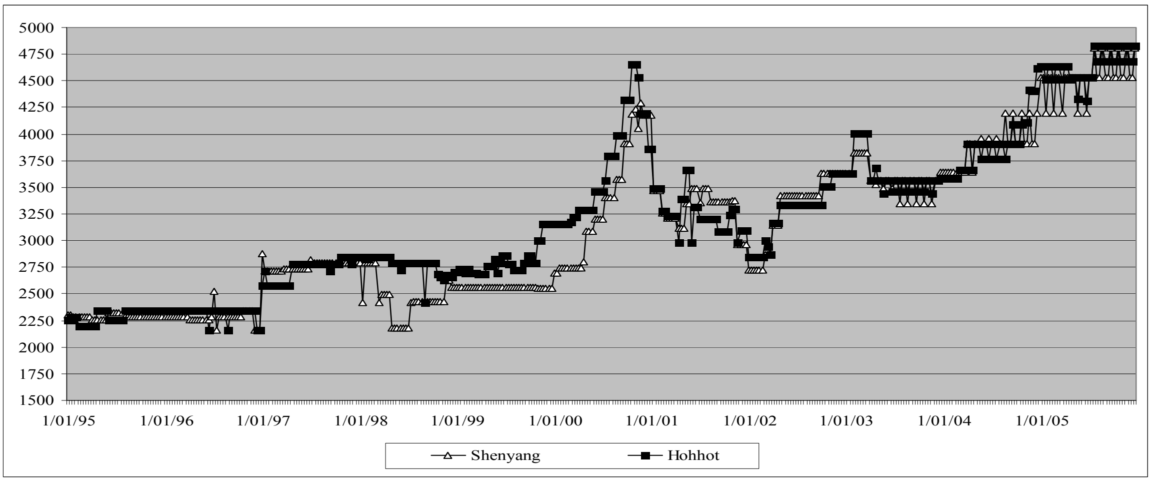


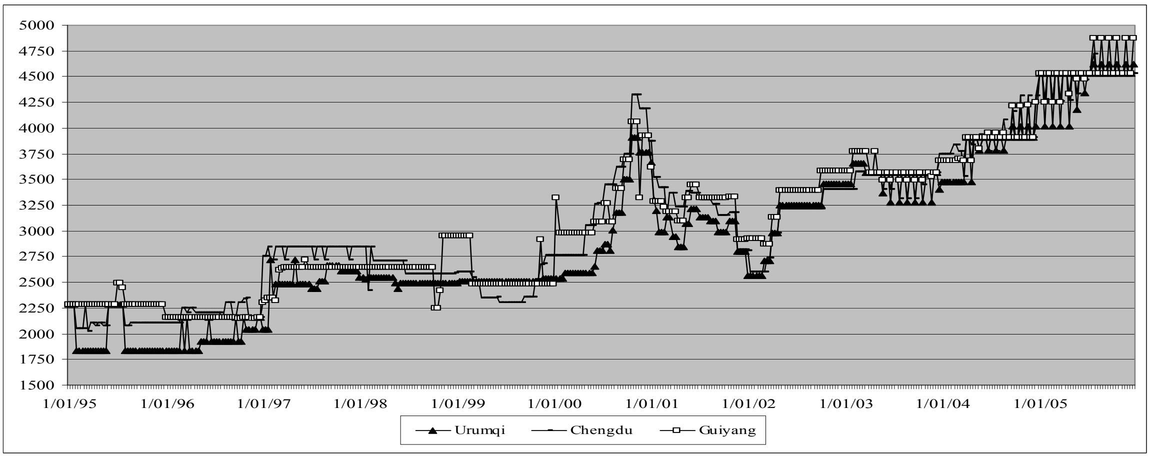
Figure 9-5. The trends of gasoline spot prices around major consuming and port areas

Note: Unit is ¥/ton

Panel A: From Shenyang to Hohhot



Panel B: From Urumqi to Chengdu and Guiyang



Panel C: From Xi'an to Chengdu and Kunming

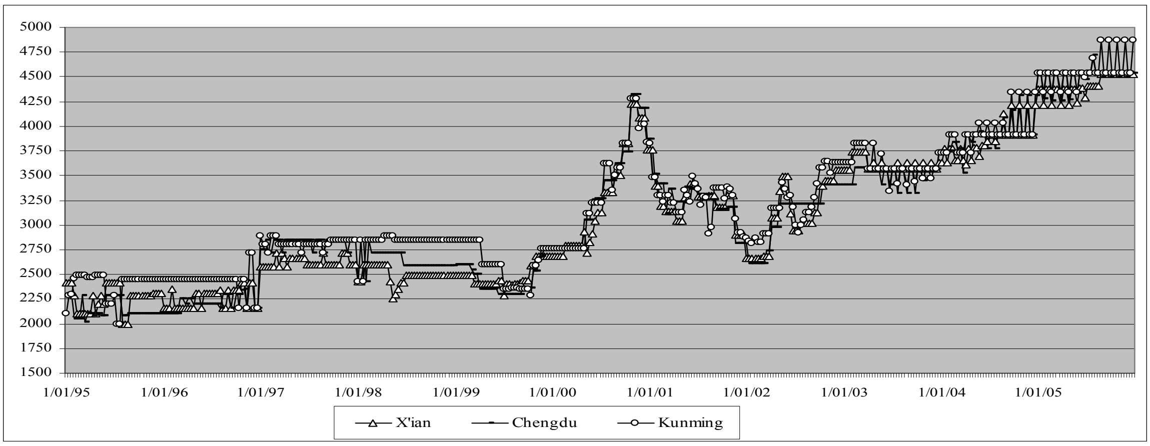
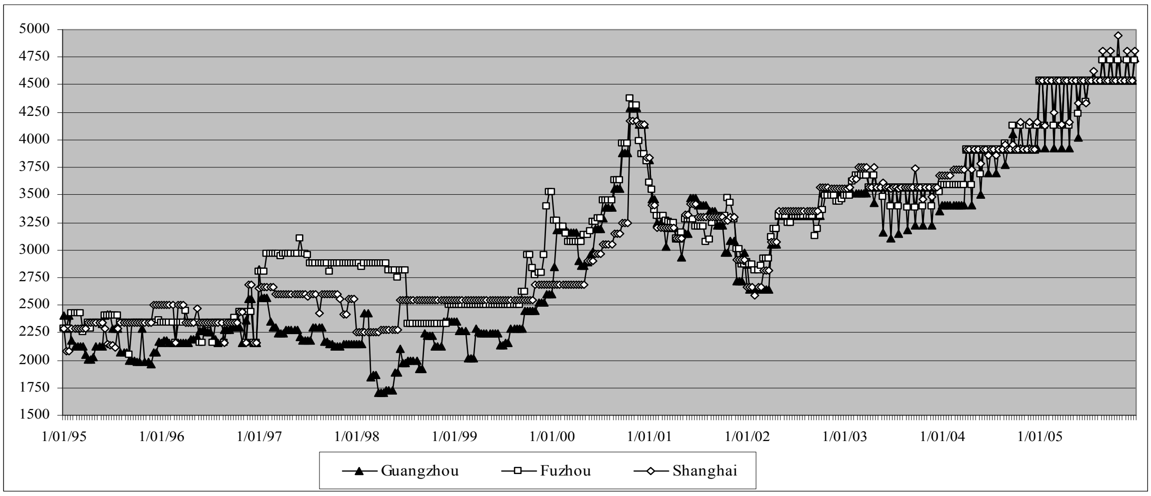


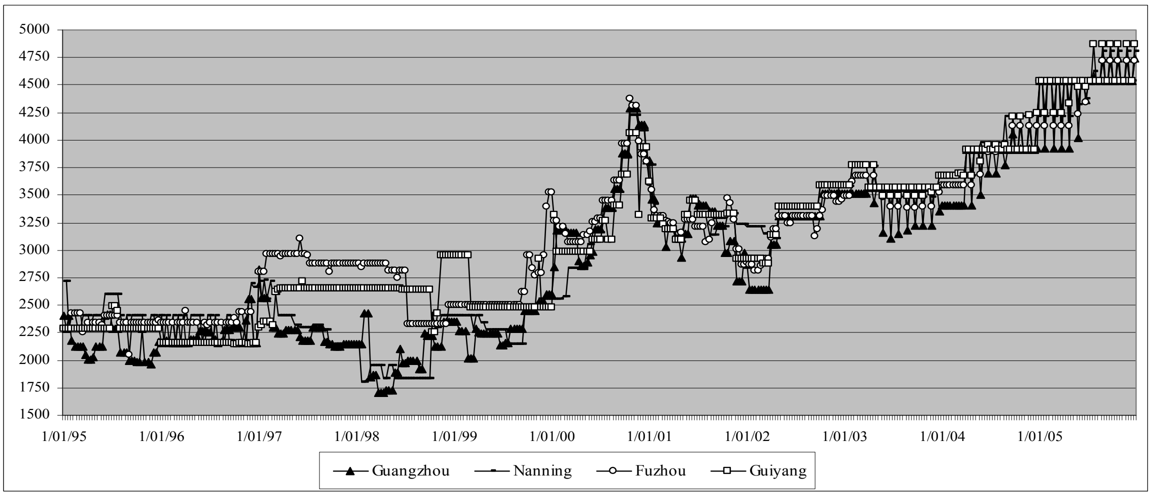
Figure 9-6. The trends of diesel spot prices from major producing to consuming areas

Note: Unit is ¥/ton

Panel A: Along east coastal Guangzhou, Fuzhou and Shanghai



Panel B: Along southern Guangzhou, Nanning, Fuzhou and Guiyang



Panel C: Along northern Taiyuan, Hohhot, Shijiazhuang and Jinan

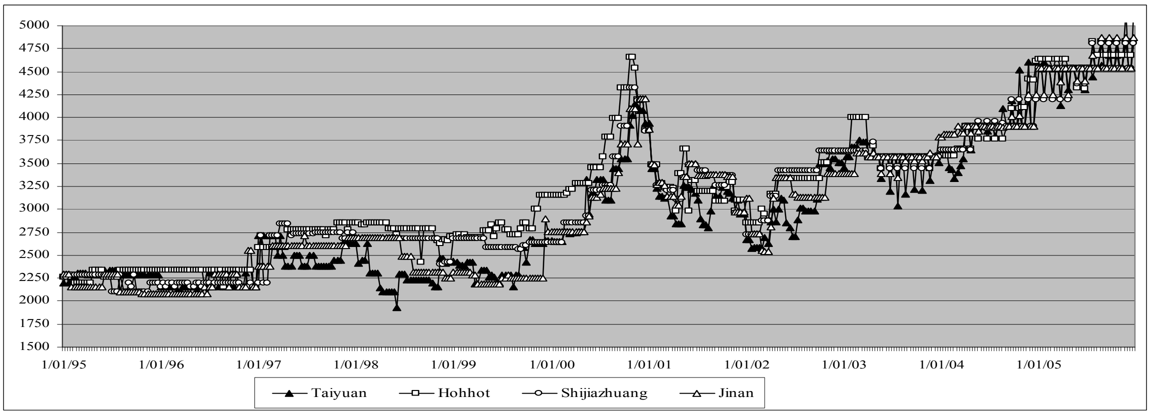
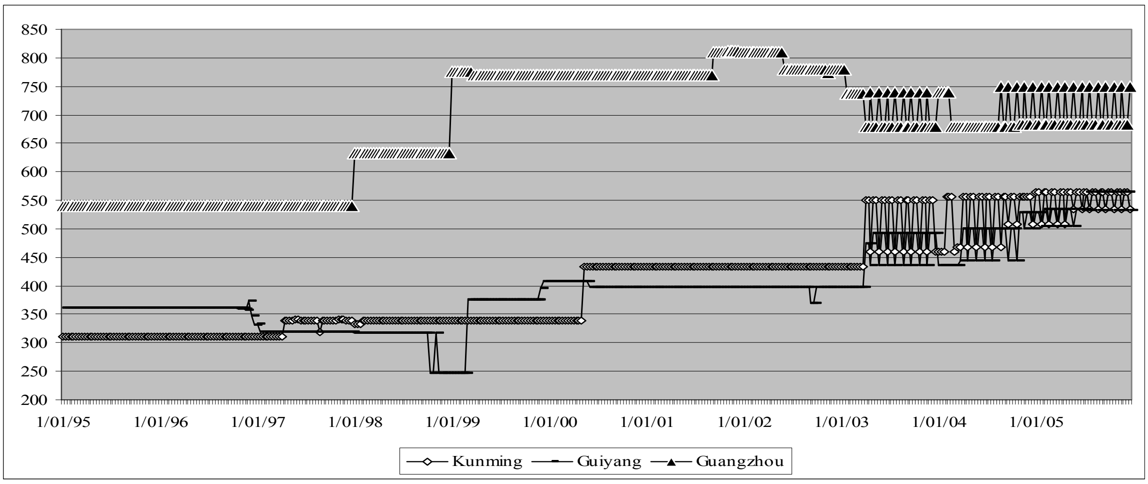


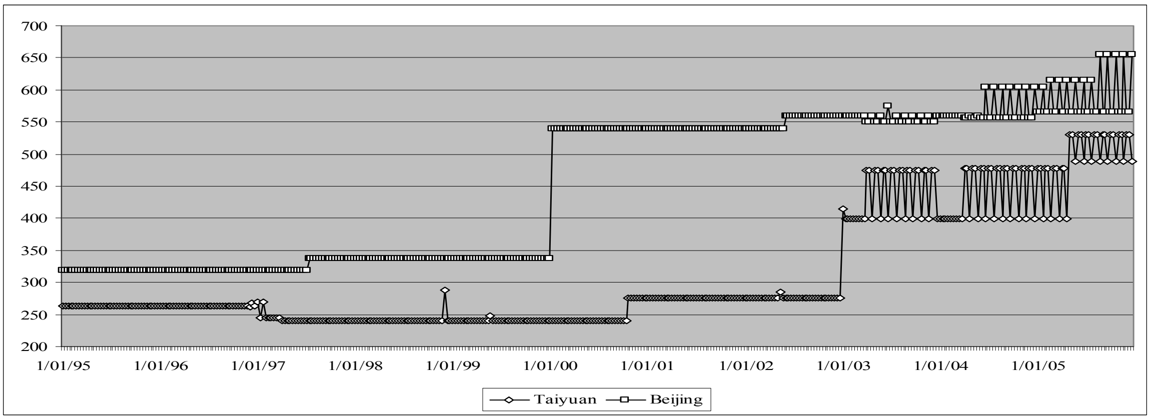
Figure 9-7. The trends of diesel spot prices along major consuming areas

Note: Unit is ¥/ton

Panel A: From Guiyang and Kunming to Guangzhou



Panel B: From Taiyuan to Beijing



Panel C: From Wuhan to Shanghai and Guangzhou

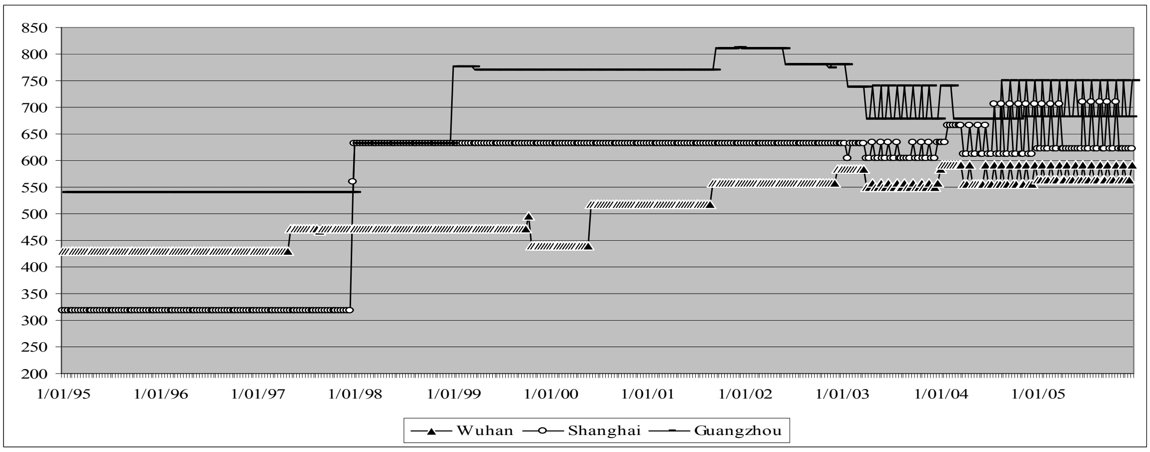
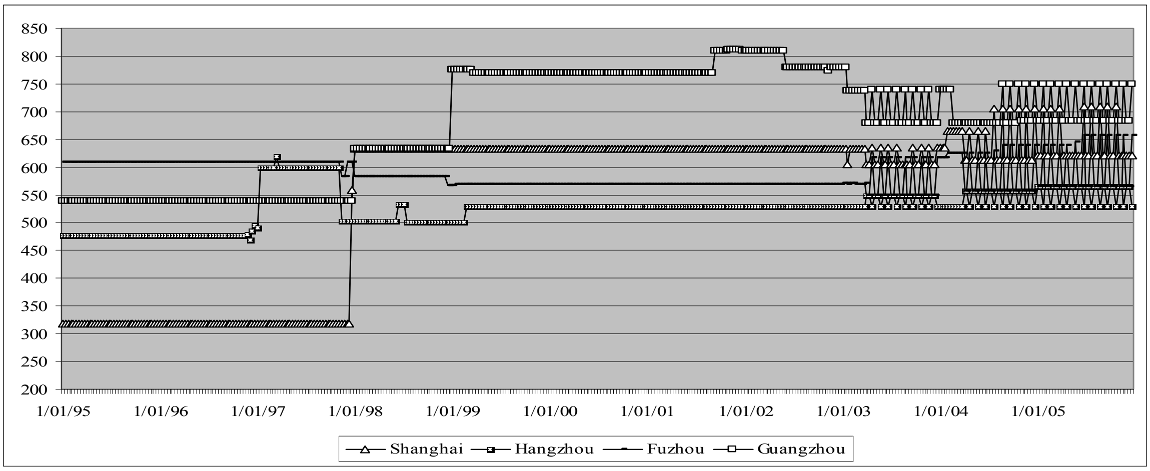


Figure 9-8. The trends of electricity spot prices from major producing to consuming areas

Note: Unit is ¥/1000 KWh

Panel A: Along east coastal Shanghai, Hangzhou, Fuzhou and Guangzhou



Panel B: Along northern Shijiazhuang, Jinan, Nanjing and Zhengzhou

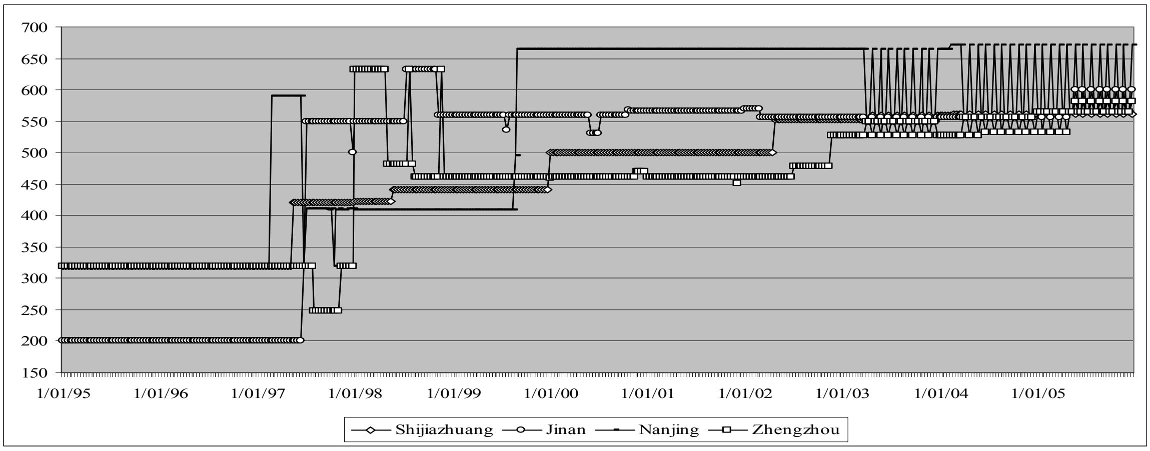
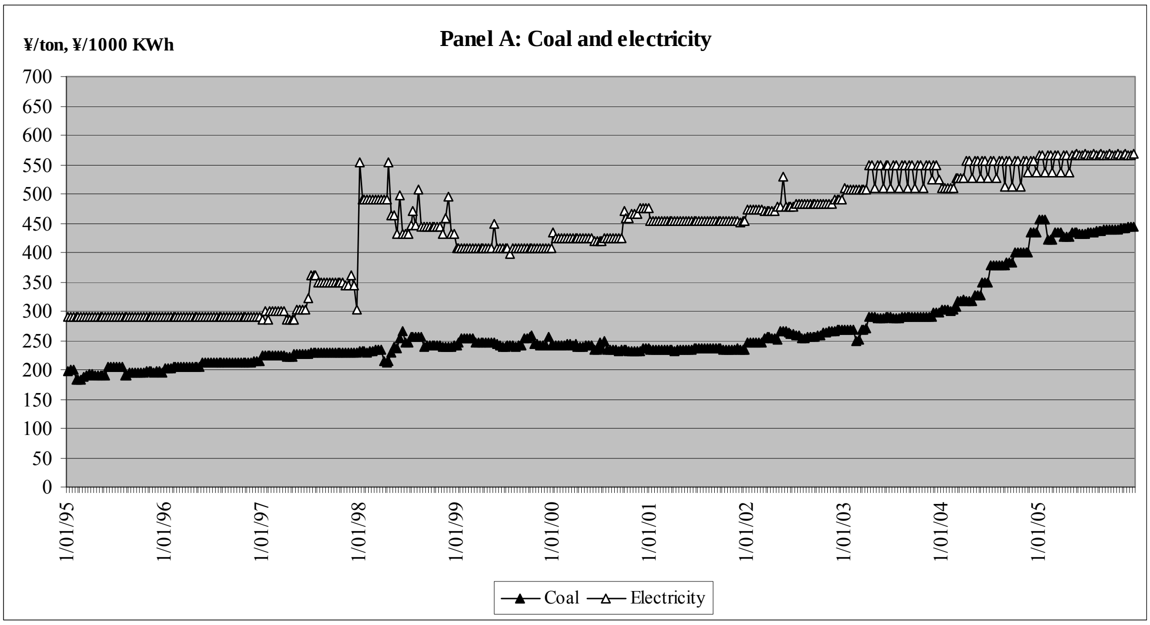


Figure 9-9. The trends of electricity spot prices along major consuming areas

Note: Unit is ¥/1000 KWh



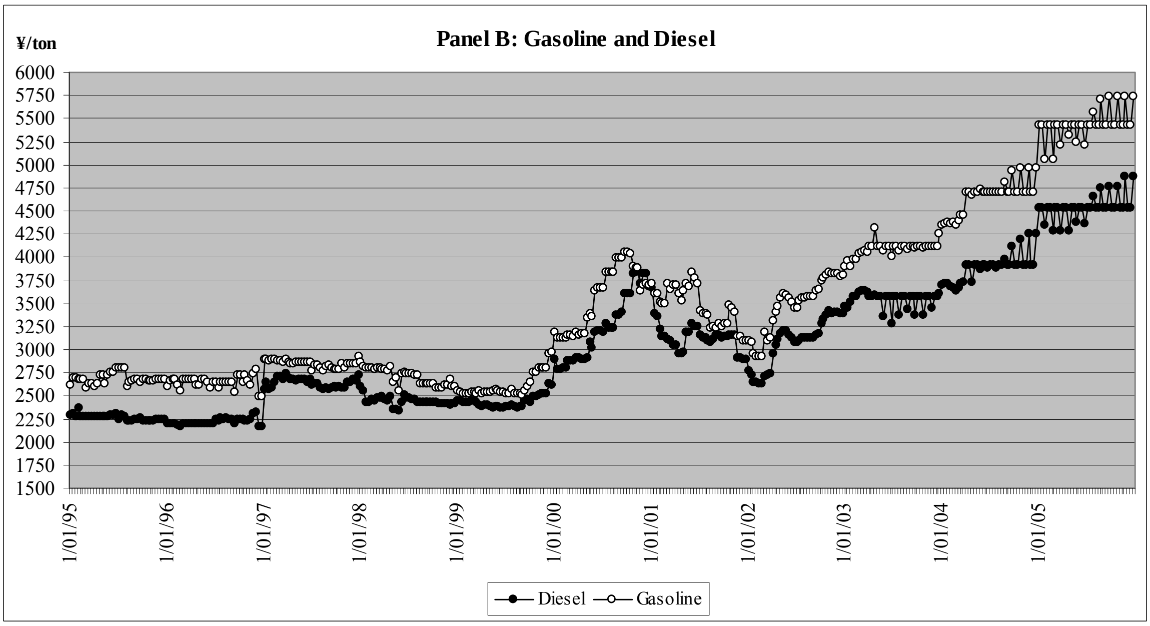
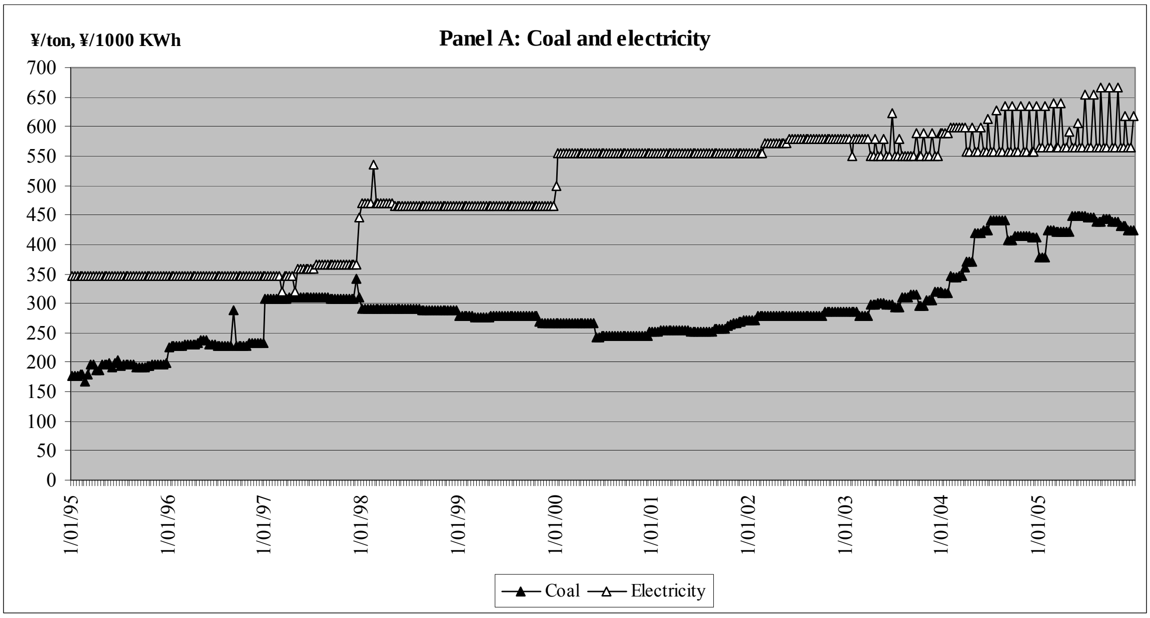


Figure 9-10. Price trends of pairs of fuels for Region 1

Region 1: Shijiazhuang, Taiyuan, Hefei, Jinan and Zhengzhou.



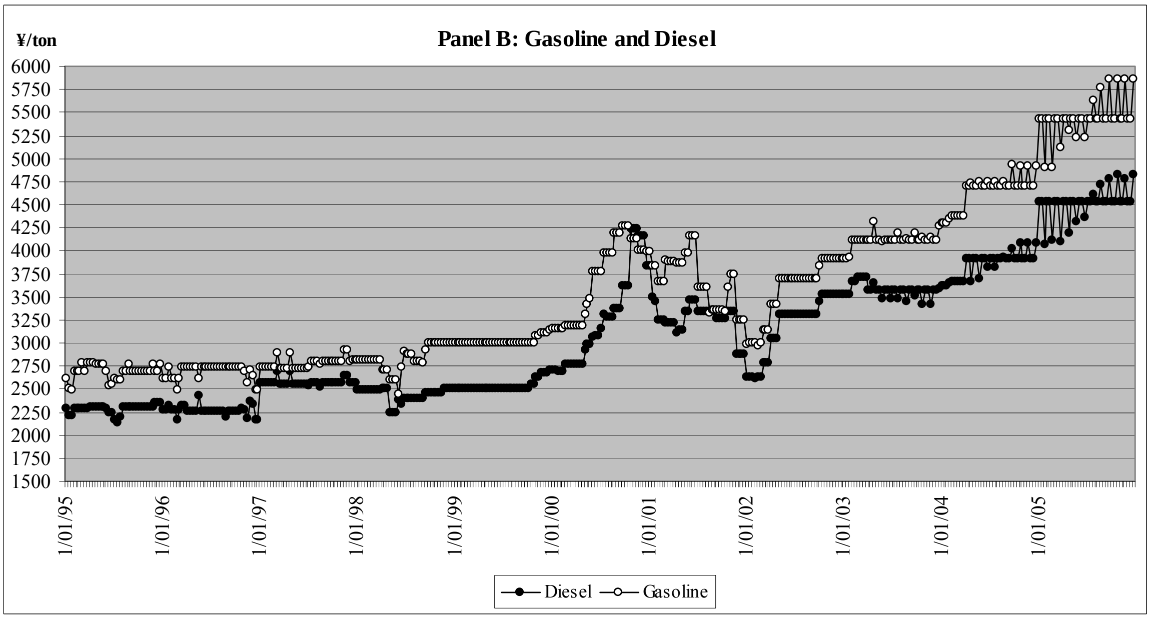


Figure 9-11. Price trends of pairs of fuels for Region 2

Region 2: Beijing, Tianjin and Shanghai.

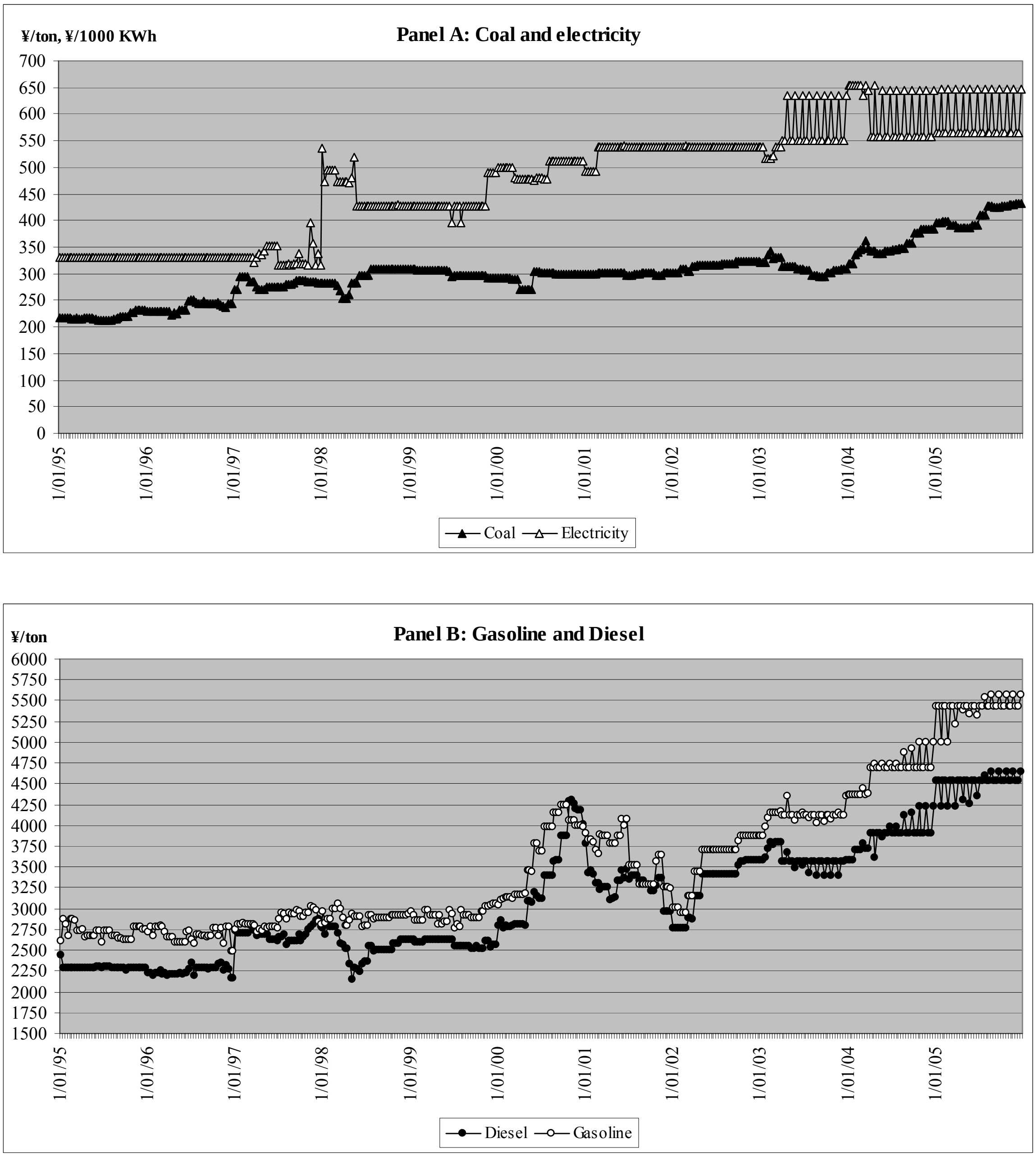
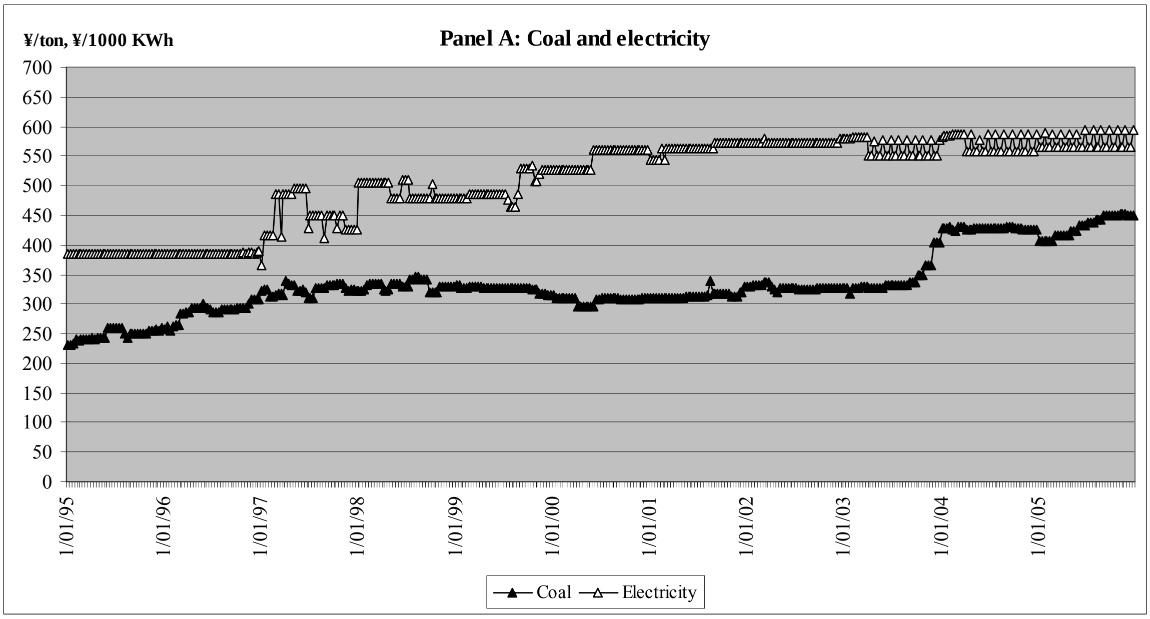


Figure 9-12. Price trends of pairs of fuels for Region 3

Region 3: Shenyang, Changchun and Harbin.



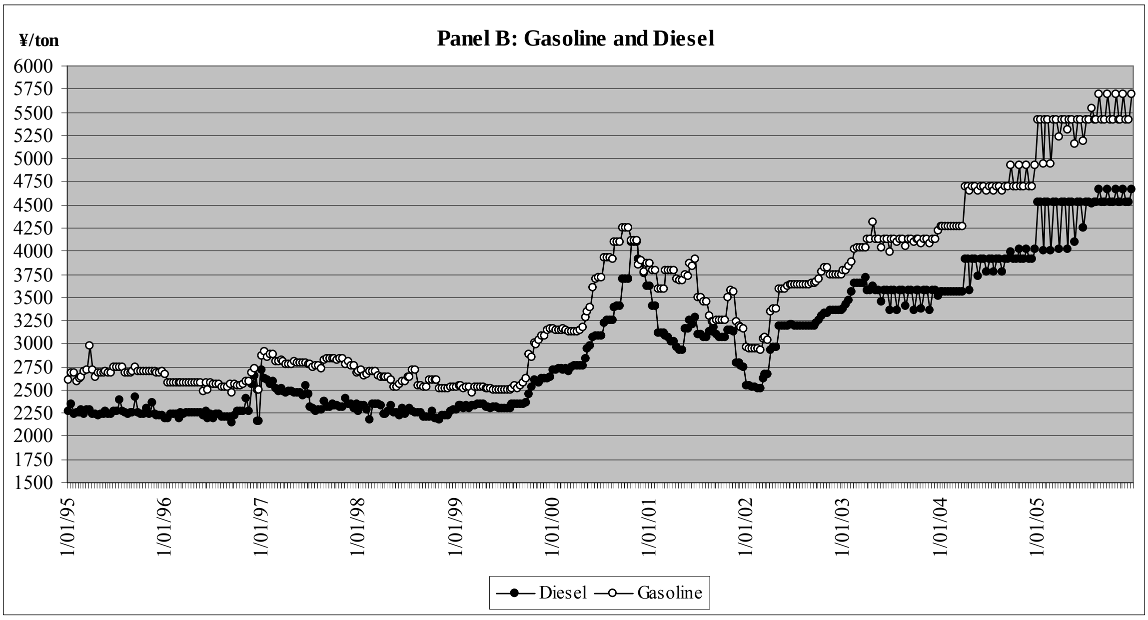


Figure 9-13. Price trends of pairs of fuels for Region 4

Region 4: Nanjing, Hangzhou, Nanchang and Wuhan.

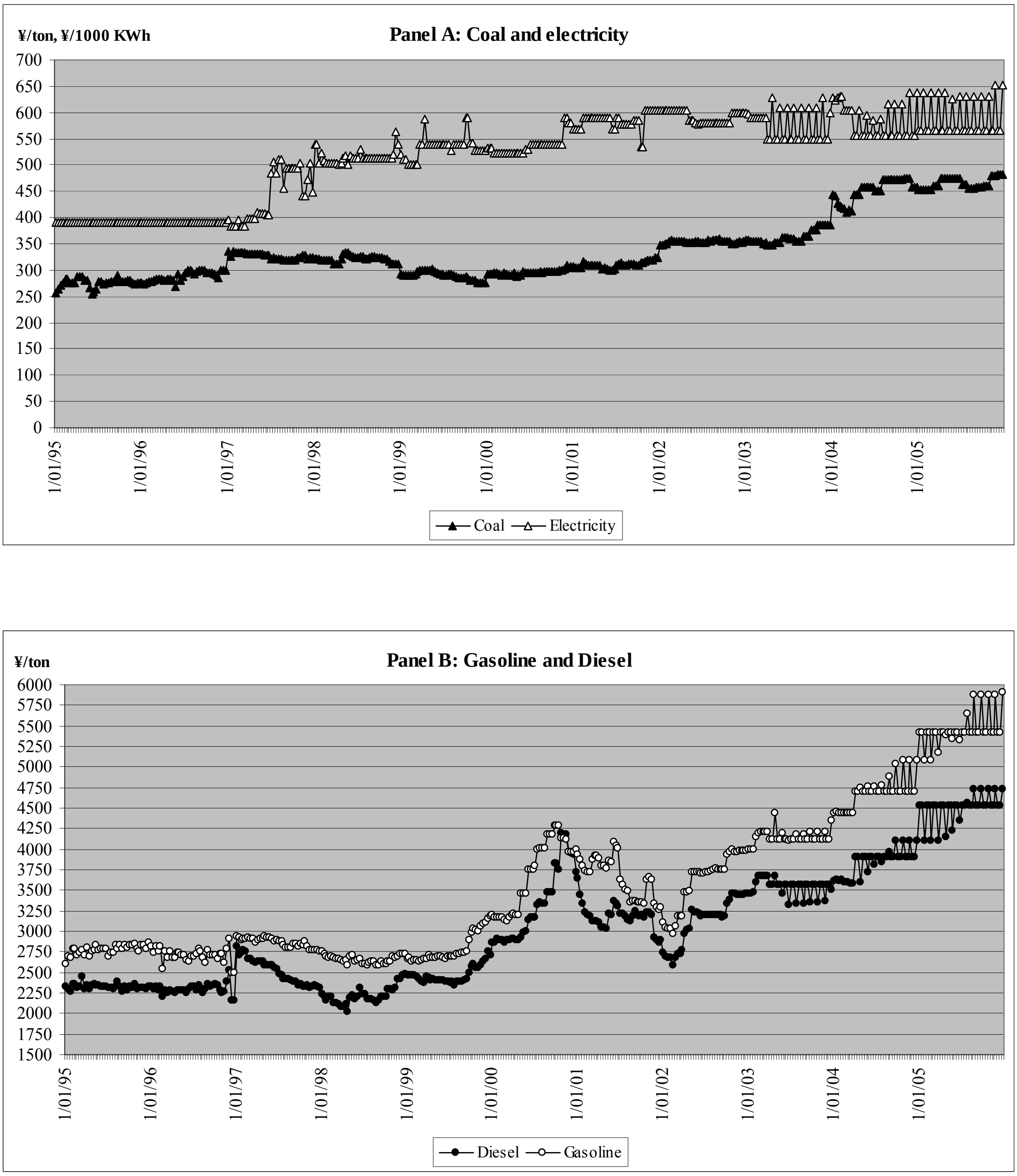


Figure 9-14. Price trends of pairs of fuels for Region 5

Region 5: Fuzhou, Changsha, Guangzhou, Nanning and Haikou.

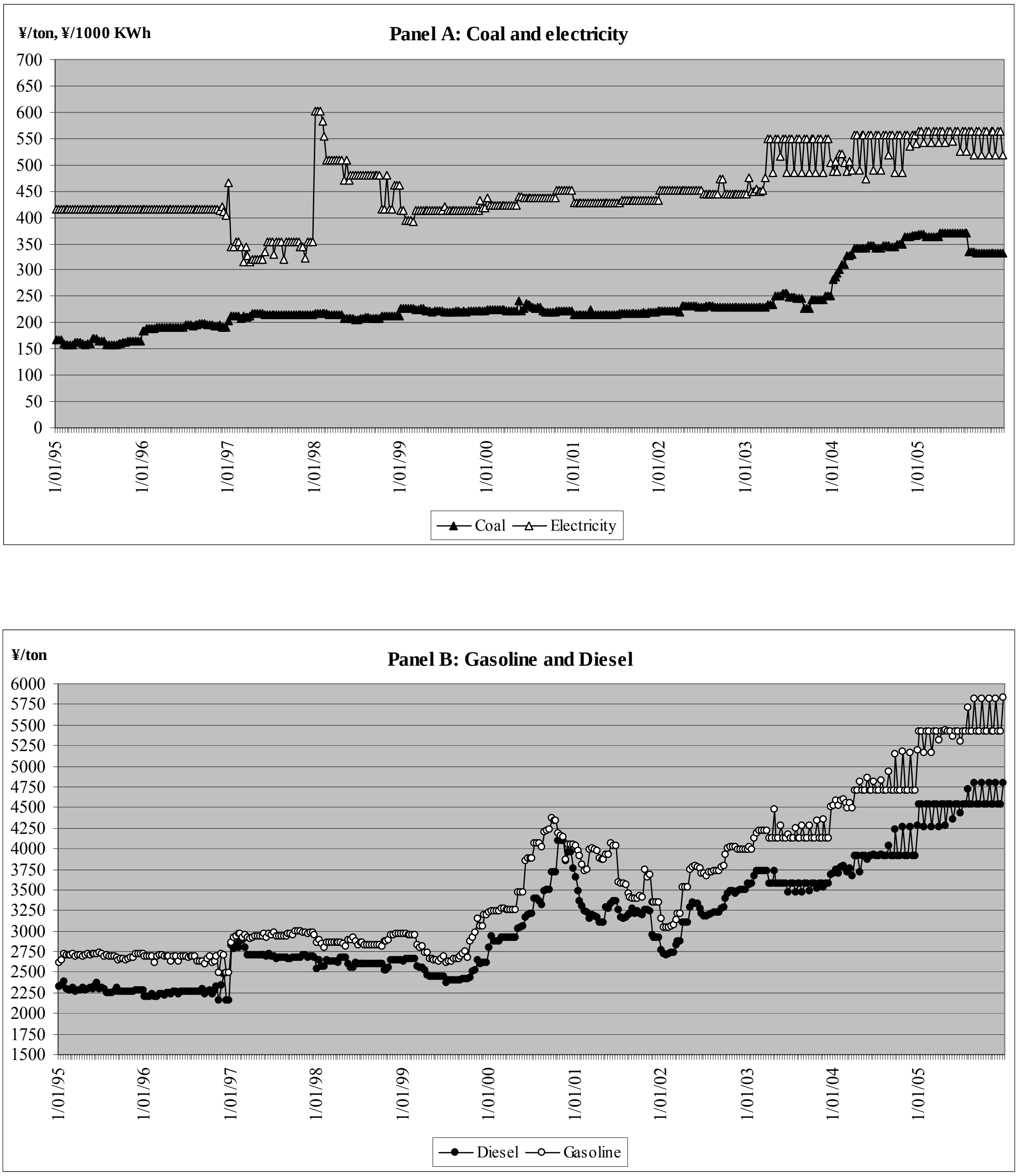
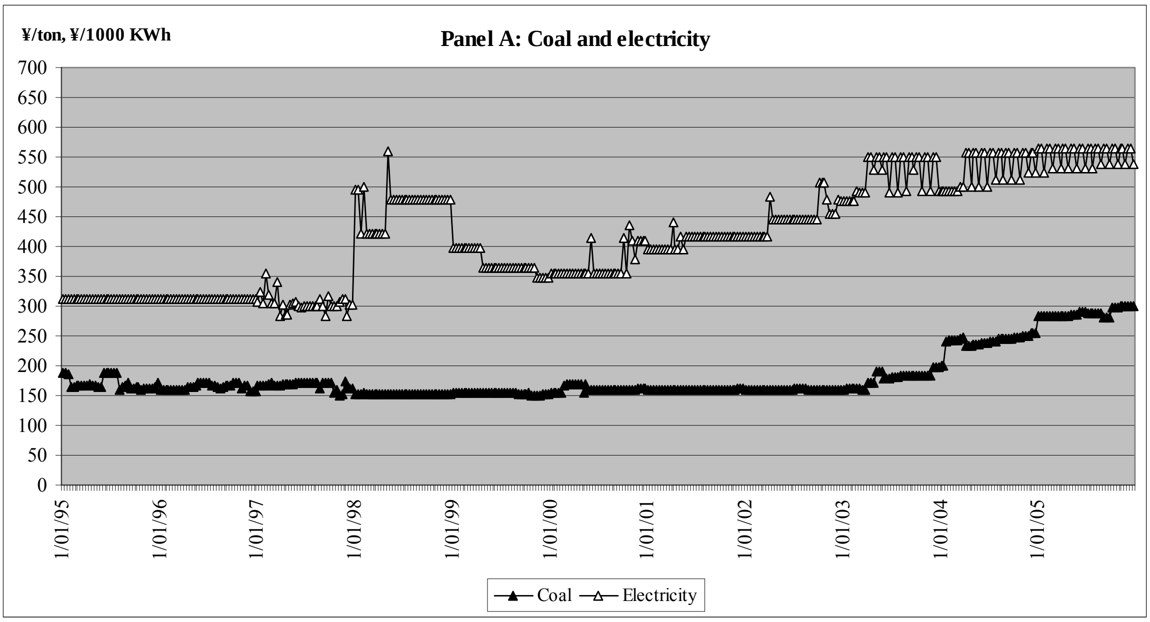


Figure 9-15. Price trends of pairs of fuels for Region 6

Region 6: Chongqing, Chengdu, Xi'an, Lanzhou, Guiyang and Kunming.



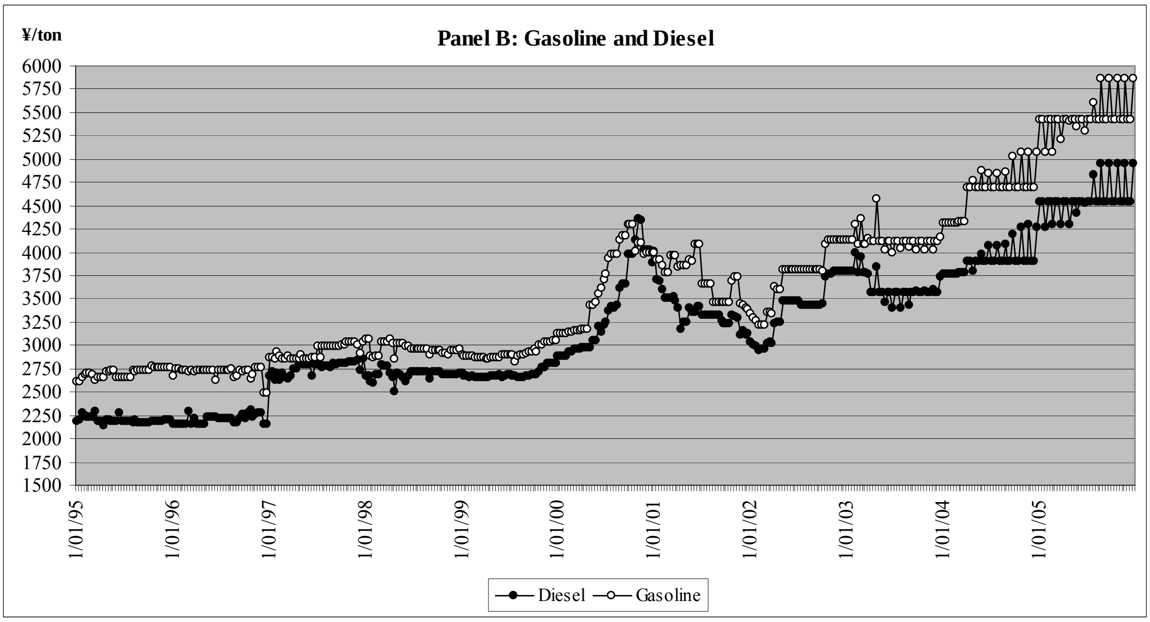


Figure 9-16. Price trends of pairs of fuels for Region 7

Region 7: Hohhot, Xining, Yinchuan and Urumqi.

Chapter Ten: Conclusions and Implications[39]

This study presents an investigation into China's energy economy: institutional evolution, emergence of market, technological change, substitution of and demand for energy, as well as the determinant of energy intensity. This thesis was motivated systematically and comprehensively by conducting a survey of the literature on the China's energy economy and reviewing, to date, China's energy situation in the new millennium. The two most important and informative topics investigated in my thesis are: the marketization of China's energy economy and technological change, energy consumption behavior and their effects on energy intensity.

This Chapter is organized as follows. I first present my main findings and conclusions in Section 1 and then discuss China's energy market with an international perspective in Section 2. Section 3 provides some policy implications drawn from my study, followed by presenting some detail policy directions for China's energy economic development in the future in Section 4. Some future work that needs to be updated is proposed in Section 5.

10.1 Main findings and conclusions

I present some conclusions at the end of each chapter, but here I draw the main conclusions together. Firstly, the study of China's energy economy remains underdeveloped. The survey of literature shows that some important areas are missing or

[39] Parts of this Chapter appear (will appear) in *Energy Economics* 2008, *Energy Policy* 2009, *Renewable and Sustainable Energy Reviews* 2009 and *Environmental Modelling and Software* together with Chapters 3, 7 and 8.

under researched by international standards, for example, the issues and the debates on whether China's energy economy has been market-oriented have not been investigated deeply prior to this study. This neglect has no doubt hindered the study and development of China's energy economy. It also blocks inhibits econometric analysis of the subject matter, for example, demand functions are seldom employed to model energy consumption behavior.

Secondly, it is crucial to review China's energy situation in the new millennium. There are two core reasons for this: i) its overwhelming economic size and fast growth which naturally leads to growing demands for energy; ii) the features of energy supply have created a dilemma for China in particular, how to balance economic development and environmental protection.

Thirdly, data used in studying China's energy economy are often very limited and more data needs to be explored. Data unavailability may be a major barrier to the development of China's energy economics. In this study, however, we have assembled a unique, ten-day interval, energy price dataset to investigate evidence on the emergence of energy market economy for China.

Fourthly, based on the review of the evolution of institutions in China, it was found that deregulation and pricing reforms have accelerated in the energy industry in China since the early 1990s. Regulation and business activities have been completely separated, while energy pricing mechanisms are now, almost, market-oriented.

Fifthly, the empirical investigations have found evidence for the emergence of a market-driven energy sector in China's using both descriptive statistics and rigorous, appropriate, econometric analysis. The feature of the reforms of China's energy economy is one of 'gradualism' and the timing and intensity has varied across energy sectors. Meanwhile, regional energy markets still exist due, in part, to the spatial imbalances of supply and demand and the distribution of energy reserves over vast distance, which incurs costly transportation costs.

Sixthly, the estimation results demonstrate that there appears to be significant substitution possibilities between energy and labor and that they appear quite elastic when compared with international findings. The elasticities of substitution are also much larger for energy-capital than energy-labor. For fuel, there are significant substitution possibilities between coal and electricity, while there is significant complementarity between coal and diesel. However, generally, the demand for energy is elastic.

Finally, after decomposing energy intensity, it was found that the 'budget effect' and 'technological change' effects are the two major drivers of the changes in energy intensity. The former reduces energy intensity while the later increases energy intensity. Significant effects of substitution mainly come from the adoption of labor-intensive technology.

10.2 An international perspective on energy markets

10.2.1 The energy industry as a special case?

The role of energy in economic growth has long been a controversial topic in the economic literature and theoretical disagreement on the role of energy is also matched by mixed empirical evidence (Yuan, Kang, Zhao and Hu, 2008). The traditional neo-classical growth model takes the role of energy in production as neutral, while energy plays an important role in income determination and therefore economic growth it is heavily affected by energy consumption in the biophysical and ecological view (Cleveland et al., 1984). Beaudreau (1995) criticizes the traditional growth model for treating energy as a secondary factor. However, even treated as a common production factor, energy regulation and market development are fairly different from those of other industries because energy industries have more linkages with other industries. For example, China's energy sector has been a special case amongst the country's industries (Andrews-Speed, Dow and Gao, 2000). It is also true that the market reforms have typically been implemented later in the energy sector relative to such reforms in other countries.

10.2.2 Market vs. regulation?

Public utilities have been regulated for hundreds, if not thousands of years (Littlechild, 2008). The global energy sector is facing enormous challenges, economically, environmentally and via social sustainability, therefore, Perez-Arriaga and Linares (2008) argue that although markets are adequate instruments to achieve an efficient allocation of resource and to promote private initiative, the resolution of the sustainability challenge cannot be left only to market forces, but requires other complementary instruments. As a result, they propose an indicative energy planning approach in their 2008 paper. In fact, electricity reforms have raised important questions about which responsibilities are left to the market and which responsibilities are left to regulated processes (Felder, 2007). There are important areas of reform, however, where regulation and markets do not 'compete' to provide necessary service, instead, regulation establishes a market, while the market provides the desired service and sets the prices. In fact, at least one aspect of the new electricity market is at the frontier between competition and monopoly. A variety of institutional arrangements exist in several parts of the world that provide a greater role for market participants and a supportive rather than exclusive role for regulation (Littlechild, 2008).

10.2.3 Why regulate the energy sector more than others?

The energy industry has linkages with other industries and therefore energy reforms can affect a wide range of people and industries. Often, political agents pursue market reforms to lower short-term electricity prices rather than to increase industry efficiency (Felder, 2007). Their concerns arise as raising energy prices to promote higher energy efficiency and reduce energy consumption may affect national level economic growth (Birol and Keppler, 2000). In fact, as Newbery (2009) points out, the very limited quantitative cost-profit analysis suggests successful reforms can reduce costs by 5-10% permanently, while two negative sequences immediately follow from this modest potential cost reduction. One is that a flawed reform can easily fail to reap these gains and lead to very costly outcomes, and the other is that redistributions from moving from market pricing may be large compared to the net gains.

10.2.4 How to evaluate China’s energy reforms?

China’s reforms of the energy economy are relatively late in the national economic reform process. Therefore, most of the literature attributes China’s inefficient use of energy to its energy pricing system (Hang and Tu, 2007). However, China’s energy reforms cannot be said too be late when compared internationally. For example, Britain was one of the first countries to introduce competition to retail energy markets in 1998 (Price, 2008).

Moreover, as Green concludes that each country's (energy reform) is affected by its own specific background, making generalizations dangerous (Felder, 2008). Therefore, it is hard to evaluate China's gradualism energy reform strategy.

10.3 Policy implications

Based upon the findings of the research and understanding of China's energy economy, the following policy implications can be drawn. First, it is important to understand the potential effects of new energy regulation and pricing mechanisms on China's future energy economy. Pre-reforms, most studies attributed the economic distortion and high energy intensity to irrational regulation and pricing mechanisms. It is naturally expected that post-reform, China's energy consumption will become more efficient. This suggests that former predictions of China's energy demand have to be greatly discounted, and the potential effect of China's energy consumption on the world energy markets and gas emissions may need to be revaluated.

Secondly, rather than showing evidence against a more market-driven price mechanism, divergence in coal prices between major coal consuming areas from major coal producing areas may actually reflect growing market power, although the statistical tests reject this null hypothesis. The prices of coal may simply be approaching its real market price. This trend is expected to continue until actual steady state market prices are attained.

Thirdly, significant substitution between energy and labor is potentially good news for China as they are abundant in labor. As it suggests, allowing energy prices to rise would tend to reduce energy use and increase labor intensiveness. However, comparing the elasticities of substitution between energy-capital and energy-labor suggests that capital more easily substitutes for energy than labor does. Therefore more policy incentives are needed for labor to substitute energy should this be deemed desirable.

Fourthly, significant substitution between coal and electricity may appear to have implications for environmental taxes, since increasing taxes could reduce the coal consumption and correspondingly encourage electricity consumption. However, since almost 80% of coal consumed in China is used for the generation of electricity the net effect of such taxes on greenhouse gas emissions might be smaller than expected. And also any shift from coal to electricity has implications for investment in transmission lines for electricity rather than railways for moving coal.

Fifthly, the estimated elasticity of substitution between energy and all other non-energy factors implies that economic growth in China to the year 2010 would be predicted to be only slightly impeded by even dramatic constraints on the growth in energy supply. Likewise, regional economic development would not be impeded by constraints on the supply of energy as most of the elasticities of substitution between energy and non-energy are fairly large.

Sixthly, there are many factors responsible for the inelasticity of demand for energy, however, growing income may be one of the most important causes given the high levels of energy prices in China. In fact, the low estimated elasticities of demand for energy suggest that increasing energy prices may not constrain energy consumption at present;

China’s energy demand could be income-driven. Therefore, some other energy policies should be used in order to encourage (reduce) some types of energy consumption.

Seventhly, technological change and innovative activities can be embodied in capital investment, specialized labor and exported goods. These changes and activities have tended to increase energy intensive since 2000. Therefore, reducing exports of energy-using commodities, depressing the high-level energy-using sectors, lowering capital investment and restraining imports of second-hand and obsolete equipment, would all help reduce the growth in energy intensity (and vice versa).

Eighthly, further researches, both domestic and international, both qualitative and quantitative, are required and should be encouraged. For the economic studies, public accesses to energy data are needed. This may be a more convenient and economical way to obtain policy guidance and suggestions from outsiders.

Finally, faced with an unfavorable energy situation, it is essential for China to support renewable energy laws and initiatives. However, how to enforce such renewable energy laws and initiatives remains a major challenge. How to balance those factors affecting energy demand and those factors affecting energy supply requires a strategy and portfolio of policies and their likely impacts, studied.

10.4 Policy directions

Even the most desirable combination of factors discussed above will not prevent a significant increase in China’s primary energy consumption (Smil, 1998). China’s energy policymakers are in a dilemma (Khan, 2005), but choices are inevitable. China’s policymakers must decide how and what to prioritize. To mitigate China's energy consumption pressures and ease the coal-use-environment dilemma, some studies have proposed some valuable policy suggestions (e.g., Sinton et al., 2005). According to our main findings and conclusions, we present the following specific policy directions for future China's energy market economic development:

- Enhancing technical innovation. Technical innovations come many forms, which are involved in both energy supply and demand sides. This also includes introducing overseas advanced energy techniques.
- Coordinating environment and resource policy. China's energy industry is confronted with dual pressures from economic development and environmental protection (Chang et al., 2003). Biomass and coal are two of the largest pollutants in China. For example, coal combustion produces 70% of China's carbon dioxide, 90% of sulfur dioxide emissions and 67% of nitrogen oxide emissions (Sinton et al., 2005). Therefore, improving biomass and coal's combustion efficiency is one of the most direct ways to reducing environmental pollution.
- Coordinating energy exploitation and conservation. Meeting rising energy demands doesn't necessarily mean having to increase energy supply, while to save energy use is also a smarter way to meeting rising energy demand. Therefore, in the long-run, China's government has to make great efforts not only to increase energy supply but to save energy use as well. Prioritizing investment in energy efficiency rather than pouring money into expanding energy supply should be strongly recommended. Wang, Wang and Zhao (2008) put forward 13 main

barriers to energy saving in China after reviewing literatures on energy saving and opinion of experts from energy industry and academia. These main barriers on energy saving are worthy of being paid attention from China's policymakers.

- Strengthening institutions. Raising the price of energy to reflect national priorities will require strengthened institutions with the capacity to make these kinds of changes. One possible solution is to establish an independent "Ministry of Energy," which would formalize the government's commitment to energy issues and improve enforcement of energy regulations and could integrate energy industry both over regional level and over energy sources, which means that energy policies are not independent implemented within each of energy sources but considered as a whole energy industry (all of energy sources).
- Employing Kyoto Protocol for self-defense. During the past two decades, China's exports were mainly energy-intensive based. China's increasing exports actually have been at the expense of depletion of domestic energy resources though exports are one of the most important drivers of fast economic growth in China. It may be impossible for China's government to choose between economic growth and resource conservation at this stage. However, China should request Kyoto parties to count the incremental cost of environment protection within the framework of the Clean Development Mechanism and would allow some of the importers of China's carbon-intensive goods to invest in lowering the carbon intensity of Chinese exports. The reason appears simple because importers of China's commodities benefit a lot. For example, Li and Hewitt (2008) find that through

trade with China the UK reduced its CO2 emissions by approximately 11% in 2004. Shui and Harriss (2006) estimate that that US CO2 emissions would have increased from 3% to 6% if the goods imported from China had been manufactured in the US while 7%–14% of China's current CO2 emissions were a result of producing exports for US consumers during 1997-2003.

- Increasing investment in renewable energies. Renewable energies only account for less than 10% of the world's total energy consumption but nearly 10% of China's total primary energy consumption. The potential of renewable energies is enormous due to its unlimited supply and its cleanliness in use. Moreover, once the Kyoto Protocol is fully implemented by all the signatories, the incentive of using renewable energies will be greatly increased. The opportunities and challenges for renewable energy policies can refer to Zhang et al. (2008).
- Improving traffic administration and enhancing traffic regulation.

10.5 Some future work

Although this study has conducted a series of empirical investigations into China's energy economics, some issues are still left unconfirmed because China's energy economy is still in transition. More importantly, many new energy economy reforms have taken place since 2005. Therefore, China's energy policy environment has possibly changed since then. As a result, China's energy consumption behaviors have probably changed. This means that the estimated parameters in this study, such as elasticities of substitution of and demand for energy and the pattern of technological changes, may need to be reestimated or updated so as to either confirm or obtain new estimates. Likewise, with many new reforms in energy economy, it is more likely that stronger evidences for the emergence of energy market will be found after 2005 than found in this study prior to 2005 in China. Therefore, it is crucial and helpful to update the estimated parameters here and the test results for the emergence of energy market in China.

Updating the work conducted here has two functions. One function immediately is to confirm what we did and found here because there have been much fewer studies on China's marketization and energy consumption behaviors. Other function is to obtain new estimated results if the estimated parameters are really changed so as to observe the role of energy reforms in determining energy price formation, energy consumption behaviors and the changes in energy intensity.

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Appendices

Appendix Tables

Appendix Table 5-1. Descriptive statistics of industry coal consumption

Province	Min	Max	Mean	STDEV
National	459.7	618.2	500.1	49.2
Beijing	5.7	7.5	6.6	0.6
Tianjin	6.1	8.4	7.7	0.8
Hebei	32.2	45.6	36.6	4.6
Shanxi	21.1	29.5	23.8	2.8
Inner Mongolia	9.7	28.7	16.4	5.8
Liaoning	19.1	28.9	23.2	3.0
Jilin	10.8	21.1	14.7	3.7
Heilongjiang	13.4	17.1	15.3	1.2
Shanghai	7.5	9.0	8.3	0.5
Jiangsu	24.3	38.2	31.1	5.4
Zhejiang	18.5	31.2	21.3	3.7
Anhui	22.5	32.9	28.7	3.3
Fujian	8.4	12.2	9.7	1.3
Jiangxi	7.5	13.1	10.0	1.7
Shandong	25.9	53.2	34.3	8.6
Henan	24.5	44.7	28.8	5.9
Hubei	26.2	38.4	29.9	3.7
Hunan	18.5	28.8	22.6	3.5
Guangdong	20.0	29.9	22.3	2.9
Guangxi	12.2	16.2	14.3	1.1
Hainan	0.0	2.7	0.8	0.8
Chongqing	10.7	19.7	14.8	3.0
Sichuan	15.3	30.4	23.0	5.4
Guizhou	8.7	23.8	13.1	4.4
Yunnan	6.4	10.5	8.1	1.3
Tibet	0.0	0.0	0.0	0.0
Shaanxi	6.5	15.0	11.0	2.7
Gansu	6.6	8.5	7.4	0.7
Qinghai	1.3	2.7	1.8	0.4
Ningxia	2.1	18.9	9.3	7.7
Xinjiang	4.7	7.4	5.9	0.8

Note: Unit is million ton, 1995-2004.
Source: China Energy Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Appendix Table 5-2. Descriptive statistics of industry electricity consumption

Province	Min	Max	Mean	STDEV
National	702.8	1480.7	965.0	261.5
Beijing	14.7	19.6	16.2	1.4
Tianjin	10.1	23.8	15.7	4.4
Hebei	41.7	86.3	55.0	14.9
Shanxi	29.6	64.7	41.1	11.6
Inner Mongolia	14.2	43.9	22.3	9.5
Liaoning	46.0	75.6	56.1	9.0
Jilin	17.5	25.4	20.0	2.2
Heilongjiang	29.2	38.1	32.6	2.7
Shanghai	28.3	51.1	36.7	7.6
Jiangsu	44.9	130.1	70.8	28.6
Zhejiang	29.4	102.2	54.6	25.4
Anhui	19.1	38.5	25.7	5.9
Fujian	16.1	41.4	25.7	9.7
Jiangxi	11.9	25.2	14.9	4.1
Shandong	57.1	133.4	81.8	27.0
Henan	39.3	89.7	53.4	16.2
Hubei	27.3	51.0	35.1	8.1
Hunan	22.7	46.3	28.3	7.3
Guangdong	45.5	146.3	79.3	33.3
Guangxi	14.8	30.3	21.0	4.7
Hainan	1.2	3.4	1.9	0.8
Chongqing	11.3	20.1	16.5	3.6
Sichuan	29.2	53.3	37.3	7.7
Guizhou	14.0	42.6	25.7	11.4
Yunnan	15.5	28.0	21.5	4.2
Tibet	0.0	0.0	0.0	0.0
Shaanxi	14.6	28.8	19.7	5.1
Gansu	17.6	32.4	21.3	4.7
Qinghai	5.6	17.2	9.6	3.5
Ningxia	0.5	18.8	11.2	6.3
Xinjiang	8.3	17.3	11.6	3.3

Note: Unit is billion KWh, 1995-2004.
Source: China Energy Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Appendix Table 5-3. Descriptive statistics of industry petroleum consumption

Province	Min	Max	Mean	STDEV
National	16.8	21.7	18.5	1.4
Beijing	0.2	0.4	0.3	0.0
Tianjin	0.3	0.5	0.4	0.1
Hebei	1.0	1.3	1.1	0.1
Shanxi	0.5	0.7	0.6	0.1
Inner Mongolia	0.2	0.4	0.3	0.1
Liaoning	0.5	1.1	0.7	0.2
Jilin	0.2	0.5	0.3	0.1
Heilongjiang	0.6	1.3	1.0	0.2
Shanghai	0.4	0.8	0.5	0.1
Jiangsu	1.0	1.7	1.3	0.2
Zhejiang	0.7	1.3	0.9	0.2
Anhui	0.3	0.5	0.4	0.1
Fujian	0.3	0.8	0.4	0.2
Jiangxi	0.1	0.4	0.2	0.1
Shandong	1.3	2.1	1.6	0.2
Henan	0.4	0.7	0.5	0.1
Hubei	1.0	1.7	1.4	0.2
Hunan	0.3	0.6	0.5	0.1
Guangdong	1.8	3.8	2.9	0.7
Guangxi	0.2	0.6	0.4	0.1
Hainan	0.0	0.1	0.1	0.0
Chongqing	0.2	0.3	0.2	0.1
Sichuan	0.3	0.6	0.4	0.1
Guizhou	0.1	0.2	0.1	0.0
Yunnan	0.2	0.4	0.3	0.1
Tibet	0.0	0.0	0.0	0.0
Shaanxi	0.5	1.1	0.8	0.2
Gansu	0.2	0.4	0.3	0.1
Qinghai	0.1	0.1	0.1	0.0
Ningxia	0.0	0.1	0.0	0.0
Xinjiang	0.3	0.6	0.4	0.1

Note: Unit is million ton, 1995-2004.
Source: China Energy Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Appendix Table 5-4. Descriptive statistics of industry employees

Province	Min	Max	Mean	STDEV
National	89.2	118.7	101.2	11.4
Beijing	1.4	2.0	1.6	0.2
Tianjin	1.3	2.1	1.6	0.3
Hebei	6.2	7.1	6.6	0.3
Shanxi	2.7	3.6	3.0	0.3
Inner Mongolia	1.1	1.8	1.4	0.3
Liaoning	3.5	6.3	4.5	1.2
Jilin	1.4	2.8	2.0	0.6
Heilongjiang	2.5	4.6	3.3	0.9
Shanghai	2.6	3.6	2.9	0.4
Jiangsu	7.7	10.0	8.7	0.9
Zhejiang	6.4	10.1	7.5	1.2
Anhui	3.3	4.2	3.7	0.4
Fujian	2.7	4.0	3.2	0.4
Jiangxi	2.0	3.0	2.5	0.4
Shandong	7.8	9.5	8.3	0.6
Henan	6.2	7.2	6.6	0.3
Hubei	3.1	4.7	3.7	0.7
Hunan	3.4	4.4	3.8	0.4
Guangdong	7.3	9.5	8.0	0.7
Guangxi	1.6	1.9	1.7	0.1
Hainan	0.2	0.3	0.2	0.0
Chongqing	1.4	2.0	1.7	0.2
Sichuan	3.6	7.0	4.6	1.3
Guizhou	1.3	1.5	1.4	0.0
Yunnan	1.3	1.5	1.4	0.1
Tibet	0.0	0.1	0.0	0.0
Shaanxi	2.0	2.5	2.2	0.2
Gansu	1.0	1.5	1.2	0.2
Qinghai	0.2	0.3	0.2	0.0
Ningxia	0.3	0.4	0.4	0.0
Xinjiang	0.6	1.0	0.8	0.1

Note: Unit is million persons, 1995-2004.
Source: China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Appendix Table 5-5. Descriptive statistics of industry nominal wage rates

Province	Min	Max	Mean	STDEV
National	4069	7949	5737	1329
Beijing	6449	18894	11678	4108
Tianjin	5193	13599	8559	2895
Hebei	3305	5962	4381	926
Shanxi	4006	8852	5387	1567
Inner Mongolia	3889	11084	6319	2272
Liaoning	4374	11682	7293	2500
Jilin	4094	11058	7085	2237
Heilongjiang	3785	10190	6303	2205
Shanghai	6992	14835	10669	2931
Jiangsu	3643	6840	5152	1230
Zhejiang	3138	5574	4250	789
Anhui	3458	5260	4345	560
Fujian	3639	8028	5744	1525
Jiangxi	3257	5175	4366	696
Shandong	3821	8278	5712	1559
Henan	3283	5702	4206	797
Hubei	3845	8483	5805	1605
Hunan	3631	6018	4732	911
Guangdong	4209	7963	6141	1198
Guangxi	4480	8358	5968	1287
Hainan	4833	8170	6463	1065
Chongqing	4249	7458	5561	1154
Sichuan	3640	6877	5176	1078
Guizhou	4122	7164	5333	1036
Yunnan	4794	10189	7228	1735
Tibet	3564	10984	7248	2471
Shaanxi	3658	9282	6075	1943
Gansu	5149	11321	7493	2021
Qinghai	4704	10809	7505	2216
Ningxia	5182	10153	7559	1683
Xinjiang	5855	14824	9669	2791

Note: Unit is ¥/year, 1995-2004.
Source: China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Appendix Table 5-6. Descriptive statistics of industry capital stock

Province	Min	Max	Mean	STDEV
National	4584	8108	5437	1038
Beijing	153	179	168	9
Tianjin	107	180	130	21
Hebei	143	335	212	57
Shanxi	106	214	136	35
Inner Mongolia	84	178	103	29
Liaoning	508	650	567	49
Jilin	98	222	136	34
Heilongjiang	147	251	184	33
Shanghai	295	471	356	51
Jiangsu	422	617	455	59
Zhejiang	218	407	256	58
Anhui	132	288	160	46
Fujian	78	207	114	38
Jiangxi	100	145	110	13
Shandong	325	722	408	121
Henan	217	365	256	42
Hubei	149	366	215	61
Hunan	110	188	129	23
Guangdong	210	472	311	79
Guangxi	79	119	89	13
Hainan	31	38	34	2
Chongqing	61	95	70	10
Sichuan	167	337	212	48
Guizhou	50	92	65	14
Yunnan	85	127	102	12
Tibet	7	9	7	1
Shaanxi	128	186	140	17
Gansu	68	117	83	15
Qinghai	25	42	31	5
Ningxia	27	49	32	7
Xinjiang	78	181	115	32

Note: Unit is ¥billion, 1995-2004.
Source: estimated based on China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Appendix Table 5-7. Descriptive statistics of industry nominal GDP

Province	Min	Max	Mean	STDEV
National	2472	6282	3980	1160
Beijing	50	129	77	25
Tianjin	45	144	78	31
Hebei	115	409	228	88
Shanxi	43	157	83	33
Inner Mongolia	25	102	51	22
Liaoning	123	283	197	52
Jilin	41	114	67	23
Heilongjiang	95	281	166	56
Shanghai	130	349	205	69
Jiangsu	247	778	416	166
Zhejiang	163	538	303	115
Anhui	77	174	119	26
Fujian	76	253	149	56
Jiangxi	31	111	64	22
Shandong	211	780	399	173
Henan	127	386	218	78
Hubei	93	259	179	51
Hunan	65	178	120	32
Guangdong	241	801	444	176
Guangxi	46	104	67	16
Hainan	4	12	7	3
Chongqing	37	93	57	17
Sichuan	83	217	143	36
Guizhou	21	57	33	11
Yunnan	48	105	72	16
Tibet	0	2	1	0
Shaanxi	34	106	59	22
Gansu	23	58	35	10
Qinghai	5	16	8	3
Ningxia	6	19	10	4
Xinjiang	22	75	40	16

Note: Unit is ¥billion, 1995-2004.
Source: China Statistical Yearbooks, 1996-2005. Beijing: Statistical Publisher.

Appendix Table 9-1. Panel unit root tests of raw data for Region 1

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-1999:								
Level:								
LLC	4.242	1.000	2.094	0.982	3.024	0.999	1.557	0.940
Breitung	-2.032	0.021	-2.069	0.019	0.338	0.632	-0.487	0.313
IPS	-0.096	0.462	0.180	0.571	-0.827	0.204	-0.541	0.294
1st difference:								
LLC	-41.387	0.000	-40.641	0.000	-54.673	0.000	-57.128	0.000
Breitung	-29.284	0.000	-27.682	0.000	-4.272	0.000	-15.196	0.000
IPS	-32.377	0.000	-35.582	0.000	-46.096	0.000	-46.359	0.000
2000-2005:								
Level:								
LLC	-0.387	0.349	2.971	0.999	1.860	0.970	2.110	0.980
Breitung	0.828	0.796	-1.174	0.120	-0.390	0.340	-2.480	0.010
IPS	0.780	0.782	-1.686	0.046	0.960	0.830	-1.410	0.080
1st difference:								
LLC	-37.394	0.000	-78.165	0.000	-18.890	0.000	-8.600	0.000
Breitung	-15.573	0.000	-18.485	0.000	-18.710	0.000	-13.790	0.000
IPS	-21.984	0.000	-58.244	0.000	-25.270	0.000	-16.060	0.000

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS. Exogenous variables include Individual effect and individual linear trend

Region 1 includes Shijiazhuang, Hohhot, Taiyuan, Hefei, Jinan and Zhengzhou.

Appendix Table 9-2. Panel unit root tests of raw data for Region 2

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-1999:								
Level:								
LLC	0.592	0.723	-0.815	0.208	1.845	0.968	1.322	0.907
Breitung	-0.647	0.259	-1.936	0.026	0.727	0.766	-0.727	0.234
IPS	0.159	0.563	-3.179	0.001	-1.567	0.059	-0.692	0.245
1st difference:								
LLC	-33.602	0.000	-32.828	0.000	-30.131	0.000	-40.166	0.000
Breitung	-6.975	0.000	-18.028	0.000	-12.038	0.000	-19.617	0.000
IPS	-27.021	0.000	-24.563	0.000	-23.672	0.000	-34.060	0.000
2000-2005:								
Level:								
LLC	-0.465	0.321	1.238	0.892	0.995	0.840	0.765	0.778
Breitung	-0.991	0.161	-1.009	0.157	-0.785	0.216	-1.881	0.030
IPS	-0.588	0.278	-0.642	0.261	0.419	0.663	-0.940	0.174
1st difference:								
LLC	-38.480	0.000	-52.722	0.000	-47.924	0.000	-26.910	0.000
Breitung	-25.331	0.000	-23.246	0.000	-12.097	0.000	-7.235	0.000
IPS	-29.053	0.000	-36.946	0.000	-38.906	0.000	-18.610	0.000

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS. Exogenous variables include Individual effect and individual linear trend

Region 2 includes Beijing, Tianjin and Shanghai.

Appendix Table 9-3. Panel unit root tests of raw data for Region 3

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-1999:								
Level:								
LLC	0.427	0.665	0.330	0.629	-0.384	0.351	-0.117	0.454
Breitung	0.017	0.507	-1.699	0.045	-0.632	0.264	-0.989	0.161
IPS	-1.288	0.099	0.378	0.647	-0.349	0.364	0.110	0.544
1^{st} difference:								
LLC	-33.439	0.000	-53.039	0.000	-44.638	0.000	-43.593	0.000
Breitung	-23.069	0.000	-32.340	0.000	-29.947	0.000	-27.783	0.000
IPS	-25.832	0.000	-41.809	0.000	-35.920	0.000	-33.966	0.000
2000-2005:								
Level:								
LLC	-0.395	0.346	4.760	1.000	1.017	0.845	-0.031	0.488
Breitung	-0.400	0.345	-0.712	0.238	-0.657	0.256	-0.792	0.214
IPS	0.270	0.606	-0.689	0.246	0.463	0.678	-0.201	0.421
1^{st} difference:								
LLC	-29.807	0.000	-63.442	0.000	-55.850	0.000	-33.861	0.000
Breitung	-17.529	0.000	-7.893	0.000	-18.905	0.000	-15.696	0.000
IPS	-18.835	0.000	-51.588	0.000	-43.730	0.000	-23.817	0.000

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS. Exogenous variables include Individual effect and individual linear trend

Region 3 includes Shenyang, Changchun and Harbin.

Appendix Table 9-4. Panel unit root tests of raw data for Region 4

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-1999:								
Level:								
LLC	2.793	0.997	0.890	0.813	1.739	0.959	2.214	0.987
Breitung	-0.073	0.471	0.040	0.516	2.721	0.997	1.134	0.872
IPS	0.591	0.723	0.359	0.640	-0.065	0.474	-1.095	0.137
1^{st} difference:								
LLC	-34.042	0.000	-48.039	0.000	-35.193	0.000	-27.379	0.000
Breitung	-24.131	0.000	-24.829	0.000	-1.553	0.060	-15.104	0.000
IPS	-26.828	0.000	-33.615	0.000	-25.809	0.000	-23.907	0.000
2000-2005:								
Level:								
LLC	-0.335	0.369	0.379	0.648	1.990	0.977	0.845	0.801
Breitung	0.352	0.638	-1.269	0.102	-1.115	0.133	-2.105	0.018
IPS	1.440	0.925	-1.878	0.030	1.039	0.851	-0.333	0.370
1^{st} difference:								
LLC	-5.998	0.000	-58.561	0.000	-57.411	0.000	-43.182	0.000
Breitung	0.145	0.558	-18.325	0.000	-18.331	0.000	-18.625	0.000
IPS	-5.715	0.000	-43.418	0.000	-46.242	0.000	-29.265	0.000

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS. Exogenous variables include Individual effect and individual linear trend

Region 4 includes Nanjing, Hangzhou, Nanchang and Wuhan.

Appendix Table 9-5. Panel unit root tests of raw data for Region 5

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-1999:								
Level:								
LLC	10.910	1.000	-0.078	0.469	5.166	1.000	4.878	1.000
Breitung	-1.350	0.089	0.021	0.509	1.777	0.962	0.590	0.722
IPS	1.440	0.925	-0.674	0.250	-0.206	0.418	0.311	0.622
1st difference:								
LLC	-53.103	0.000	-48.233	0.000	-65.271	0.000	-57.365	0.000
Breitung	-18.834	0.000	-29.983	0.000	-32.704	0.000	-4.243	0.000
IPS	-41.207	0.000	-34.930	0.000	-53.412	0.000	-46.703	0.000
2000-2005:								
Level:								
LLC	-0.124	0.451	1.218	0.888	2.135	0.984	0.404	0.657
Breitung	0.683	0.753	-1.791	0.037	-0.818	0.207	-3.824	0.000
IPS	0.218	0.586	-1.467	0.071	1.018	0.846	-1.113	0.133
1st difference:								
LLC								
Breitung	-34.319	0.000	-80.301	0.000	-73.698	0.000	-39.500	0.000
IPS	-19.282	0.000	-23.324	0.000	-17.490	0.000	-15.468	0.000

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS. Exogenous variables include Individual effect and individual linear trend

Region 5 includes Fuzhou, Changsha, Guangzhou, Nanning and Haikou.

Appendix Table 9-6. Panel unit root tests of raw data for Region 6

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-1999:								
Level:								
LLC	4.000	1.000	0.681	0.752	3.222	0.999	1.020	0.846
Breitung	-0.769	0.221	-2.910	0.002	1.912	0.972	-1.716	0.043
IPS	1.504	0.934	0.000	0.500	-1.650	0.050	-1.561	0.059
1st difference:								
LLC	-40.386	0.000	-58.216	0.000	-49.033	0.000	-41.531	0.000
Breitung	-26.806	0.000	-37.597	0.000	-19.514	0.000	-20.625	0.000
IPS	-29.829	0.000	-46.278	0.000	-40.829	0.000	-34.495	0.000
2000-2005:								
Level:								
LLC	-0.124	0.451	1.218	0.888	2.135	0.984	0.404	0.657
Breitung	0.683	0.753	-1.791	0.037	-0.818	0.207	-3.824	0.000
IPS	0.218	0.586	-1.467	0.071	1.018	0.846	-1.113	0.133
1st difference:								
LLC	-34.319	0.000	-80.301	0.000	-73.698	0.000	-39.500	0.000
Breitung	-19.282	0.000	-23.324	0.000	-17.490	0.000	-15.468	0.000
IPS	-21.488	0.000	-60.580	0.000	-60.054	0.000	-26.389	0.000

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS. Exogenous variables include Individual effect and individual linear trend

Region 6 includes Chongqing, Chengdu, Xi'an, Lanzhou, Guiyang and Kunming.

Appendix Table 9-7. Panel unit root tests of raw data for Region 7

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-1999:								
Level:								
LLC	1.884	0.970	2.030	0.979	1.034	0.849	1.981	0.976
Breitung	-2.162	0.015	-2.883	0.002	2.174	0.985	2.327	0.990
IPS	-0.032	0.487	-1.614	0.053	-2.675	0.004	0.404	0.657
1^{st} difference:								
LLC	-31.269	0.000	-32.756	0.000	-51.637	0.000	-48.152	0.000
Breitung	-14.378	0.000	-22.065	0.000	-8.215	0.000	-27.435	0.000
IPS	-22.296	0.000	-25.151	0.000	-39.325	0.000	-38.724	0.000
2000-2005:								
Level:								
LLC	-0.528	0.299	1.817	0.965	1.741	0.959	1.041	0.851
Breitung	-0.028	0.489	-1.168	0.121	-0.882	0.189	-1.720	0.043
IPS	0.355	0.639	-0.827	0.204	0.843	0.800	-0.279	0.390
1^{st} difference:								
LLC	-43.731	0.000	-78.665	0.000	-63.995	0.000	-25.152	0.000
Breitung	-8.878	0.000	-17.752	0.000	-18.515	0.000	-8.981	0.000
IPS	-30.121	0.000	-61.789	0.000	-49.882	0.000	-17.769	0.000

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS. Exogenous variables include Individual effect and individual linear trend

Region 7 Lhasa (data unavailable), Xining, Yinchuan and Urumqi.

Appendix Table 9-8. Panel unit root tests of relative prices for Region 1

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-2005:								
LLC	1.95	0.97	-0.09	0.46	-1.79	**0.04**	-2.96	**0.00**
Breitung	-0.43	0.33	-3.10	**0.00**	-2.57	**0.01**	-3.83	**0.00**
IPS	0.09	0.54	-0.59	0.28	-1.46	**0.07**	-2.10	**0.02**
Fisher ADF	10.39	0.58	14.57	0.27	17.17	0.14	25.27	**0.01**
Fisher PP	53.36	**0.00**	78.76	**0.00**	184.58	**0.00**	212.77	**0.00**
2000-2005:								
LLC	-0.88	0.19	-0.96	0.17	0.71	0.76	2.64	0.99
Breitung	-1.09	0.13	-1.74	**0.04**	-2.48	**0.01**	-1.26	0.10
IPS	-0.10	0.46	-2.49	**0.01**	-1.94	**0.03**	-3.01	**0.00**
Fisher ADF	8.87	0.71	22.62	**0.03**	20.50	**0.05**	29.57	**0.00**
Fisher PP	11.38	0.50	224.08	**0.00**	310.01	**0.00**	228.08	**0.00**
1995-1999:								
LLC	4.24	0.99	2.09	0.98	5.01	0.99	1.56	0.94
Breitung	-2.03	**0.02**	-2.07	**0.02**	1.42	0.92	-0.49	0.31
IPS	-0.10	0.46	0.18	0.57	0.35	0.64	-0.54	0.29
Fisher ADF	18.92	0.09	7.82	0.80	9.01	0.70	12.49	0.41
Fisher PP	57.31	**0.00**	81.36	**0.00**	67.56	**0.00**	93.26	**0.00**

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS, Fisher ADF and Fisher PP. Group is used as a benchmark. Both individual effect and linear trend are included.

Region 1 includes Shijiazhuang, Taiyuan, Hefei, Jinan and Zhengzhou.

Appendix Table 9-9. Panel unit root tests of relative prices for Region 2

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-2005:								
LLC	-2.09	**0.02**	0.82	0.79	0.50	0.69	-4.90	**0.00**
Breitung	-2.96	**0.00**	-0.02	0.49	-2.72	**0.00**	-3.61	**0.00**
IPS	-2.18	**0.01**	0.57	0.71	-3.00	**0.00**	-2.87	**0.00**
Fisher ADF	15.41	**0.02**	4.63	0.59	21.84	**0.00**	19.25	**0.00**
Fisher PP	26.52	**0.00**	123.89	**0.00**	99.29	**0.00**	119.29	**0.00**
2000-2005:								
LLC	-1.64	**0.05**	1.71	0.95	0.85	0.80	0.45	0.67
Breitung	-3.44	**0.00**	-0.89	0.19	-0.61	0.27	-2.40	**0.01**
IPS	-2.61	**0.00**	-0.28	0.39	-0.62	0.27	-2.20	**0.01**
Fisher ADF	18.17	**0.01**	4.89	0.56	7.35	0.29	16.55	0.11
Fisher PP	46.78	**0.00**	286.68	**0.00**	70.89	**0.00**	80.73	**0.00**
1995-1999:								
LLC	-0.21	0.42	1.76	0.96	0.32	0.62	-0.25	0.40
Breitung	-1.36	0.09	-1.50	**0.07**	-1.47	**0.07**	-1.74	**0.04**
IPS	-0.99	0.16	-0.25	0.40	-1.89	**0.03**	-1.14	0.13
Fisher ADF	8.89	0.18	5.46	0.49	12.68	**0.05**	8.92	0.18
Fisher PP	17.84	**0.01**	31.04	**0.00**	41.00	**0.00**	56.76	**0.00**

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS, Fisher ADF and Fisher PP. Group is used as a benchmark. Both individual effect and linear trend are included.

Region 2 includes Beijing, Tianjin and Shanghai.

Appendix Table 9-10. Panel unit root tests of relative prices for Region 3

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-2005:								
LLC	5.30	0.99	1.11	0.87	-1.02	0.15	-1.03	0.15
Breitung	-0.07	0.47	-1.32	0.09	-3.38	**0.00**	-4.49	**0.00**
IPS	1.03	0.85	0.14	0.56	-1.47	**0.07**	-2.79	**0.00**
Fisher ADF	2.56	0.96	4.85	0.77	14.44	**0.07**	21.90	**0.01**
Fisher PP	31.92	**0.00**	317.42	**0.00**	90.98	**0.00**	153.54	**0.00**
2000-2005:								
LLC	-0.57	0.28	8.10	0.99	1.06	0.86	-0.12	0.45
Breitung	-0.99	0.16	-1.44	**0.07**	-1.70	**0.04**	-1.50	**0.06**
IPS	0.24	0.59	-0.96	0.17	-2.42	**0.01**	-2.02	**0.02**
Fisher ADF	5.12	0.75	8.91	0.35	19.04	**0.01**	16.31	**0.03**
Fisher PP	5.10	0.75	390.34	**0.00**	134.78	**0.00**	82.66	**0.00**
1995-1999:								
LLC	8.84	0.99	1.61	0.95	-1.16	0.12	1.17	0.88
Breitung	-0.68	0.25	-1.82	**0.03**	-0.94	0.17	-0.08	0.45
IPS	2.09	0.98	0.76	0.78	-0.19	0.42	0.23	0.59
Fisher ADF	2.38	0.97	2.75	0.95	10.04	0.26	6.04	0.64
Fisher PP	24.78	**0.01**	156.71	**0.00**	55.96	**0.00**	56.53	**0.00**

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS, Fisher ADF and Fisher PP. Group is used as a benchmark. Both individual effect and linear trend are included.

Region 3 includes Shenyang, Changchun and Harbin.

Appendix Table 9-11. Panel unit root tests of relative prices for Region 4

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-2005:								
LLC	1.03	0.85	-0.37	0.36	-1.80	**0.04**	-2.04	**0.02**
Breitung	-1.00	0.16	-1.24	0.11	-1.70	**0.04**	-3.87	**0.00**
IPS	-0.15	0.44	0.28	0.61	-2.37	**0.01**	-4.09	**0.00**
Fisher ADF	9.57	0.30	5.66	0.69	17.45	**0.03**	33.45	**0.00**
Fisher PP	14.75	**0.06**	34.11	**0.00**	268.92	**0.00**	179.86	**0.00**
2000-2005:								
LLC	0.27	0.61	-0.27	0.39	-1.20	0.12	-0.95	0.17
Breitung	-0.79	0.21	-1.81	**0.04**	-1.07	0.14	-0.28	0.39
IPS	0.72	0.77	-1.06	0.15	-3.85	**0.00**	-4.11	**0.00**
Fisher ADF	4.71	0.79	10.80	0.21	32.44	**0.00**	35.07	**0.00**
Fisher PP	6.31	0.61	135.18	**0.00**	333.03	**0.00**	255.39	**0.00**
1995-1999:								
LLC	0.24	0.60	1.18	0.88	-0.02	0.49	0.78	0.78
Breitung	-1.54	**0.06**	-0.25	0.40	1.00	0.84	-3.19	**0.00**
IPS	-3.47	**0.00**	-0.32	0.37	-1.45	**0.07**	-3.64	**0.00**
Fisher ADF	29.04	**0.00**	6.85	0.55	12.81	0.12	29.53	**0.00**
Fisher PP	38.97	**0.00**	21.06	**0.01**	93.21	**0.00**	74.16	**0.00**

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS, Fisher ADF and Fisher PP. Group is used as a benchmark. Both individual effect and linear trend are included.

Region 4 includes Nanjing, Hangzhou, Nanchang and Wuhan.

Appendix Table 9-12. Panel unit root tests of relative prices for Region 5

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-2005:								
LLC	3.56	0.99	0.06	0.52	4.42	0.99	1.75	0.96
Breitung	0.80	0.79	-1.59	**0.06**	-2.15	**0.02**	-3.29	**0.00**
IPS	-0.26	0.40	0.26	0.60	-2.33	**0.01**	-2.65	**0.00**
Fisher ADF	18.58	0.18	8.60	0.86	26.95	**0.02**	30.62	**0.01**
Fisher PP	86.10	**0.00**	166.62	**0.00**	307.76	**0.00**	233.18	**0.00**
2000-2005:								
LLC	0.01	0.50	1.31	0.90	-3.50	**0.00**	-1.00	0.16
Breitung	-0.82	0.21	-1.75	**0.04**	-2.02	**0.02**	-1.78	**0.04**
IPS	-0.09	0.47	-0.89	0.19	-7.12	**0.00**	-5.88	**0.00**
Fisher ADF	13.84	0.46	14.66	0.40	85.51	**0.00**	71.99	**0.00**
Fisher PP	16.66	0.27	418.91	**0.00**	413.57	**0.00**	359.81	**0.00**
1995-1999:								
LLC	13.52	0.99	1.38	0.92	8.79	0.99	1.66	0.95
Breitung	-1.45	**0.07**	0.11	0.54	0.19	0.58	-1.04	0.15
IPS	1.29	0.90	-0.13	0.45	-0.34	0.37	-0.92	0.18
Fisher ADF	6.76	0.94	15.74	0.33	23.54	**0.05**	27.65	**0.02**
Fisher PP	104.39	**0.00**	87.97	**0.00**	206.62	**0.00**	97.72	**0.00**

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS, Fisher ADF and Fisher PP. Group is used as a benchmark. Both individual effect and linear trend are included.

Region 5 includes Fuzhou, Changsha, Guangzhou, Nanning and Haikou.

Appendix Table 9-13. Panel unit root tests of relative prices for Region 6

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-2005:								
LLC	1.96	0.98	-1.19	0.12	-1.73	**0.04**	-2.02	**0.02**
Breitung	-2.19	**0.01**	-2.37	**0.01**	-4.13	**0.00**	-4.67	**0.00**
IPS	-1.33	0.09	-0.38	0.35	-3.06	**0.00**	-3.82	**0.00**
Fisher ADF	19.10	0.09	11.04	0.53	31.44	**0.00**	39.70	**0.00**
Fisher PP	41.96	**0.00**	127.25	**0.00**	295.92	**0.00**	160.85	**0.00**
2000-2005:								
LLC	-0.59	0.28	0.88	0.81	-2.68	**0.00**	-1.66	**0.05**
Breitung	-1.42	0.08	-1.51	**0.07**	-5.69	**0.00**	-4.67	**0.00**
IPS	-1.23	0.11	-2.18	**0.01**	-6.42	**0.00**	-3.99	**0.00**
Fisher ADF	15.51	0.21	22.81	**0.03**	78.15	**0.00**	42.94	**0.00**
Fisher PP	18.38	0.10	425.99	**0.00**	288.88	**0.00**	186.15	**0.00**
1995-1999:								
LLC	4.13	0.99	0.70	0.76	2.03	0.98	2.56	0.99
Breitung	-1.09	0.14	-4.53	**0.00**	-0.50	0.31	-0.21	0.42
IPS	0.19	0.58	-1.08	0.14	-1.77	**0.04**	-0.63	0.27
Fisher ADF	8.50	0.74	15.04	0.24	23.13	**0.03**	14.94	0.24
Fisher PP	42.67	**0.00**	55.45	**0.00**	134.85	**0.00**	59.36	**0.00**

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS, Fisher ADF and Fisher PP. Group is used as a benchmark. Both individual effect and linear trend are included.

Region 6 includes Chongqing, Chengdu, Xi’an, Lanzhou, Guiyang and Kunming.

Appendix Table 9-14. Panel unit root tests of relative prices for Region 7

Tests	Coal		Electricity		Gasoline		Diesel	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
1995-2005:								
LLC	-0.36	0.36	2.23	0.99	-6.40	**0.00**	-0.96	0.17
Breitung	-1.96	**0.03**	-3.97	**0.00**	-4.23	**0.00**	-2.94	**0.00**
IPS	-2.65	**0.00**	-2.06	**0.02**	-6.46	**0.00**	-2.75	**0.00**
Fisher ADF	23.15	**0.01**	17.44	**0.07**	69.31	**0.00**	22.94	**0.01**
Fisher PP	46.77	**0.00**	352.53	**0.00**	393.84	**0.00**	274.28	**0.00**
2000-2005:								
LLC	0.25	0.60	0.30	0.62	-1.25	0.10	-2.44	**0.01**
Breitung	-0.89	0.19	-0.29	0.39	-1.68	**0.05**	-2.69	**0.00**
IPS	-1.32	0.09	-0.53	0.30	-3.04	**0.00**	-3.38	**0.00**
Fisher ADF	16.92	0.08	8.88	0.54	31.65	**0.00**	28.06	**0.00**
Fisher PP	28.10	**0.00**	382.46	**0.00**	291.99	**0.00**	156.05	**0.00**
1995-1999:								
LLC	1.17	0.88	4.43	1.00	-0.35	0.36	-1.52	**0.06**
Breitung	-2.99	**0.00**	-2.94	**0.00**	-2.78	**0.00**	-0.28	0.39
IPS	-1.24	0.11	-1.03	0.15	-3.30	**0.00**	-2.63	**0.00**
Fisher ADF	13.40	0.20	11.86	0.29	31.54	**0.00**	34.96	**0.00**
Fisher PP	28.35	**0.00**	58.87	**0.00**	160.83	**0.00**	140.79	**0.00**

Note: Null hypothesis is common unit root for LLC and Breitung, and individual unit root for IPS, Fisher ADF and Fisher PP. Group is used as a benchmark. Both individual effect and linear trend are included.

Region 7 includes Hohhot, Lhasa (data unavailable), Xining, Yinchuan and Urumqi.

Appendix Table 9-15. Panel cointegration tests between coal and electricity as well as gasoline and diesel in all 35 markets

Test statistics	Electricity and coal						Diesel and gasoline					
	1997-2005		1997-1999		2000-2005		1997-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	-1.052	0.229	0.540	0.345	-1.832	0.075	24.308	0.000	9.065	0.000	29.437	0.000
Panel ρ -statistic	-9.590	0.000	-4.266	0.000	-21.821	0.000	-74.687	0.000	-20.545	0.000	-57.328	0.000
Panel t -statistic [a]	-5.796	0.000	-3.340	0.002	-12.742	0.000	-30.106	0.000	-14.138	0.000	-25.360	0.000
Panel t -statistic [b]	3.491	0.001	-0.924	0.260	2.665	0.011	-19.132	0.000	-9.137	0.000	-16.985	0.000
Group ρ -statistic	-4.659	0.000	-3.690	0.000	-32.542	0.000	-68.423	0.000	-17.282	0.000	-52.061	0.000
Group t -statistic [a]	-5.803	0.000	-3.483	0.001	-12.474	0.000	-32.559	0.000	-14.322	0.000	-27.122	0.000
Group t -statistic [b]	-6.101	0.000	1.006	0.240	3.732	0.000	-21.076	0.000	-9.946	0.000	-19.538	0.000
Deterministic intercept and trend:												
Panel v -statistic	-2.587	0.014	0.167	0.393	-1.663	0.100	13.996	0.000	4.313	0.000	19.066	0.000
Panel ρ -statistic	-6.881	0.000	-6.958	0.000	-0.847	0.279	-63.940	0.000	-19.242	0.000	-51.384	0.000
Panel t -statistic [a]	-5.386	0.000	-6.948	0.000	-1.251	0.182	-32.355	0.000	-15.779	0.000	-27.920	0.000
Panel t -statistic [b]	1.729	0.090	-7.367	0.000	0.272	0.385	-18.263	0.000	-9.830	0.000	-17.908	0.000
Group ρ -statistic	-6.481	0.000	-4.659	0.000	-1.799	0.079	-55.323	0.000	-16.311	0.000	-43.597	0.000
Group t -statistic [a]	-3.896	0.000	-5.803	0.000	-1.063	0.227	-32.060	0.000	-15.576	0.000	-27.388	0.000
Group t -statistic [b]	2.687	0.011	-6.101	0.000	1.006	0.240	-19.067	0.000	-10.783	0.000	-19.099	0.000

Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is based on Engle-Granger. Pedroni (1999) shows that the panel-ADF and group-ADF statistics have better small sample properties than the other statistics, and hence they are more reliable.
[a] Non-parametric and [b] parametric.

Appendix Table 9-16. Panel cointegration tests for Region 1

Test statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	0.481	0.355	0.458	0.359	0.863	0.275	2.028	0.051	3.344	0.002	12.178	0.000
Panel ρ -statistic	-4.136	0.000	-14.397	0.000	-6.805	0.000	-22.843	0.000	-7.266	0.000	-29.404	0.000
Panel t -statistic [a]	-4.447	0.000	-9.651	0.000	-5.601	0.000	-10.712	0.000	-4.677	0.000	-12.419	0.000
Panel t -statistic [b]	-3.491	0.001	-0.615	0.330	-4.534	0.000	-3.461	0.001	-1.649	0.102	-7.220	0.000
Group ρ -statistic	-8.586	0.000	-43.841	0.000	-13.614	0.000	-60.942	0.000	-6.687	0.000	-28.646	0.000
Group t -statistic [a]	-7.073	0.000	-20.582	0.000	-8.111	0.000	-20.765	0.000	-5.064	0.000	-14.211	0.000
Group t -statistic [b]	-4.349	0.000	-1.404	0.149	-5.381	0.000	-3.162	0.003	-1.579	0.115	-8.835	0.000
Deterministic intercept and trend:												
Panel v -statistic	0.527	0.347	1.191	0.196	1.008	0.240	2.262	0.031	1.611	0.109	7.511	0.000
Panel ρ -statistic	-5.823	0.000	-30.359	0.000	-8.838	0.000	-41.491	0.000	-7.153	0.000	-26.520	0.000
Panel t -statistic [a]	-7.140	0.000	-17.665	0.000	-8.457	0.000	-18.288	0.000	-5.071	0.000	-13.806	0.000
Panel t -statistic [b]	-4.873	0.000	-1.999	0.054	-6.654	0.000	-3.615	0.001	0.405	0.368	-7.658	0.000
Group ρ -statistic	-7.594	0.000	-43.474	0.000	-10.619	0.000	-56.449	0.000	-6.258	0.000	-24.222	0.000
Group t -statistic [a]	-7.768	0.000	-24.060	0.000	-8.993	0.000	-25.424	0.000	-4.888	0.000	-14.474	0.000
Group t -statistic [b]	-3.642	0.001	-1.577	0.115	-5.161	0.000	-3.022	0.004	0.274	0.384	-8.917	0.000

Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is Engle-Granger based. Pedroni (1999) shows that the panel-ADF and group-ADF statistics have better small sample properties than the other statistics, and hence they are more reliable. Region 1 includes Shijiazhuang, Hohhot, Taiyuan, Hefei, Jinan and Zhengzhou.

[a] Non-parametric and [b] parametric.

Appendix Table 9-17. Panel cointegration tests for Region 2

Test	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
Statistics	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Stat.	Prob.	Stat.	Stat.	Prob.	Stat.	Stat.	Prob.	Stat.
No deterministic trend:												
Panel ν-statistic	2.360	0.025	1.315	0.168	1.959	0.059	0.348	0.376	3.959	0.000	11.675	0.000
Panel ρ-statistic	-5.755	0.000	-44.359	0.000	-9.215	0.000	-62.009	0.000	-8.020	0.000	-12.521	0.000
Panel t-statistic [a]	-5.397	0.000	-17.704	0.000	-5.911	0.000	-17.552	0.000	-5.378	0.000	-5.914	0.000
Panel t-statistic [b]	-5.289	0.000	0.070	0.398	-5.375	0.000	-1.178	0.199	-4.499	0.000	-5.255	0.000
Group ρ-statistic	-7.428	0.000	-38.117	0.000	-11.105	0.000	-50.422	0.000	-5.837	0.000	-10.505	0.000
Group t-statistic [a]	-6.475	0.000	-16.430	0.000	-7.092	0.000	-16.653	0.000	-4.816	0.000	-6.225	0.000
Group t-statistic [b]	-5.727	0.000	0.502	0.352	-6.248	0.000	-1.484	0.133	-4.084	0.000	-6.077	0.000
Deterministic intercept and trend:												
Panel ν-statistic	1.141	0.208	1.027	0.236	0.003	0.399	-0.490	0.354	1.764	0.084	7.702	0.000
Panel ρ-statistic	-4.564	0.000	-59.578	0.000	-6.323	0.000	-86.919	0.000	-6.171	0.000	-10.069	0.000
Panel t-statistic [a]	-5.272	0.000	-24.959	0.000	-5.589	0.000	-26.408	0.000	-5.662	0.000	-5.909	0.000
Panel t-statistic [b]	-5.393	0.000	-0.647	0.324	-5.215	0.000	-1.218	0.190	-4.720	0.000	-5.171	0.000
Group ρ-statistic	-5.355	0.000	-40.813	0.000	-7.656	0.000	-52.519	0.000	-4.474	0.000	-7.863	0.000
Group t-statistic [a]	-5.229	0.000	-18.928	0.000	-6.002	0.000	-19.938	0.000	-4.891	0.000	-5.697	0.000
Group t-statistic [b]	-4.715	0.000	-0.058	0.398	-5.414	0.000	-1.078	0.223	-3.998	0.000	-5.601	0.000

Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is Engle-Granger based. Pedroni (1999) shows that the panel-ADF and group-ADF statistics have better small sample properties than the other statistics, and hence they are more reliable. Region 2 includes Beijing, Tianjin and Shanghai.

[a] Non-parametric and [b] parametric.

Appendix Table 9-18. Panel cointegration tests for Region 3

Test Statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	-0.457	0.359	0.600	0.333	-0.811	0.287	0.945	0.255	-0.202	0.391	6.815	0.000
Panel ρ -statistic	-16.488	0.000	-41.345	0.000	-33.026	0.000	-56.906	0.000	-7.135	0.000	-20.562	0.000
Panel t -statistic [a]	-14.992	0.000	-16.754	0.000	-16.588	0.000	-16.161	0.000	-5.089	0.000	-9.046	0.000
Panel t -statistic [b]	-14.753	0.000	0.501	0.352	-16.601	0.000	-0.803	0.289	-3.283	0.002	-4.599	0.000
Group ρ -statistic	-17.586	0.000	-46.049	0.000	-18.584	0.000	-49.965	0.000	-4.983	0.000	-16.065	0.000
Group t -statistic [a]	-15.423	0.000	-23.596	0.000	-11.402	0.000	-18.855	0.000	-3.600	0.001	-7.793	0.000
Group t -statistic [b]	-14.475	0.000	0.543	0.344	-10.927	0.000	-0.697	0.313	-2.101	0.044	-4.556	0.000
Deterministic intercept and trend:												
Panel v -statistic	-1.518	0.126	0.297	0.382	-2.201	0.035	0.679	0.317	-0.797	0.290	4.370	0.000
Panel ρ -statistic	-16.281	0.000	-50.789	0.000	-26.755	0.000	-84.717	0.000	-7.645	0.000	-18.436	0.000
Panel t -statistic [a]	-16.191	0.000	-23.129	0.000	-19.019	0.000	-26.667	0.000	-5.842	0.000	-9.914	0.000
Panel t -statistic [b]	-15.630	0.000	-1.279	0.176	-18.860	0.000	-2.038	0.050	-6.067	0.000	-5.406	0.000
Group ρ -statistic	-15.324	0.000	-55.731	0.000	-14.176	0.000	-76.163	0.000	-3.787	0.000	-13.411	0.000
Group t -statistic [a]	-14.660	0.000	-30.864	0.000	-11.468	0.000	-32.532	0.000	-2.828	0.007	-8.069	0.000
Group t -statistic [b]	-11.875	0.000	-1.002	0.241	-10.736	0.000	-1.950	0.060	-2.846	0.007	-4.896	0.000

Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is Engle-Granger based. Pedroni (1999) shows that the panel-ADF and group-ADF statistics have better small sample properties than the other statistics, and hence they are more reliable. Region 3 includes Shenyang, Changchun and Harbin.
[a] Non-parametric and [b] parametric.

Appendix Table 9-19. Panel cointegration tests for Region 4

Test Statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	0.799	0.290	1.990	0.055	2.537	0.016	1.209	0.192	3.985	0.000	9.478	0.000
Panel ρ -statistic	-1.744	0.087	-19.470	0.000	-3.576	0.001	-38.403	0.000	-6.135	0.000	-19.513	0.000
Panel t -statistic [a]	-2.169	0.038	-12.789	0.000	-2.462	0.019	-14.656	0.000	-4.400	0.000	-8.628	0.000
Panel t -statistic [b]	0.390	0.370	-0.369	0.373	-0.641	0.325	-0.433	0.363	-2.376	0.024	-6.192	0.000
Group ρ -statistic	-5.066	0.000	-41.124	0.000	-6.010	0.000	-60.573	0.000	-5.294	0.000	-17.880	0.000
Group t -statistic [a]	-4.877	0.000	-18.645	0.000	-3.984	0.000	-18.894	0.000	-5.134	0.000	-9.616	0.000
Group t -statistic [b]	-2.001	0.054	-2.254	0.032	-0.458	0.359	-1.404	0.149	-1.799	0.079	-7.025	0.000
Deterministic intercept and trend:												
Panel v -statistic	0.587	0.336	1.592	0.112	1.782	0.082	0.026	0.399	1.739	0.088	5.773	0.000
Panel ρ -statistic	-2.505	0.017	-24.083	0.000	-4.885	0.000	-36.963	0.000	-4.689	0.000	-15.321	0.000
Panel t -statistic [a]	-2.849	0.007	-16.567	0.000	-3.793	0.000	-19.007	0.000	-4.132	0.000	-8.654	0.000
Panel t -statistic [b]	0.216	0.390	-0.217	0.390	-1.360	0.158	0.089	0.397	-1.743	0.087	-5.826	0.000
Group ρ -statistic	-5.226	0.000	-36.293	0.000	-6.732	0.000	-50.257	0.000	-3.554	0.001	-13.232	0.000
Group t -statistic [a]	-5.337	0.000	-18.513	0.000	-5.438	0.000	-20.952	0.000	-4.377	0.000	-8.930	0.000
Group t -statistic [b]	-2.082	0.046	-2.035	0.050	-2.572	0.015	-1.733	0.089	-1.029	0.235	-5.974	0.000

Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is Engle-Granger based. Pedroni (1999) shows that the panel-ADF and group-ADF statistics have better small sample properties than the other statistics, and hence they are more reliable. Region 4 includes Nanjing, Hangzhou, Nanchang and Wuhan.

[a] Non-parametric and [b] parametric.

Appendix Table 9-20. Panel cointegration tests for Region 5

Test Statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	-0.221	0.389	5.762	0.000	2.316	0.027	2.444	0.020	4.862	0.000	14.336	0.000
Panel ρ -statistic	-4.809	0.000	-35.637	0.000	-10.998	0.000	-59.609	0.000	-9.078	0.000	-27.199	0.000
Panel t -statistic [a]	-4.709	0.000	-19.297	0.000	-6.744	0.000	-21.366	0.000	-6.422	0.000	-11.736	0.000
Panel t -statistic [b]	-2.163	0.038	-0.190	0.392	-4.769	0.000	-1.407	0.148	-5.614	0.000	-9.361	0.000
Group ρ -statistic	-4.453	0.000	-51.768	0.000	-9.764	0.000	-80.854	0.000	-6.846	0.000	-23.641	0.000
Group t -statistic [a]	-4.939	0.000	-24.526	0.000	-6.950	0.000	-25.875	0.000	-6.812	0.000	-12.146	0.000
Group t -statistic [b]	-3.116	0.003	-1.595	0.112	-5.234	0.000	-1.895	0.066	-5.949	0.000	-10.190	0.000
Deterministic intercept and trend:												
Panel v -statistic	-1.235	0.186	5.241	0.000	0.293	0.382	0.346	0.376	2.290	0.029	9.333	0.000
Panel ρ -statistic	-10.772	0.000	-42.572	0.000	-16.945	0.000	-60.318	0.000	-7.894	0.000	-24.135	0.000
Panel t -statistic [a]	-9.655	0.000	-24.596	0.000	-11.006	0.000	-26.395	0.000	-6.736	0.000	-12.833	0.000
Panel t -statistic [b]	-2.892	0.006	-0.063	0.398	-4.918	0.000	-1.033	0.234	-5.284	0.000	-9.852	0.000
Group ρ -statistic	-6.719	0.000	-48.603	0.000	-10.495	0.000	-63.357	0.000	-7.227	0.000	-20.114	0.000
Group t -statistic [a]	-7.297	0.000	-25.446	0.000	-8.267	0.000	-27.801	0.000	-7.783	0.000	-12.272	0.000
Group t -statistic [b]	-3.737	0.000	-1.363	0.158	-4.917	0.000	-2.201	0.035	-5.809	0.000	-10.196	0.000

Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is Engle-Granger based. Pedroni (1999) shows that the panel-ADF and group-ADF statistics have better small sample properties than the other statistics, and hence they are more reliable. Region 5 includes Fuzhou, Changsha, Guangzhou, Nanning and Haikou.
[a] Non-parametric and [b] parametric.

Appendix Table 9-21. Panel cointegration tests for Region 6

Test Statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	1.638	0.104	9.793	0.000	5.247	0.000	2.545	0.016	1.496	0.130	13.313	0.000
Panel ρ -statistic	-6.536	0.000	-58.409	0.000	-8.991	0.000	-71.483	0.000	-5.277	0.000	-27.416	0.000
Panel t -statistic [a]	-5.571	0.000	-22.598	0.000	-5.961	0.000	-20.364	0.000	-4.446	0.000	-11.663	0.000
Panel t -statistic [b]	0.165	0.394	-1.036	0.233	-0.741	0.303	-0.983	0.246	-2.208	0.035	-6.910	0.000
Group ρ -statistic	-5.139	0.000	-54.933	0.000	-5.973	0.000	-69.385	0.000	-3.615	0.001	-25.591	0.000
Group t -statistic [a]	-4.711	0.000	-24.456	0.000	-4.835	0.000	-21.832	0.000	-3.671	0.001	-13.089	0.000
Group t -statistic [b]	-0.321	0.379	-0.792	0.292	-1.162	0.203	-1.281	0.176	-1.886	0.067	-8.516	0.000
Deterministic intercept and trend:												
Panel v -statistic	1.038	0.233	9.169	0.000	3.747	0.000	1.855	0.071	0.207	0.391	8.693	0.000
Panel ρ -statistic	-7.949	0.000	-61.175	0.000	-10.937	0.000	-100.182	0.000	-6.385	0.000	-25.646	0.000
Panel t -statistic [a]	-7.410	0.000	-26.679	0.000	-8.139	0.000	-30.911	0.000	-5.706	0.000	-13.334	0.000
Panel t -statistic [b]	-4.773	0.000	-0.475	0.356	0.164	0.394	-1.991	0.055	-3.722	0.000	-7.134	0.000
Group ρ -statistic	-5.654	0.000	-52.741	0.000	-6.251	0.000	-76.732	0.000	-4.896	0.000	-22.218	0.000
Group t -statistic [a]	-5.591	0.000	-25.783	0.000	-5.207	0.000	-28.453	0.000	-5.147	0.000	-13.610	0.000
Group t -statistic [b]	-3.112	0.003	0.005	0.399	0.179	0.393	-1.429	0.144	-3.971	0.000	-8.158	0.000

Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is Engle-Granger based. Pedroni (1999) shows that the panel-ADF and group-ADF statistics have better small sample properties than the other statistics, and hence they are more reliable. Region 6 includes Chongqing, Chengdu, Xi'an, Lanzhou, Guiyang and Kunming.

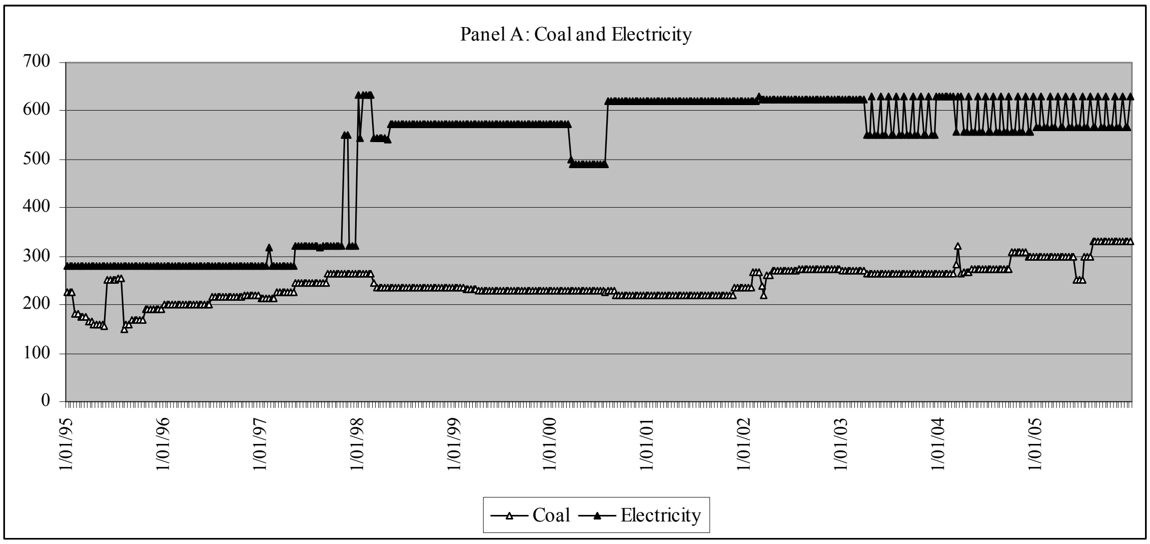
[a] Non-parametric and [b] parametric.

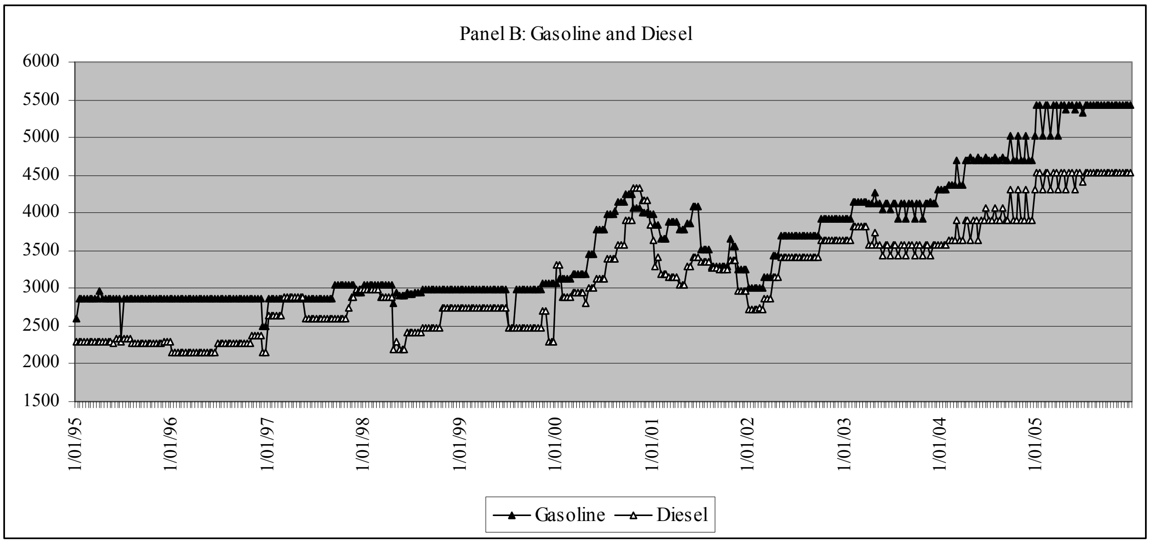
Appendix Table 9-22. Panel cointegration tests for Region 7

Test Statistics	Electricity, coal, diesel and gasoline				Electricity and coal				Diesel and gasoline			
	1997-1999		2000-2005		1997-1999		2000-2005		1997-1999		2000-2005	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
No deterministic trend:												
Panel v -statistic	2.698	0.011	2.889	0.006	4.374	0.000	0.927	0.260	1.298	0.172	8.249	0.000
Panel ρ -statistic	-2.723	0.010	-36.983	0.000	-5.633	0.000	-61.369	0.000	-11.583	0.000	-11.363	0.000
Panel t -statistic [a]	-2.611	0.013	-17.357	0.000	-3.670	0.001	-18.003	0.000	-6.596	0.000	-5.888	0.000
Panel t -statistic [b]	0.122	0.396	-0.956	0.253	-1.229	0.188	-1.298	0.172	-6.618	0.000	-4.704	0.000
Group ρ -statistic	-3.779	0.000	-54.535	0.000	-6.862	0.000	-70.080	0.000	-8.847	0.000	-10.444	0.000
Group t -statistic [a]	-3.594	0.001	-23.976	0.000	-4.674	0.000	-22.286	0.000	-6.538	0.000	-6.529	0.000
Group t -statistic [b]	0.314	0.380	-0.923	0.261	-1.544	0.121	-0.950	0.254	-7.070	0.000	-5.353	0.000
Deterministic intercept and trend:												
Panel v -statistic	1.487	0.132	2.103	0.044	1.933	0.062	-0.319	0.379	0.276	0.384	5.711	0.000
Panel ρ -statistic	-2.435	0.021	-44.425	0.000	-3.875	0.000	-68.121	0.000	-13.025	0.000	-11.838	0.000
Panel t -statistic [a]	-2.702	0.010	-22.555	0.000	-3.152	0.003	-24.309	0.000	-9.139	0.000	-7.154	0.000
Panel t -statistic [b]	0.794	0.291	-0.359	0.374	-0.090	0.397	-1.125	0.212	-7.207	0.000	-5.639	0.000
Group ρ -statistic	-2.938	0.005	-54.814	0.000	-4.772	0.000	-76.741	0.000	-10.334	0.000	-9.648	0.000
Group t -statistic [a]	-3.282	0.002	-27.972	0.000	-3.847	0.000	-29.049	0.000	-8.640	0.000	-7.031	0.000
Group t -statistic [b]	0.998	0.242	-0.608	0.332	-0.388	0.370	-1.089	0.221	-8.252	0.000	-5.498	0.000

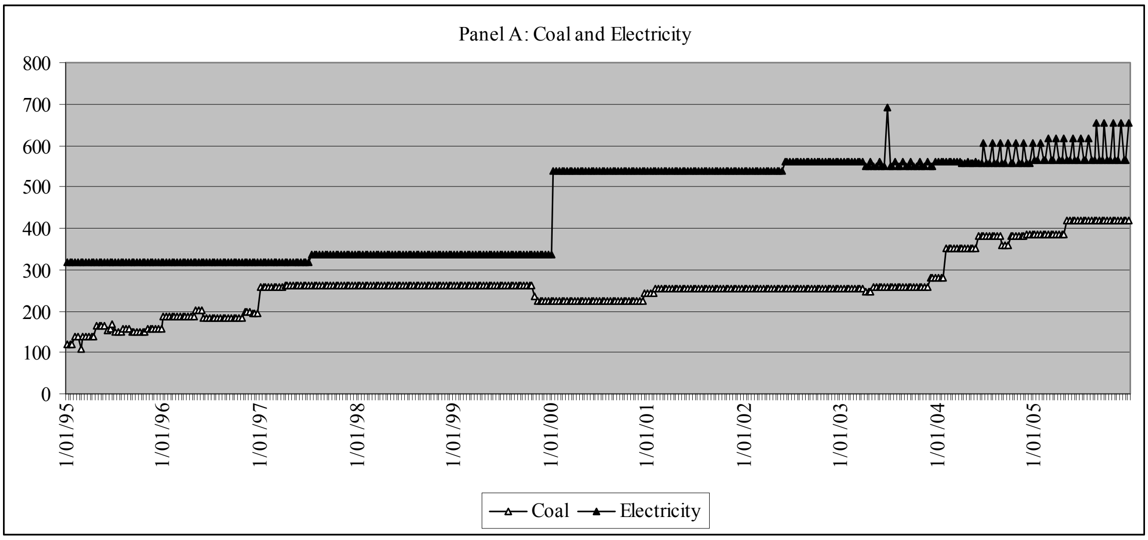
Note: Statistics are asymptotically distributed as normal. The statistic ratio test is right-sided, while the others are left-sided. Null hypothesis is no cointegration among the fuel prices and no exogenous variables are included in test equation. Pedroni panel cointegration test is Engle-Granger based. Pedroni (1999) shows that the panel-ADF and group-ADF statistics have better small sample properties than the other statistics, and hence they are more reliable. Region 7 includes Lhasa (data unavailable), Xining, Yinchuan and Urumqi.
[a] Non-parametric and [b] parametric.

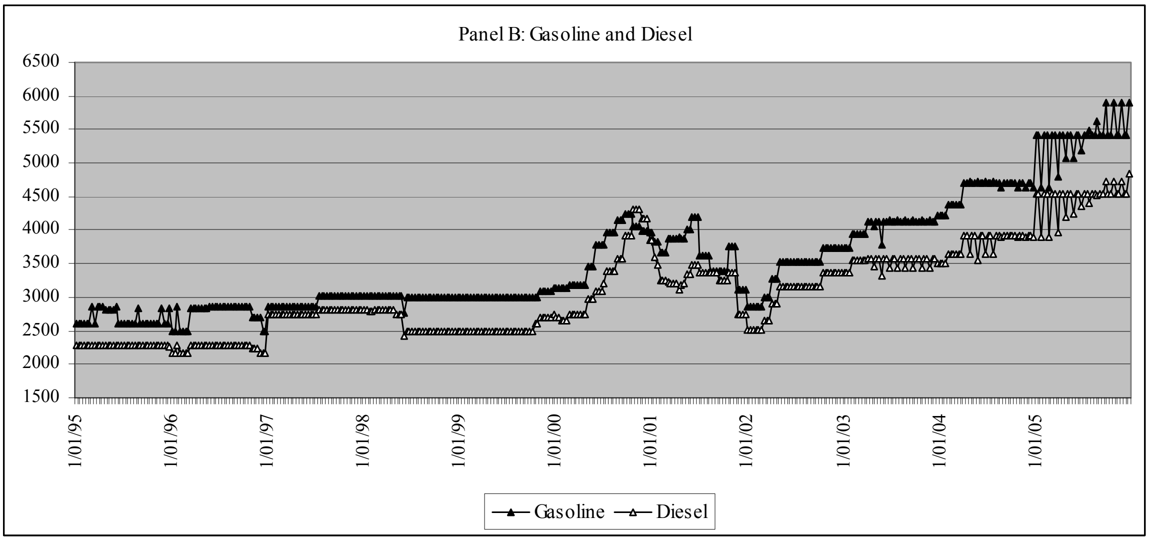
Appendix Figures



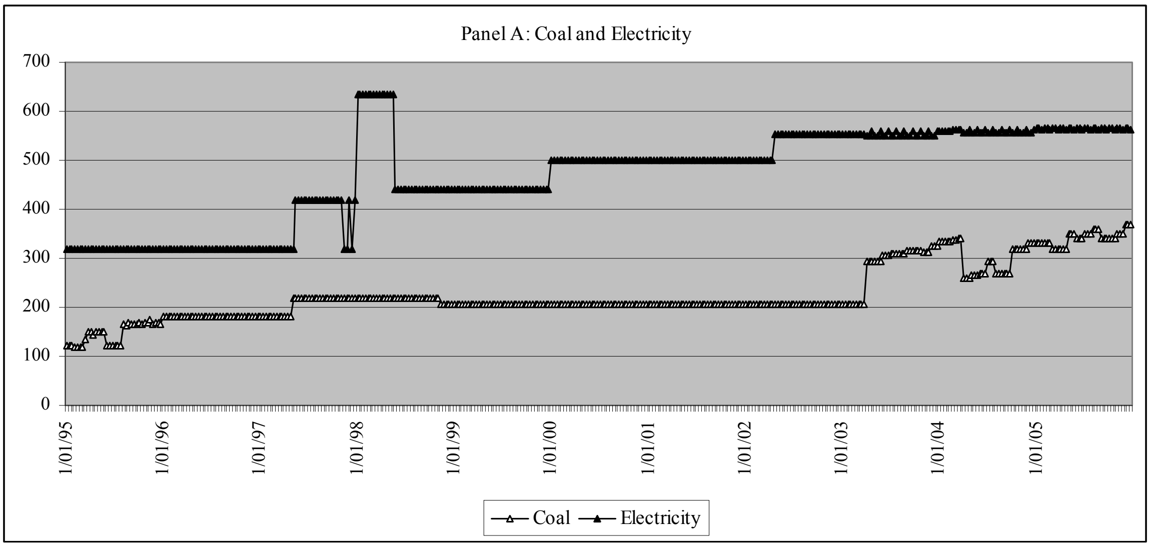


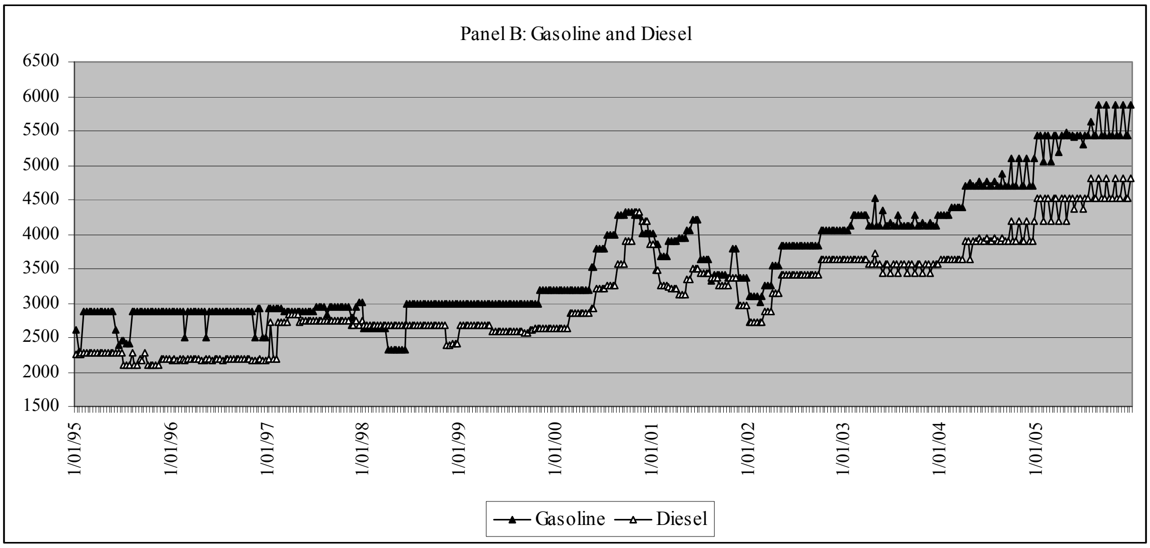
Appendix Figure 9-1. Price trends of pairs of fuels in Harbin



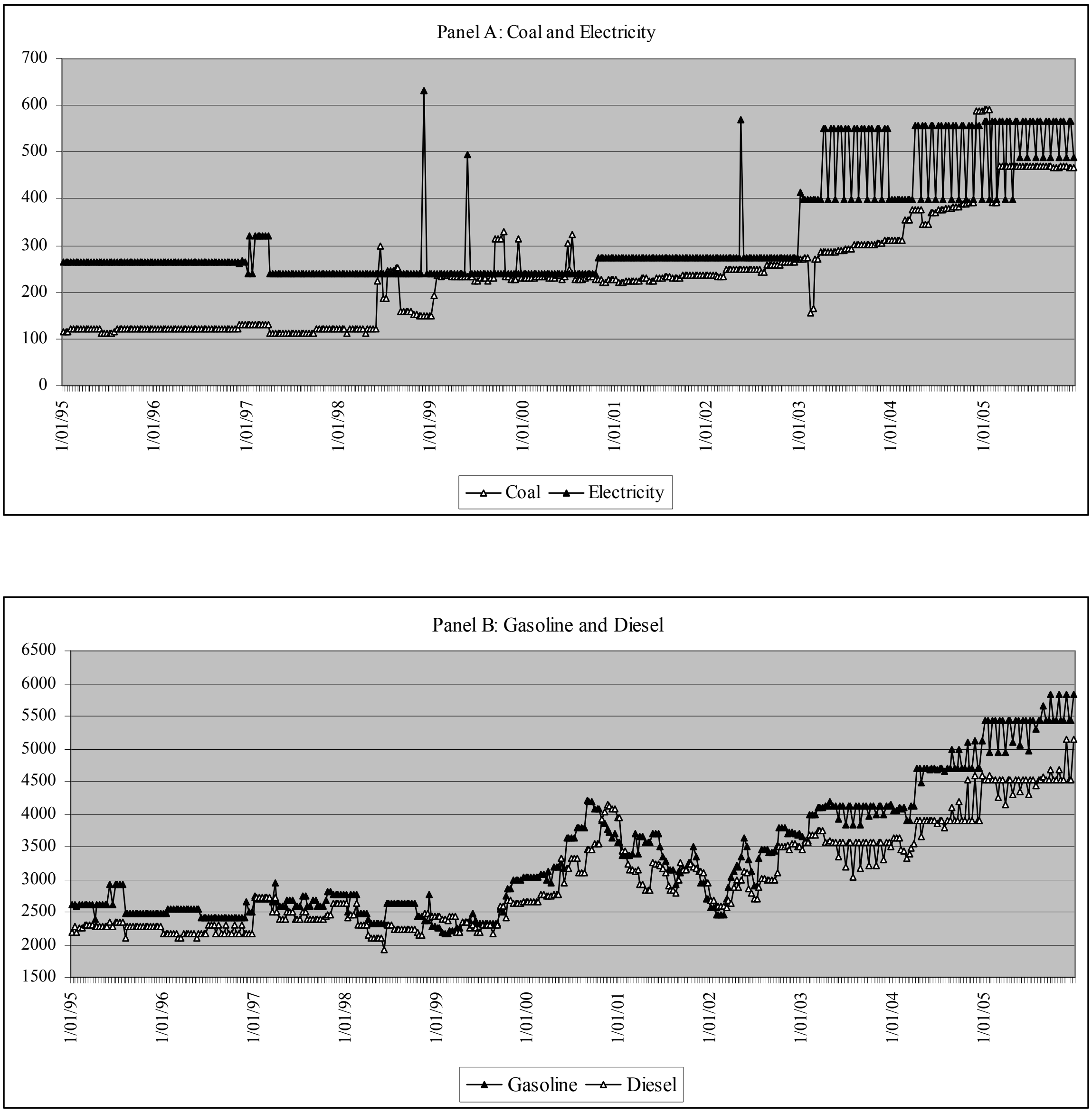


Appendix Figure 9-2. Price trends of pairs of fuels in Beijing

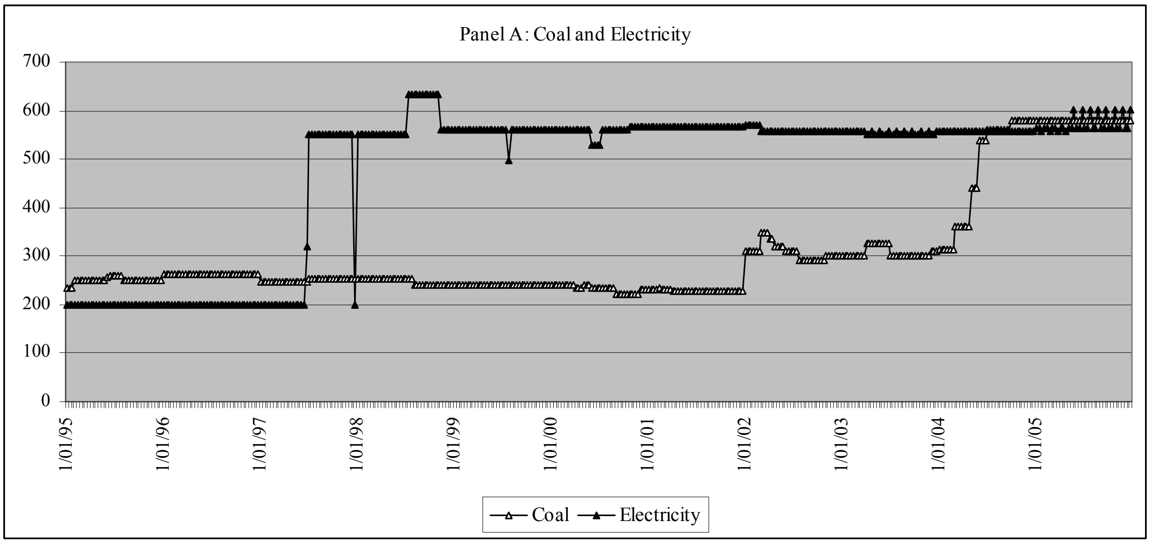


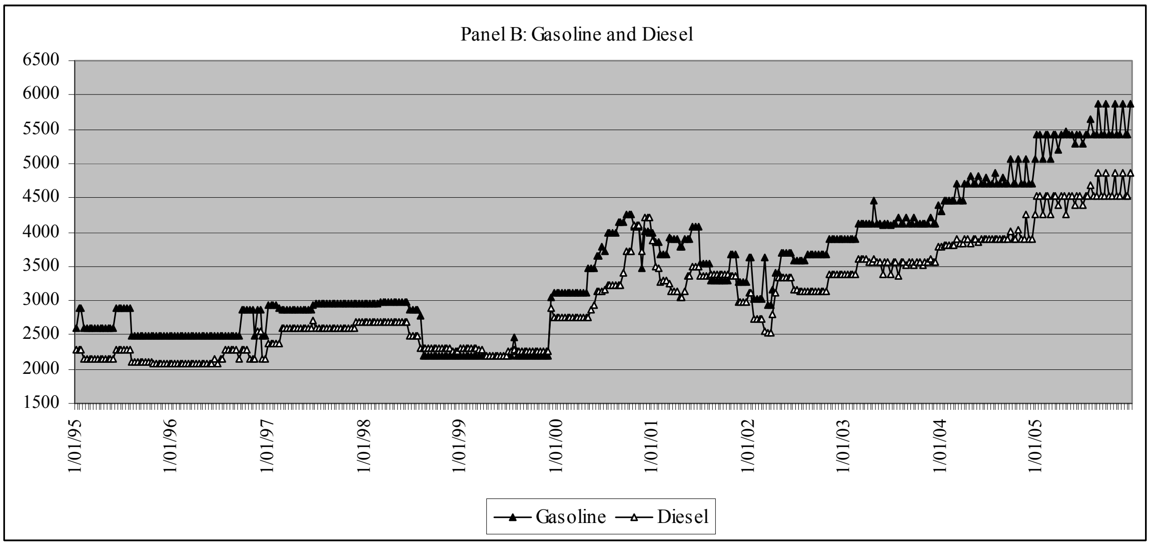


Appendix Figure 9-3. Price trends of pairs of fuels in Shijiazhuang

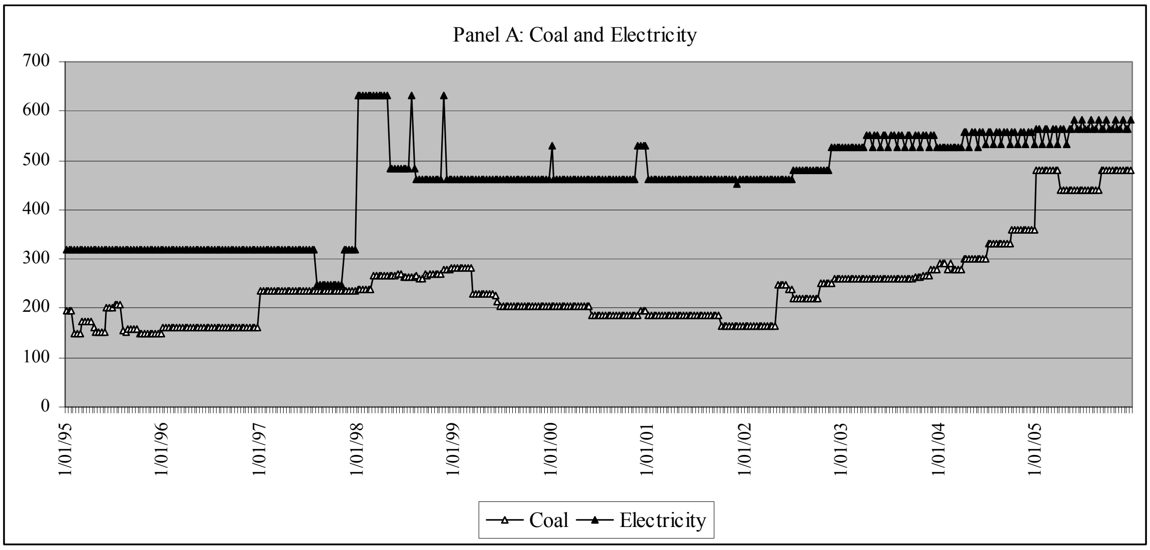


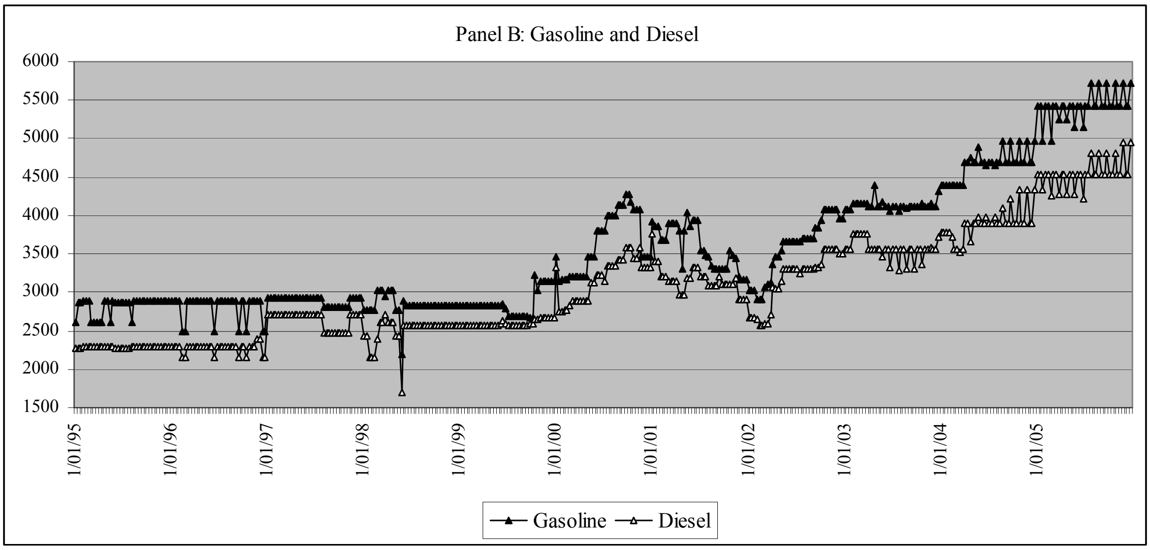
Appendix Figure 9-4. Price trends of pairs of fuels in Taiyuan



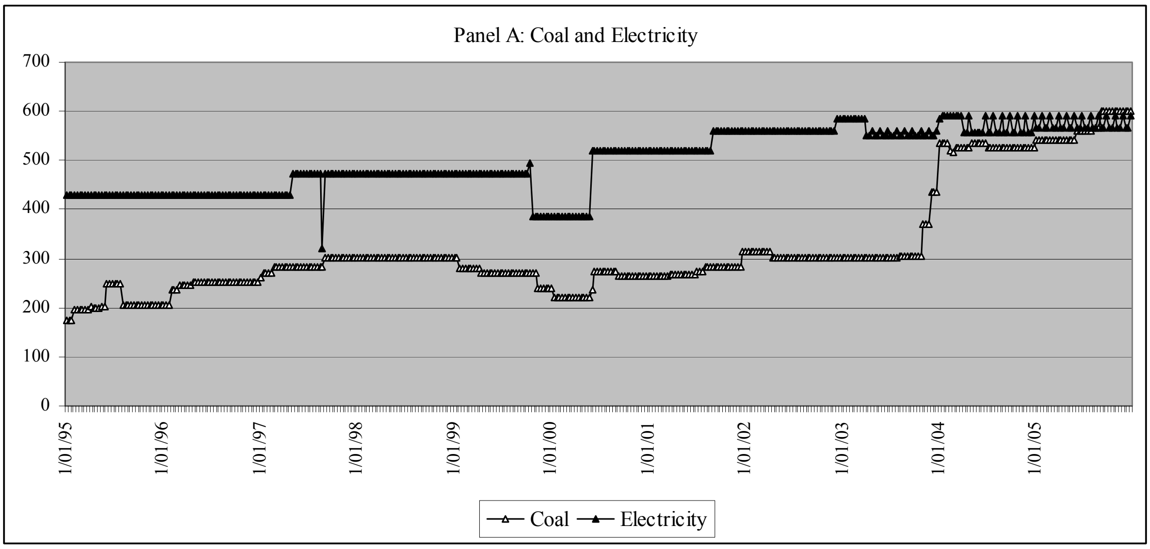


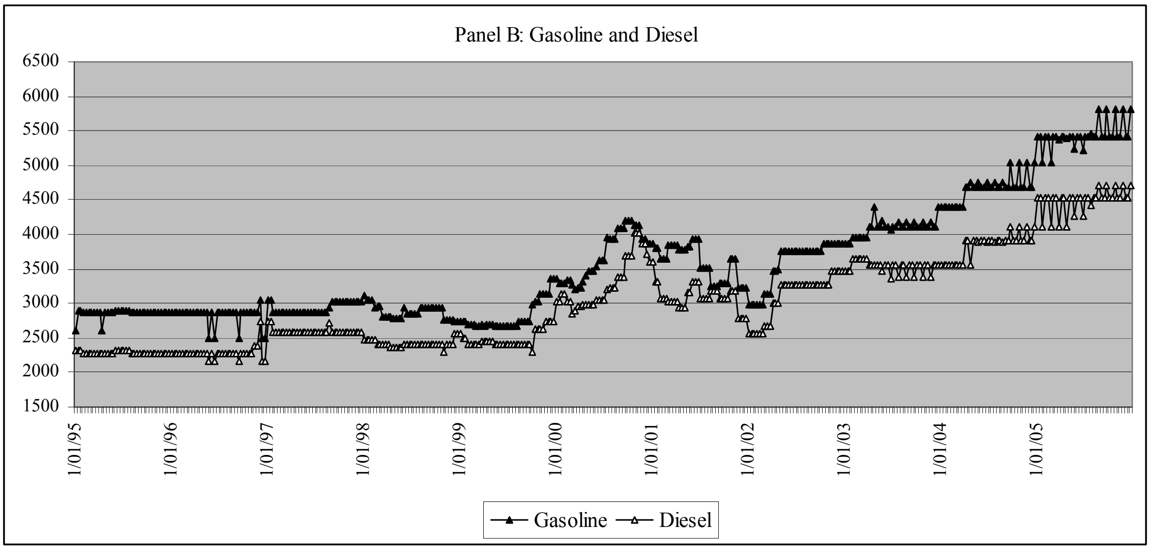
Appendix Figure 9-5. Price trends of pairs of fuels in Jinan



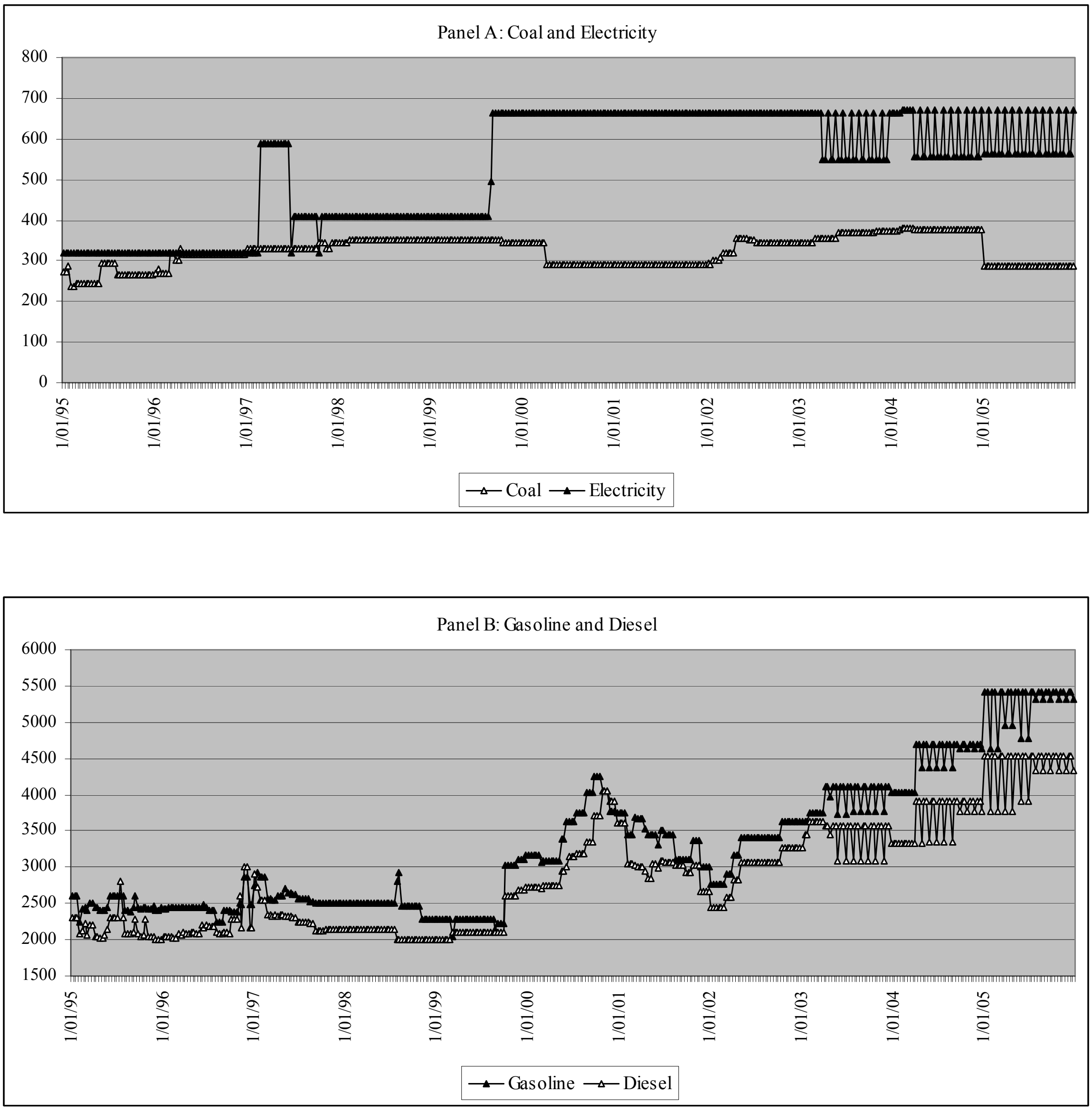


Appendix Figure 9-6. Price trends of pairs of fuels in Zhengzhou

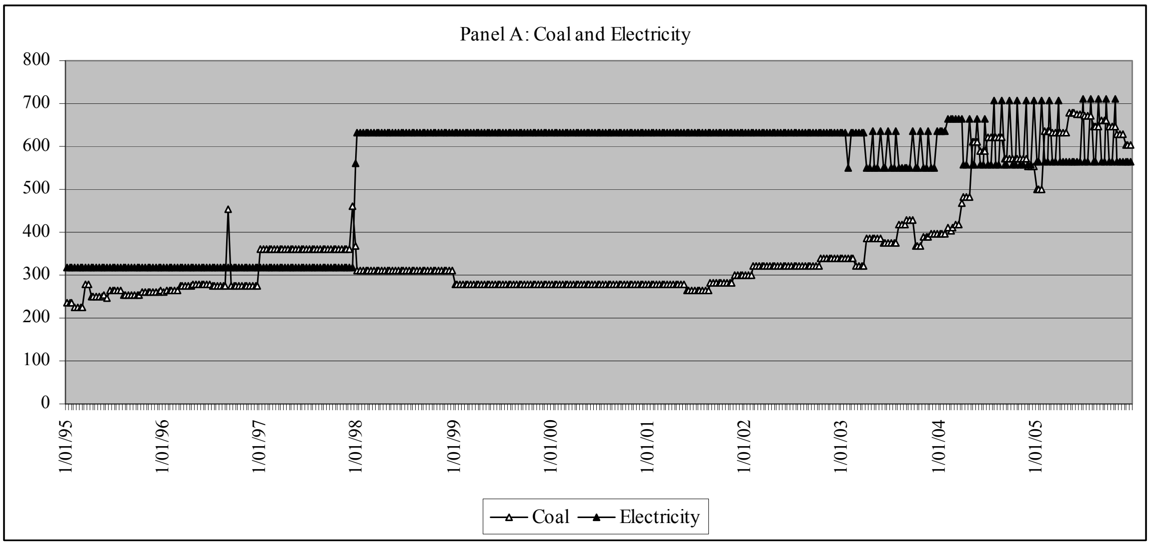


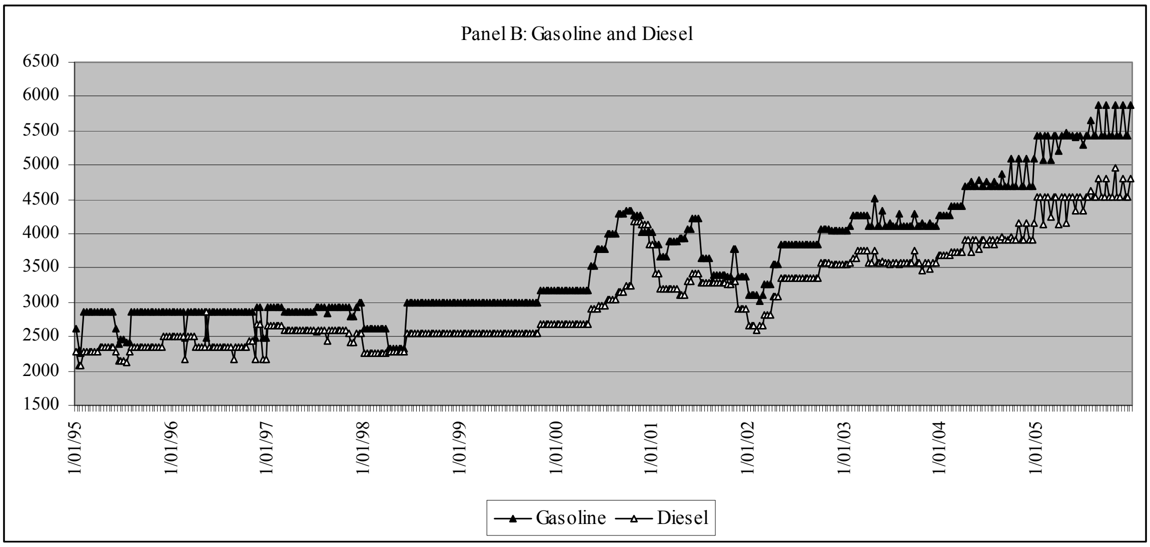


Appendix Figure 9-7. Price trends of pairs of fuels in Wuhan

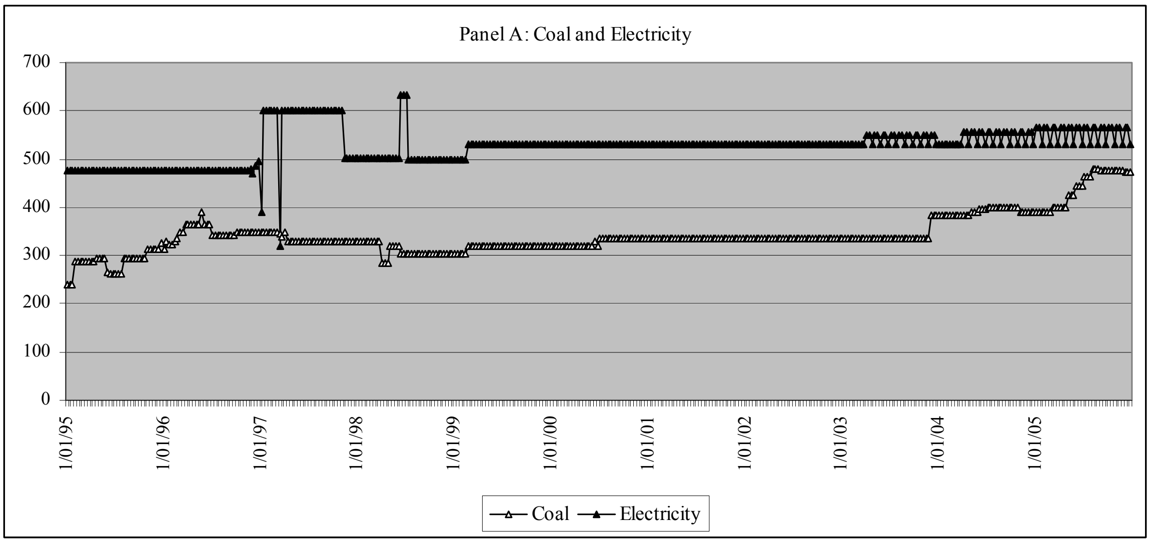


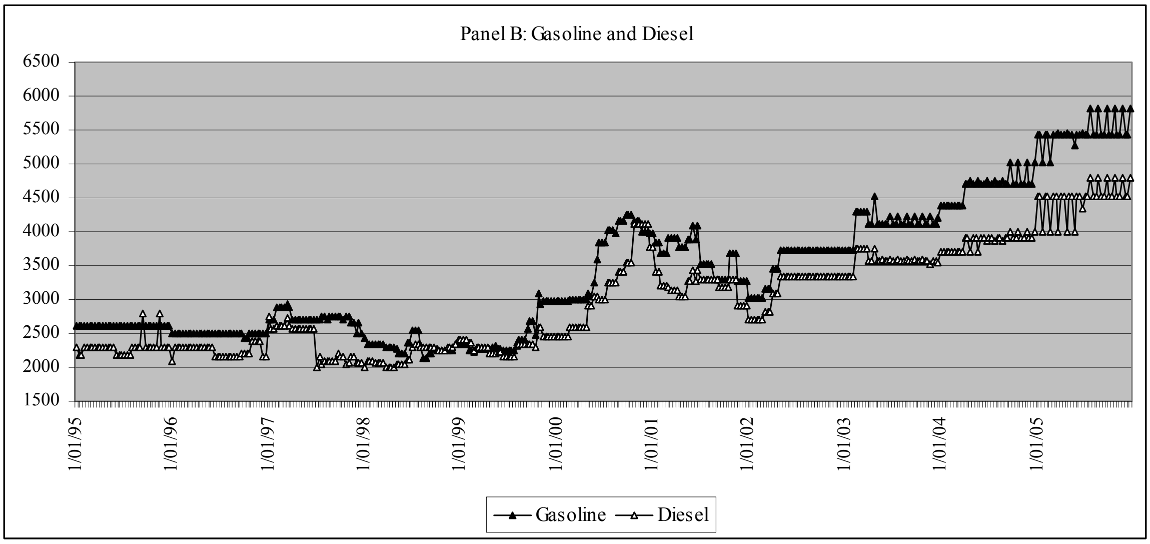
Appendix Figure 9-8. Price trends of pairs of fuels in Nanjing



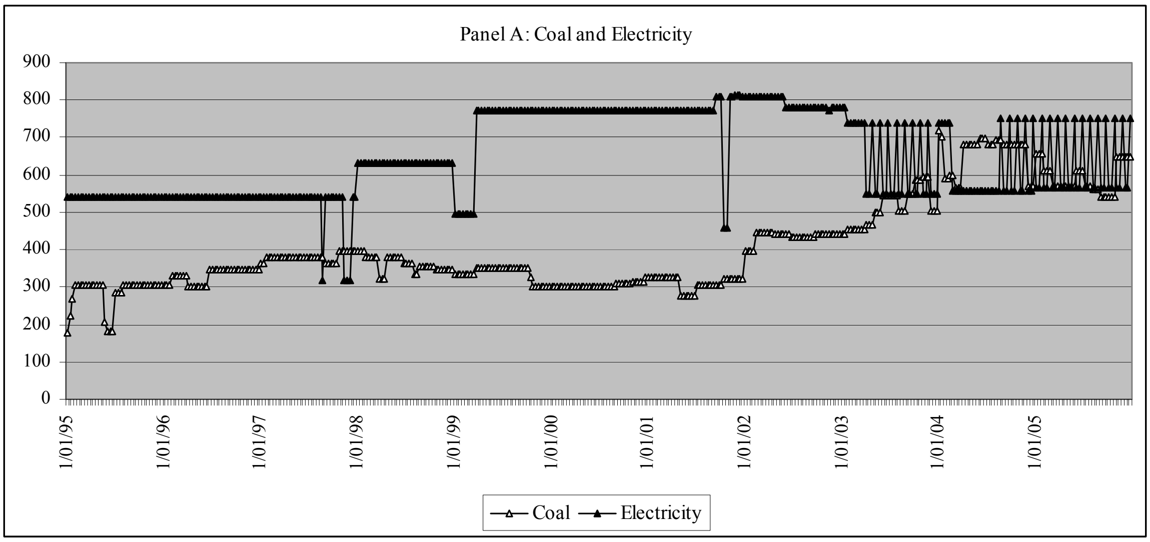


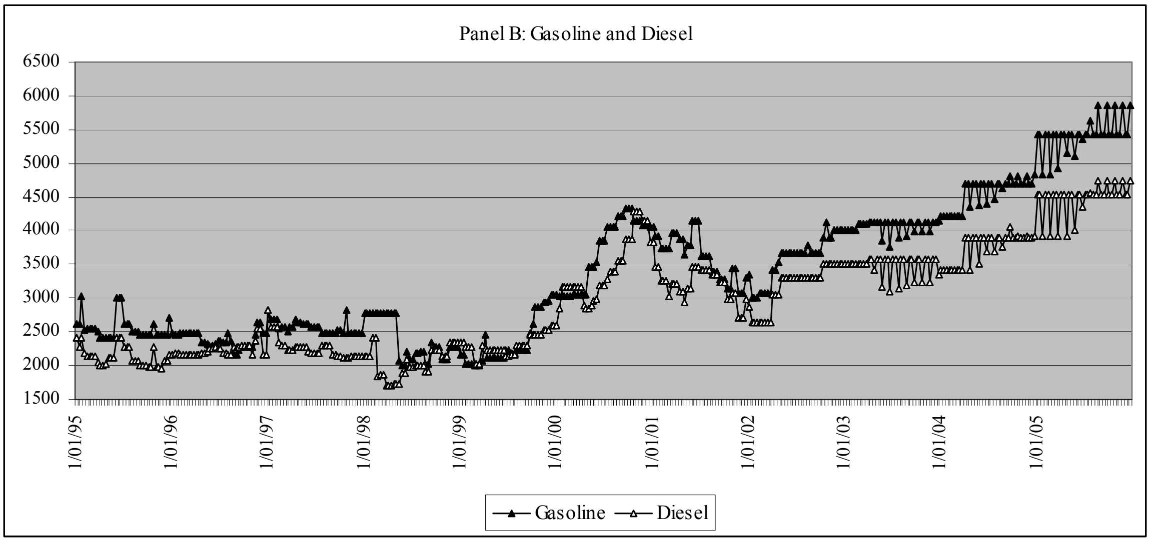
Appendix Figure 9-9. Price trends of pairs of fuels in Shanghai



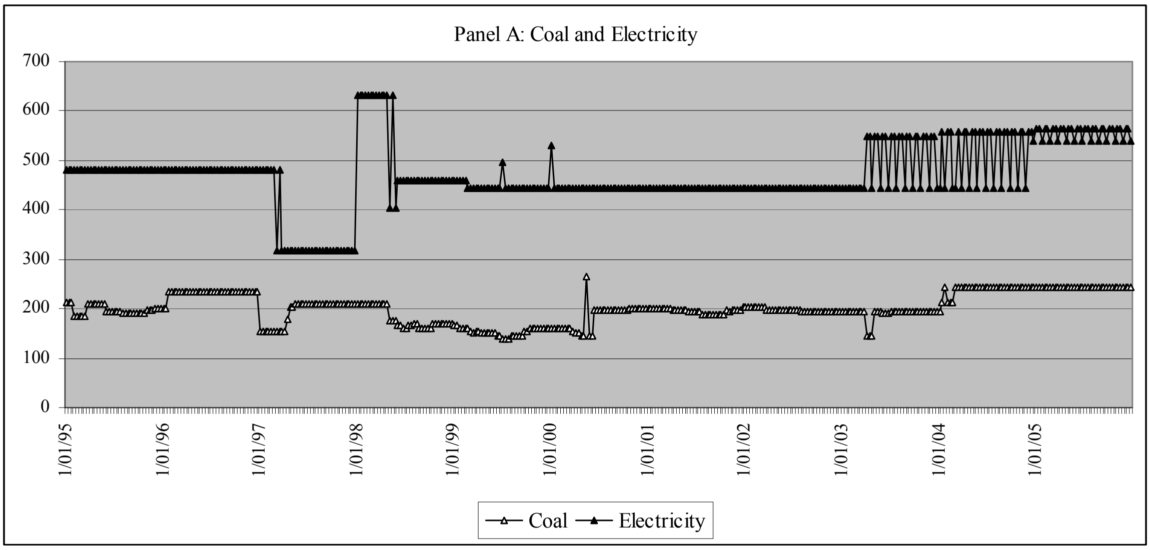


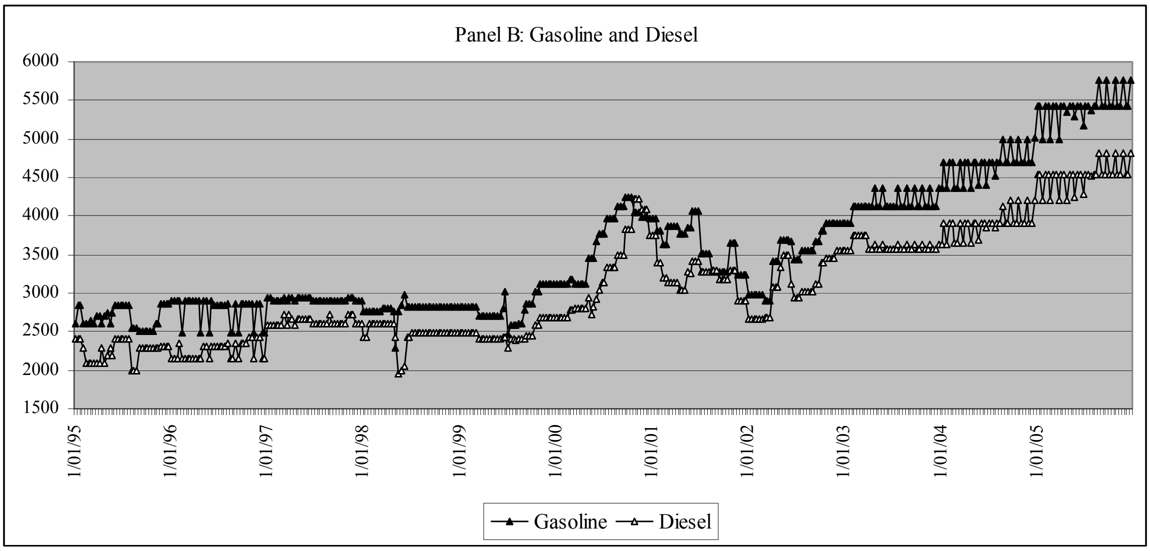
Appendix Figure 9-10. Price trends of pairs of fuels in Hangzhou



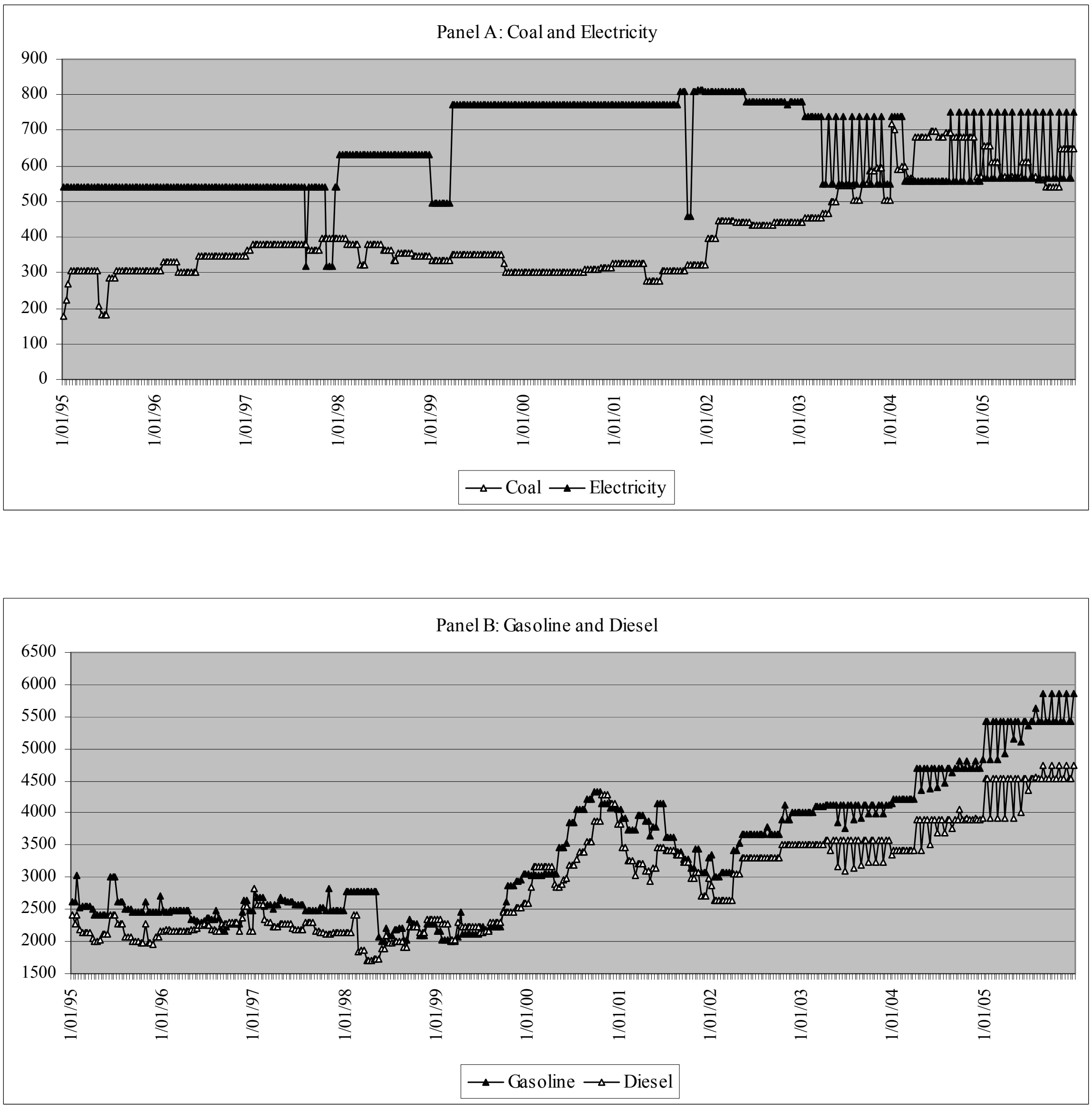


Appendix Figure 9-11. Price trends of pairs of fuels in Guangzhou

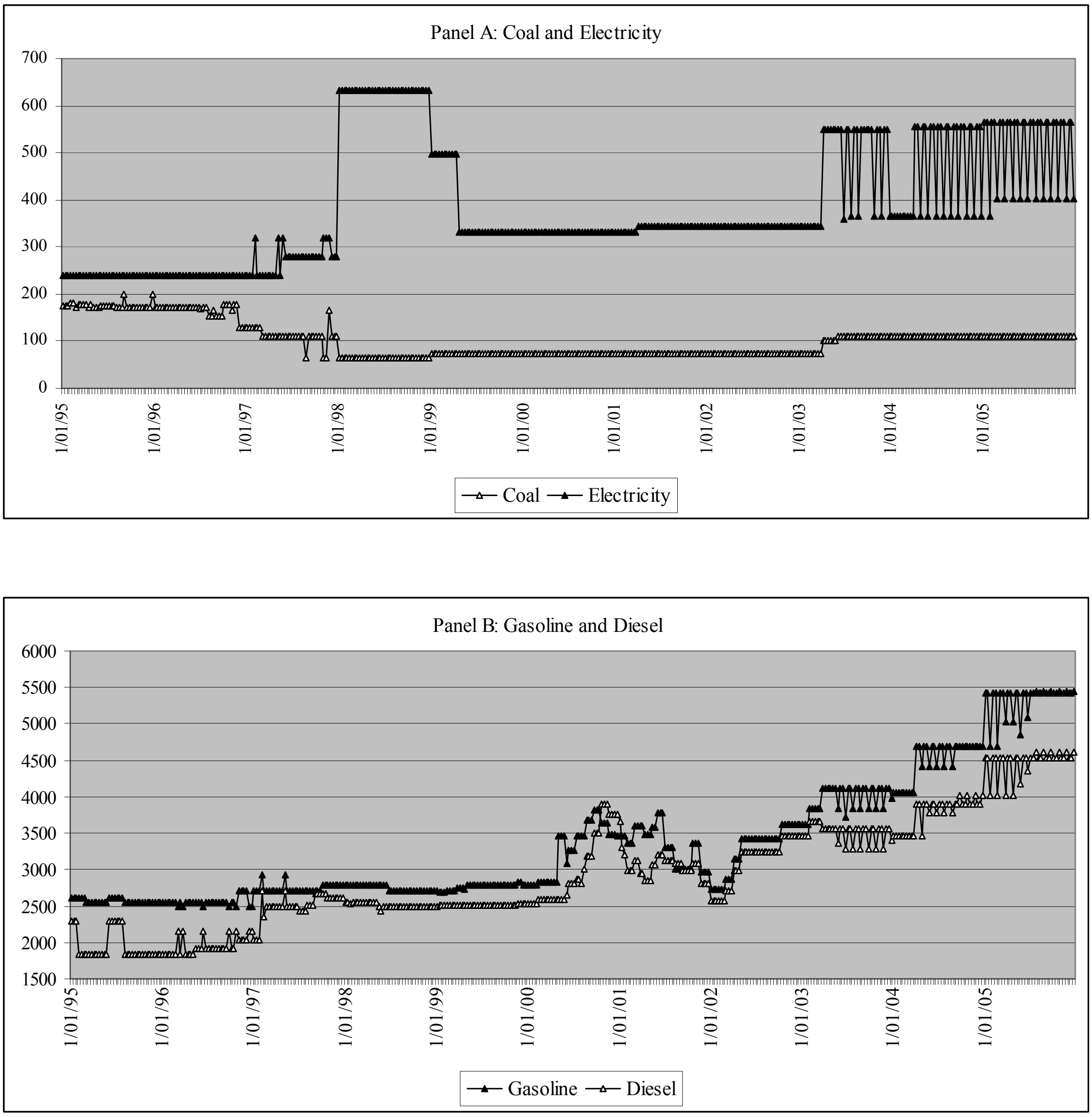




Appendix Figure 9-12. Price trends of pairs of fuels in Xi'an



Appendix Figure 9-13. Price trends of pairs of fuels in Chengdu



Appendix Figure 9-14. Price trends of pairs of fuels in Urumqi