The Reformed Plan System: China's Electric Power Industry

A Thesis submitted to Brunel University of West London for the Degree

of Doctor of Philosophy

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September 2010

DEPARTMENT OF ECONOMICS AND FINANCE

SCHOOL OF SOCIAL AND SCIENCES

BRUNEL UNIVERSITY

Abstract

Since the reform in the 1980s, the Chinese electric power industry has experienced rapid expansion in both capacity and outputs, which is surprising since the industry is still under a plan control. The shortage of supply is a common problem in a plan economy according to the conventional wisdom. But China provides very different experience that challenges the wisdom. Why? This thesis attempts to understand why the plan-controlled industry can achieve such rapid growth over a short period of time. The study pursues its investigation through exploring three issues: the price and cost structures, the pricing setting and the capacity expansion with reference to OECD experience. By comparing power prices of China with the West, we find that China has successfully kept its household prices as lower as its industrial prices, while the OECD economies are reverse, a lower power price for the industry but higher for the household users. The finding shows that the plan increases consumers' welfare more than the market does. With further investigation to the cost structure of Chinese power plants with reference to the UK experience, we find that the Chinese power producers have lower variable costs than the Western plants, but similar overheads costs. To further explain such finding, we studied a sample of 100 coal-fired power plants from 2003 to 2005 for their pricing behaviour. We find that the firms adopt a high cost strategy to bargain with the state for higher plan prices, because of the one-firm-with-one-plan-price policy. This causes a soft price constraint on costs, which inevitably protects high cost firms, driving up the total costs of the firm, and providing a lower incentive to the firm to improve their cost efficiency. The firms are planned by the state for their outputs. Will the state plan affect the capacity of power supply in favour? The study argues yes, because (1) entry is free and capacity investment is under firm's autonomy, (2) the firms are very responsive to capacity utilization and demand in choosing their capacity investment, and (3) the firms seek more profits through seeking more plan outputs that are linked with capacity. Therefore, the firms do not compete in prices but the capacity of power generation. These explain why the reformed plan system works in stimulating capacity growth.

Acknowledgement

On the occasion of submitting my thesis, first of all I would like to express my sincere gratitude and appreciation towards Prof. Guy Liu, my supervisor, for his valuable and effective guidance and supervision throughout the four-year's study. His strict and responsible research attitude and passion at work will exert profound and positive influence on my future professional career.

Also, I am in debt to my father with gratitude here for his persistent supporting both in morale and finance. His timely encouragement always comes up to me, which cheered me up for moving ahead and ahead.

To the end, my thanks shall also be given to Brunel University for its excellent environment and facilities, especially the people who give me valuable help directly and generously when I asked for. I completed my PhD research here with experience that becomes a very important part in my beautiful memory forever.

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Chapter 1. Introduction

1.1. Context and background

After 30 year's economic reform and development, China has become the third largest economy in the world by 2009, and its nominal GDP reached $4,909 billion, just behind the US ($14,256 billion) and Japan ($5,067 billion), according to the World Bank. To fuel its production and to improve its living standards, demand for electricity power has been soaring in China. By 2007, China became the second largest power producer and consumer in this world, just behind the US (3.8 million GWh), where over 2.8 million GWh of electricity was supplied and consumed within China, i.e. equal to around 16% of the total electric power produced in the world (Electricity Information 2009). In 2009, China produced around 3.6 million GWh of electric power[1].

In contrast, 30 years ago China suffered economic shortages, and its industries experienced limited capacity, high costs, and low efficiency. In order to increase industrial supply and power as well, the market-oriented reform has been introduced to the Chinese industry and the power sector in 1985. One reform was to break down the old Central Electricity Generating Board into five central state-owned power producers and two grids companies in the early 2000s. And in 2002, the on-grid price was also introduced. Under such restructuring, the Chinese electric power sector was significantly improved its strength and made impressive advancement.

However, the market mechanism has not been fully implemented in the Chinese electric power sector yet. The transmission, distribution and retail functions are still

[1] http://www.ce.cn/macro/more/201002/01/t20100201_20901602.shtml, visited on 22nd September, 2010.

bundled together. The price competition has not yet come into place. Both the price and output of the power generation are still under the control of the state. These have resulted in cost inefficiency in power plants. Against this, many studies advocated market liberalisation like what the developed countries have adopted.

The UK is the pioneer of restructuring its electricity industry in the West. Unlike China trying to raise the electricity price in the name of reducing the cost burden of generators, the UK reform mainly aims to lower down electricity price, and to provide a secure and reliable power supply. In the past, the state-owned Central Electricity Generating Board (CEGB) was separated into four companies, while in the UK the Area Electricity Boards were replaced by twelve regional electricity retailers. The Electricity Pool was also established as the trading mechanism in the UK. In order to promote competition, the decentralised New Electricity Trading Arrangements (NETA) was introduced to replace the Electricity Pool in 2001. In 2005, NETA was extended into the British Electricity Trading and Transmission Arrangements (BETTA). By the end of 2008, the market concentration in the UK becomes more separated, where there were 32 major power producers in the UK (United Kingdom Energy Statistics 2009). During the same period, the UK government also promotes the development of CCGT plants to reduce the electricity prices further.

However, in order to prevent the potential market manipulation, the UK doesn't completely give up the right to intervene the electricity market, where the price cap regulation remains as the proper resorts of the regulation at proper time (Bower, 2002). Jamison (2007) even thinks that the price-cap regulation adopted by the UK is superior to the rate-of-return regulation adopted by the US, in terms of improving generation efficiency. However, we should admit that the price-cap regulation may not be suitable in all situations. For example, the retail price cap ruined the power retailers in California in 2001. It implies that even the market-oriented mechanism still exposes to the various risks, and a good electric power supply system should be a mixture of competition with proper regulation.

Obviously, without thorough understanding and proper supervision, the ill-designed market mechanism will weaken the power industry, and so the whole economy of a nation. Therefore, it's necessary for policy makers in China to take more balanced approach to the Chinese power industry from the view of both regulatory plan and market advantages, before taking the future action of reform. That's one major argument that this thesis intends to develop.

Again, there is one thing we would like to highlight. There could be a most preferential at a time, but there would not be a perfect one forever. Even the best practice still needs continuous improvement in response to changes in the world.

1.2. Motivation

The main topic of this thesis is the "the reform of the Chinese electric power industry and its impact on China's industry and economy". This thesis attempts to investigate the price and cost structures, the pricing behaviour, the drivers for the power consumption, and the capacity expansion of Chinese electric power supply, with reference to international experience, in particular, OECD and UK's ones. There are several motivations for us to undertake this study, and they are as follows:

1) This study is derived from a consultancy study about the cross-border acquisition for China Power International Development (CPID) Ltd., i.e. one of the big five power producers in China. From this project, we collected the valuable data from both sides of the acquirer and the target, and also the background information of the two different countries. The project recommends that it's a best strategy for the power producer to takeover high-value assets and businesses from the target firm to improve its own competitiveness. The consultancy project gives us a direct perception about power plants in China and the UK. In

order to obtain a comprehensive understanding about power generation industries in both countries at a wider and deeper view, we extended the project to this academic study. It's also a good opportunity for us to make an interim review about background, achievements, the current development and the missions of the electric power reform in China's electricity reform.

2) China has been carrying out its economic reform in its electric power supply sector. However, the market mechanism may fail, such as the California electricity crisis (in 2000), the market manipulation observed in the UK power market (OFGEM, 1996). However, most previous studies, which advocated market-oriented reform for the Chinese power industries, hardly referred those failures to the policy makers in China. However, it doesn't mean that such failure lessons learnt by the West will not repeat in China in the future when the Chinese power market is liberalised. Thus, with the reference to the international cases, it's a need for us to extend the existing studies to develop an argument on how market liberalisation should be cautiously regarded, in particular, for China's future reform in the sector.

3) When confronted to the global financial crisis, it's a critic time for us to review China's power supply policy and renew our knowledge about the current situation. With the up-to-date data collected at the aggregated level and the plant level, it enables us to access current policy and practice, which can help identify improvements in terms of policy of the future reform and industry restructuring.

1.3. Methodology and main data employed for research

1.3.1. Methodology

In this thesis, we employed various research techniques in pursuing our analysis, including statistical description, economic modelling, econometric test and even case studies. The appropriate robustness tests are performed to check the validity of the models that we built up. For econometrics, we employed both panel data estimation models and time-series estimation respectively, to process data accordingly.

In more detail, for cost and price structure study in Chapter 3, our analysis is mainly on the basis of comparatively statistical description using sample data collected from various sources.

We also performed case studies to examine the price and the cost structure between the UK and Chinese leading power plants in 2004 and 2005. The largest coal-fired power plants in the UK, Drax, is selected and compared to the five coal-fired power plants and also the group of Chinese International Power Development Corporation (CIPD), which is one of the big-five power producers in China. All the selected samples are the most advanced coal-fired power producers in the two countries.

The calculations, tables and charts in this chapter are prepared with Microsoft Excel, Microsoft Visio and STATA for our analysis of cost and price structure.

Further, we developed a pricing theory to characterise the pricing behaviour of power generation companies. For this study, a panel-data regression on three-year's data is performed to test the pricing model with a group of variables, including the regional output, the average cost of the rival plants, the regional market share of the plant, the cost of the plant, the cost of capital, the inflation of the fuel price, and the load factor. Besides, following adjustments are made to the models: 1) A series of dummy data are included to test the individual effects upon the explained variable, i.e. the state of the profit of the plant, the location of the plant and the affiliation of the plant. 2) In order to present a better linear relationship, all of those variables are converted into the logarithm except the dummies. 3) In order to avoid the loop causality in the model, the regional market share, the costs of the plant and the load factor have a lagged one year. 4) The extreme observations have been removed from the dataset before running the regression. The Hausman test is performed to the price model to decide whether to choose the fixed-effect model or the random-effect model. The robustness tests are performed to check the validity of the models, where the cost of capital is separated into interest rate and the depreciation rate.

To address the link between electricity consumption, economic growth and capacity of power production, Chapter 5 uses a two-stage estimation to investigate the questions raised. We employ time series estimation techniques to verify appropriateness of data for time-series model estimation. This includes Augmented Dickey-Fuller test (unit-root tests) and Granger Causality test etc. The demand and supply functions are specified and the multivariate models are built to examine the direct and indirect factors such as power demand affecting the capacity expansion in China. This research is conducted in a comparative way with a reference to the other six OECD countries.

The unit root test, causality test and the time-series regression are performed by using STATA.

1.3.2. Data sources

Data used in supporting this study can be classified into three categories that are shown as follows:

1) The aggregate-level data:

a) The data of the real GDP, the power production, the power consumption, the installed capacity of the UK and China from 1991 to 2007 are collected from the Department of Trade and Industry of the UK (DTI) and the National Bureau of Statistics of China respectively;

b) The industrial and household electricity prices of the OECD countries from 2000 to 2004 are extracted from the Electricity Information 2006, and the Chinese prices come from the Electricity Market and Electricity Prices Monitoring Report 2005;

c) The coal prices in the UK and China from 2000 to 2005 come from Electricity Information 2007, and China Electric Power Yearbook 2005 and Energy Data 2005 respectively.

d) The exchange rates are collected from DataStream;

e) And, the Purchase Power Parity conversion rates are collected from the International Monetary Fund, "World Economic Outlook Database April 2007";

f) The financial data, including the sales figure, the costs and some quantitative variables are obtained from the Chinese power plants database prepared by the National Bureau of Statistics of China in 2008;

g) The data of the output and the capacity of the power plants in the five southern provinces are collected from the China Electric Power Yearbook 2005 and 2006, issued by China Electric Power Press.

2) The plant-level data:

a) The financial and operational data of Drax and Uskmouth in 2004 and 2005 are collected from the relevant annual reports, DTI's website and also the FAME. The financial and operational data of Chinese International Power Development Corporation from 2003 to 2005 are collected from their annual reports in relevant years;

b) The data of the energy efficiency of the UK and Chinese power plants from 1962 to 2006 are extracted from the Department of Trade and Industry of the UK, and the "Review of Assumptions as to Changes in the Electricity Generation Sector in Nautilus Institute's Clean Coal Scenarios Report" (Xie, 2002) and "Energy Data 2005" (Wang, 2005) respectively;

c) The indicative cost breakdown for the UK household and industrial & commercial customers in 2002 are prepared on the basis of the information from "Gas and Electricity Price Projections" (OXERA, 2004), "The New Electricity Trading

Arrangements in England and Wales" (National Audit Office, 2003) and Electricity Information 2006;

d) The data of the average labour cost of the Chinese power producers from 1999 to 2005 are collected from National Bureau of Statistics of China;

3) Other market-level data:

a) The average on-grid electricity prices in China from 2000 to 2004, collected from "Electricity Market and Electricity Price Supervision Report 2005" (CPNN, 2005);
b) The provincial on-grid electricity price of the Chinese coal-fired power plants in 2005, collected from "Risk Analysis of the Coal-fired Power Generation in China 2006";
c) The financial and operational data of the UK power plants, i.e. Drax(2004) and Uskmouth (2006), obtained from their annual reports and FAME;
d) The regional GDP per capita across China in 2005, obtained from the National Bureau of Statistics of China in 2008.

4) Time-series data

In Chapter 5, we use a set of time-series data of seven countries for the modelling. The seven countries are China, France, Germany, Italy, Japan, the UK and the US. The sources of those data are listed as below:

a) The data of the Real GDP and the percentage of the industrial value-added out of the real GDP are obtained from the UN data and the World Bank databases respectively. And the industrial value-added is calculated by multiplying the two variables;
b) The real electricity price index of the OECD countries and China are obtained from Electricity Information 2009 and National Bureau of Statistics of China respectively. The electricity price of the OECD countries and China refers to the industrial and household price, and the price of Chinese electric power industry respectively. As they are all the end prices, it's justified to regard

those prices as comparable;

c) The data of the power consumption, the power exports, and the net capacity of all those seven countries up to 2006 are collected from the Electricity Information 2009. In terms of the latest data in 2007 and 2008, the Chinese, French and the UK figures come from the National Bureau of Statistics of China, the International Energy Agency, and the Department of Energy and Climate Change of the UK respectively.

5) Other industrial supplementary data supporting the study. They are:

a) The percentage of GDP by type of expenditure, from the UN data;
b) The gross industrial output of light and heavy industries in China from 1999 to 2007, obtained from the National Statistics Bureau of China;
c) The production of the iron and steel (metric tonnes) and the cement and glass (metric tonnes) from 1990 to 2006, from the World Steel Association and the US Geological Survey Minerals Information Team;
d) The power consumption by types of usage from 1990 to 2006, from the National Statistics Bureau of China and the Electricity Information 2009;
e) The energy consumption and the value-added by the types of the industries in China from 1997 to 2007, from the National Statistics Bureau of China;
f) The energy efficiency of the energy-intensive products in China, from the National Statistics Bureau of China and "China End Use Energy Consumption and Energy Efficiency in 2007" (Wang, 2009);
g) The market share of the main power producers in the European Union and China in 2008, obtained from Eurostat and the websites of the Chinese big-five generators;
h) The capacity of the large power plants in the UK and China from 2005 to 2008, obtained from the Department of Energy and Climate Change of the UK and the National Bureau of Statistics of China, the China Economic Information Network.

1.4. Analytical structure and arguments

The whole thesis is structured into six parts. The first chapter is the introduction. The second chapter is the general background of the Chinese power sector. This introduction is followed by further exploring details of the industry in terms of its cost and price structure in Chapter 3. Having discussed the price structure, we then move to address an issue about pricing electricity for sales by coal-fired plants. We find that at the firm level, the firm's price and output is fixed by the plan that is expected to meet demand with supply at an aggregate level. So, the production shall be responsive to demand for power. The state breaks down demand and allocates these to individual firms to produce according to the plan. For any demand in excess of the plan, the state takes discretion to allocate them to individual firms either at a pre-planned price or at adjusted plan price. The point is that, given plan price, the aggregate supply is expected to respond to a change in aggregate demand. Then this expectation leads us to ask what determines demand and so production at an aggregate level. Chapter 5 investigates this question: the demand for power consumption — its determinants and its impact on change in supply in the long-run. Chapter 6 will conclude the findings and arguments of the thesis. For arguments discussed in each chapter, they are highlighted as follows:

Chapter 2

This chapter draws a general background about the Chinese electric power industry. It covers a wide scope of different fields, including the history of the reform, the power supply, the network, electricity price control and the link to the coal price. It attempts to provide the facts for the readers to gain a fundamental knowledge and the direct perception of the topics studied in the main chapters of this thesis.

Chapter 3

Many previous studies focused on the background and history of the power sector reform in China (Li and Dorian, 1995; Andrews-Speed and Dow, 2000; Hafsi and Tian, 2005; Xu and Chen 2006; Yao, Bin and Wu 2006; Hang and Tu, 2007; Yang, 2008). The common view among them is that China should introduce competition, privatisation and liberalisation into the power sector for three main reasons:

1) The plan mechanism encourages the high generating cost, and then leads to the low thermal efficiency and the heavy environment damages (Wu and Li, 1995; Li and Dorian, 1995; Andrews-Speed and Dow, 2000);
2) The power sector cannot be separated from the economic transformation of the whole country. The plan mechanism makes the low profit for the power producers, and could be difficult to attract sufficient investment into the power generation sector to fuel the economic development (Yeoh and Rajaraman, 2004; Hafsi and Tian, 2005; Wang, 2007);
3) The market-oriented mechanism will encourage the technology advance and the optimisation of the resources allocation. (Lin 2004; Andrews-Speed and Dow, 2000; Wang 2006).

Those papers promote a market-oriented mechanism to the Chinese policy makers without stating the potential risk of market failure and its possible impacts on the industry that this has been experienced by the US and noticed by the Western researchers.

California electricity crisis in 2001 is a good lesson about the failure of the liberalised power market. (Woo, 2001; Hogan, 2002; Woo, Lloyd and Tishler, 2003). The similar risks also exist in other Western countries, such as the UK. Some studies investigated the UK electricity market reform and argued that the dominant generators could obtain the extra gain from the market by market manipulation (Wolak and Patrick, 1996; OFGEM, 1999; Sweeting, 2007). As to the UK retail electricity market, the previous studies also found that the liberalisation of the power sector didn't protect the benefit of the small consumers as expected (Thomas, 2003; Graham, 2006; OXERA, 2004). Moreover, through a series studies, Pollitt and his colleagues delivered the point that the liberalisation and privatisation of the power sector without proper regulation would harm the total outputs of other industries. Those studies do reveal another side of the market-oriented mechanism in the power sector, but unfortunately they do not refer to the Chinese case.

Therefore, can a market approach really work in China? Can it stimulate the improvement of supply, productive efficiency and impacts on growth as asserted? In order to address this question, this chapter makes a comprehensive and direct comparison of the price and cost structure of the power supply between China and Western countries. With public information at the aggregated level and also the private information at the plant level, it clearly shows the benefits and risks of both the plan system and the market system of the power sectors. And the case study is also a feature of this study, which provides the first-hand, intuitive and valuable information about the UK coal-fired power plants, with the cross reference to the leading Chinese plants. The whole chapter attempts to deliver a good understanding of the industry with an international reference to the study.

This chapter generally consists of two parts. The first part is the general comparison of the electricity price schemes between the China and the OECD member countries, with a further discussion about the different power sector structures under the plan mechanism and market-oriented system. The second part is largely a specific firm-level case study, which carries out an item-to-item comparison of the cost structure between the top Chinese and UK plants. In short, this chapter studies the cost and price structure of the Chinese power supply with the reference to cases in the West.

In the first part, it begins with an overall description and comparison about the different tariff schemes in the OECD member countries and China over the period from 2000 to 2004. It clearly shows that the industrial users in China do not pay power less than those in the OECD member countries, but those households do. In another aspect, it also clear reflect the truth that the current plan price mechanism employed in China does protect the benefits of the household users, while the OECD member countries secure their industrial competiveness at the expenses of those small end-users who are blocked from the whole market.

Then the discussion is narrowed to the comparison of the liberalisation of the electricity industries between the UK and China, so as to find out the reason behind such phenomenon. In terms of the power sector structure in China and the UK, it clearly shows that both two countries have adopted the vertical unbundling process during the reform of their power sectors. However, the full vertical separation and the competition mechanism have been implemented in the UK power system, while the governmental control over the production volume and the electricity prices still remain in the Chinese power system.

With the illustration of the aggregated historical data of electricity prices from both the UK and China, it shows that neither market competition in the UK nor the plan system in China could effectively restrain the upward trends of the tariffs caused by the inflated fuel price. However, due to the segment of the wholesale and retail market in the UK power sector, small users take more pains from the higher price inflation than the large users. By contrast, in China, the growth of the tariffs for small consumers has been effectively limited to the same level of the industrial price growth. Besides, the dominant generators could also exert considerable market power in the UK power market (Sweeting 2007). Based on this observation, we argue that the plan, rather than liberalisation, could better protect the small consumers such as householders for their benefits, especially low income group of consumers.

In the second part of the chapter, two top thermal plants from both China and the UK are selected for a case study. The unit cost of the two in 2004 and 2005 are decomposed and then an item-to-item comparison is performed. Together with other supporting evidence of the aggregated data, several interesting findings appear. First, the UK and the Chinese coal-fired generators in similar size have almost equal thermal efficiency. Second, the UK generator has greater earning ability than the Chinese generator, but the latter one has the cost advantage over the former one. Third, compared to the UK generator, it could be more difficult for the Chinese generator to transfer the variable cost to the electricity price, due to the plan control of the state. So control of the cost transfer to final users shows another advantage of state plan than market.

This chapter includes the comprehensive comparison at the country level and also the specific case study at the firm level and then provides the evidence to argue that the plan mechanism can be able to deliver an effective power supply system. First, the state plan mechanism does protect the benefits for the small users better than the fully liberalised market, according to the findings of our international comparison. Second, the plan regulation in China can promote sufficient growth of the power supply to match its fast growing power demand over the past two decades. Thirdly, the partial plan also can stimulate technological advances, and thus reduce the gap of the thermal efficiency between the top Chinese and the UK generators, which is the evidence shown in recent years. Fourth, according the UK experience, the fully liberalised market may not be perfect for the power-generating industry, where the dominant producers can exercise their market power to erode the competitiveness of other industries. The market-oriented power supply system can fail in delivering the reliable power supply at a competitive price. As a whole, this chapter on the market-oriented reform on the power sector in China argues that fully-liberalised market has some disadvantages when compared with the Chinese reformed plan system in terms of welfare production.

Chapter 4

In the preceding chapter, we find that market is not superior to the reformed plan in the power industry. So what’s the rationale behind such argument? This chapter attempts to answer how plan prices are formed in terms of pricing behaviour of a firm.

There are a number of previous papers examined the pricing behaviour of the Western power producers (Green and Newbery, 1992; Wolak and Patrick, 1996; Ofgem's report, 1999; Borenstein and Bushnell, 1999; Woo, Lloyd and Tishler, 2003; Lopez, 2004). One of the recent studies (Sweeting, 2007) showed that the dominant producers "could have increased their short-run profits by submitting lower bids and increasing their output", which suggests that "generators exercised considerable market power in the late 1990s despite falling market concentration". However, most of the western studies are based on the oligopoly model, which may not be able to explain the Chinese situation, because the Chinese power sector is still under the plan control rather than a liberalised market economy.

There are also a plenty of articles about the Chinese power sector (Li and Dorian 1995, Andrews-Speed and Dow 2000, Hafsi and Tian 2005, Xu and Chen 2006, Hang and Tu 2007 and Yang 2008). Wang (2007) in his paper suggested the link between the electricity prices and the fuel prices. Liu, Wang and Song (2007) suggested that the power plant would be paid according to "the guaranteed rates of return and total costs of the plant". Unfortunately, most of them didn't use the quantitative methods to measure the pricing behaviour of the Chinese power firms. Lam's study (2004) is the only paper among them, which provides the empirical estimation of the pricing behaviour of the Chinese power firms. By adopting the cross-sectional data for the year 1998, he claimed that "the electricity prices across China are mainly determined by short run cost factors, like fuel costs and investment expenditure." However, Lam employed the catalogue price rather than the on-grid price for his model, because the power generators were not separated from the grids before 2002. It means that the dependent variable in Lam's study not only includes the ex-factory prices but also the prices of the transmission and the distribution, which only examined the situation before the power producers was separated from the transmission business.

Against the background above, this study is aimed to fill up a research gap of study in pricing behaviour of Chinese power producers, using ex-factory on-grid prices to estimate southern Chinese provinces over the period from 2003 to 2005.

Unlike the West, the Chinese power sector is facing a reformed plan system. The plan price is formed on the basis of certain pre-determined formula and then adjusted on the basis of the particular cost condition of each plant. It's reasonable to assume that the state planner plans an aggregate price in order to maximise the total output of the whole industry for given resources available at time. Under the assumption that the higher cost technology has the dominant effect on setting up a plan price. On the basis of this assumption, a price can be explained by both the output of supply and the cost of individual generator. Under the special institutional arrangement of the one-price-for-one-plant, the firm is expected to play a high cost strategy, where the state planner sets up a higher price for accommodating generator's higher costs. In other words, costs would be a central factor to affect the plan price of the power generators in China. In order to test this expectation, a price function is developed by including the variables of the total regional output, the average unit cost of rivals, the cost of capital, the fuel cost, the unit cost of the individual generator, and also the dummy variables to identify the location and the affiliation of those observations. We test these cost-related factors. And the load factor is added in into the second model to test if there is any existence of a soft price constraint. Besides, the robust tests are also specified for the models.

Through our econometric tests on the pricing model, we find that the negative relationship between the profitability and the price. This indicates that the high-costs plants get the bargaining power to the government to grant them with higher price in selling their high cost electricity. This also implies that there is no market competition at all in selling power in China.

Moreover, we also find a positive relationship between the lagged regional market share and the profit margin. It means that the large producers have more bargaining power to negotiate with the state for more planned output, and more output will help the firm improve utilisation of capacity and so profit. Another interesting finding is that the negative relationship between the price and total output of power. This empirical phenomenon implies that the state intends to plan a low price in favour of economic growth.

Chapter 5

There are two important issues in assessing supply of power: pricing producer's outputs and capacity of firms. Having studies the pricing, the thesis also investigates what determines capacity expansion in China's power supply. Due to lack of firm-level data, we study the capacity issue at a regional level with reference to OECD experience.

There are many previous studies (Ramcharran, 1990; Stern, 1993; Ghosh, 2002; Hondroyiannis, Lolos and Papapetrou, 2002; Shiu and Lam, 2004; Crompton and Wu, 2005; He, Zhao, Li and Huang, 2006; Yoo, 2006; Yoo and Kim, 2006; Lee and Chang, 2007; Mahadevan and Asafu-Adjaye, 2007; Yuan, Zhao, Yu and Hu, 2007; Yuan, Kang, Zhao and Hu, 2008; Abosedra, Dah and Ghosh, 2009; Apergis and Payne, 2009; Wolde-Rufael, 2009) estimating the power consumption with explanatory forced economic growth, using the error correction model. However, the error correction model only tests the causality relationship between the power consumption and the GDP but ignored other potential factors. Bianco, Manca and Nardini (2009) tested the electricity prices in addition to the real GDP. And the results showed that the power consumption was relevant to the GDP rather than the electricity prices in Italy. Wu (2009) performed a similar work with the Chinese provincial data in 2004. He employed the multivariate linear model to test the GDP, the electricity price, the population, and the economic structure upon the power consumption, and found the negative impact of the electricity price and the positive impact of the other three upon the dependent variable. Those studies hold a common assumption that power consumption drives power production, so that consumption in a key determinant for production and so production capacity as well.

Rosen (2007) made a very comprehensive description about the Chinese energy sector, from the driving demand, energy supply system, and global impacts, including the electricity industry. It suggested that the heavy industry is driving the energy demand in China at the moment, and also claimed that “strong corporate interests on both the supply and demand sides” encourages the capacity expansion in China. Kroeber (2008) discussed the issue of the power generation capacity in China, from a wide scope covering the demand, the supply, the ownership, the pricing and the profit distribution of the entire power supply system. And he concluded that it would only encourage “the construction of more unneeded generating capacity”, by “simply raising end-user electricity prices”. Again, Ma, Oxley, Gibson (2009) presented the situation capacity building and claimed that “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.” However, those studies didn't employ statistical data to pursue econometric verification of their arguments on what drives capacity of power supply in China.

In order to extend the previous studies in this field, the thesis performs the following tasks:

1) It examines a group of direct and indirect factors, which would affect the capacity expansion in China, through rigorous econometric tests;
2) It compares Chinese case with other international cases, which provides a comparative understanding of Chinese experience;
3) It uses the latest time-series data up to 2006, rather than the cross-sectional data in one year, to provide the up-to-date results of tests.

Following the introduction, it’s a comprehensive description about the power demand and supply in China, from the point of view of economic development, power consumption pattern, installed capacity, international power trades and the electricity prices, with an international comparison to other six OECD countries. It reveals the facts that the power-intensive industries dominate China's economic growth at the moment. To satisfy the fast growing demands for power, the state planner adopts the option of building up more power plants. Thus, such energy strategy makes China as one of biggest power consumers in this world, with increasing power-intensity in recent years.

A two-stage-estimation approach is performed, to identify the direct and indirect factors for the capacity expansion of the power supply in China and also other six OECD countries. In the first stage, the demand function is specified to test both the long-run and short-run relationships impact of the determinants on the power consumption. In the second stage, the power supply function is specified, where the power consumption and several other variables are tested to explain the capacity expansion. The Augmented Dickey-Fuller unit-root test is performed as a criterion to identify the stationarity of those time-series variables of all the seven countries. The Granger causality tests are also performed to confirm the validity of the empirical model. In terms of the OECD countries, the real GDP is employed as the proxy of the demand in the second stage. In terms of China, both the real GDP and the power consumption are tested along with other variables, such as load factor and electricity prices.

There are several findings are obtained from our estimation results. In terms of those OECD countries except Germany, the economic structure didn't show a positive relationship with the power consumption in the long run. But, in China, both the economic development and structure have the positive impact upon the power consumption. And, an increase in the long-run plan price, but not the short-run price adjustment, would have negative impact on the power consumption in China. This finding is consistent with our argument developed from the pricing study that the state intends to plan a low price in favour of growth of economy. Our estimation also shows the positive relationship between the supply capacity and the economic growth in China. It suggests that the increase in power consumption can change the capacity utilisation of the power industry to promote further investment in capacity, which is a generic phenomenon across different countries including China. Moreover, it also suggests that the change of end prices would not have any impact on the growth of the capacity in China, which confirms our argument that the competition of the Chinese power plants is not in the price but in the capacity.

One implication of our findings is that, by taking into account the current global financial crisis, it could be reasonable for the state to limit its high growth of the generation capacity and also close more small and inefficient plants, so as to restructure the power industry in China. Otherwise, it may cause the massive overcapacity problem in the foreseeable future, if the current trend of the capacity expansion investment continues.

1.5. Summary and contributions

Although the power sector in China has never been fully liberalised from the plan mechanism, it has achieved a rapid development since 1980s. Therefore, this thesis tries to explain the rationale behind such phenomenon, through study of three topics of the Chinese power supply with an international reference, i.e. the price and cost structure, the pricing behaviour and the capacity expansion.

Through the comparison of the price schemes between China and the West, we discover that China has successfully kept its household prices at a relatively low level just as its industrial prices, while the West countries tried to provide the competitive industrial prices at the expense of the household users. With the further insight into the cost structure of both the UK and Chinese power plants, we also find that the Chinese generators actually have various cost advantages over their West peers, but with a relatively lower profit margin. Thus, it could bring down the overall level of the electricity price in China. Again, it also suggests that the Chinese power supply under the plan mechanism would effectively protect the benefits of small consumers, compared to the West.

In such a situation, the state wants to set a proper electricity price to balance the interests of different groups in China. In other words, the plan price should be high enough to encourage the power production, but should not be too high for other industries. The empirical evidence shows that the state planner allows part of the cost inflation to be passed to the grids, but doesn't tolerate the inefficient power generation. Although the inflation of the fuel costs and the cost of capital are covered by the electricity prices, the generator still needs all kinds of way to lower down its overall generation costs to yield higher profits and also to meet the given output requirements. Besides, the evidence also shows that the large plants would gain high the profit margin. It implies that the state planner would give the production priority to the large plants with higher efficiency. Those findings could perfectly explain the rapid growth of the output and the great advance in the thermal efficiency of the Chinese power supply for the last three decades.

As there is no competition in the price, it's assumed that the power plants in China would compete with each other in the capacity expansion. The capacity built in China is heavily driven by the power demand and the load factor, while the economic growth has significant and positive impact upon power consumption. In order to smooth the swing from the power shortage to power surplus in short-term, one strategy is to change the economic structure of China.

As becoming the second largest power consumer in the world, it's important for China to improve its overall power profile. To achieve this, one option for China is to convert its heavy-industry-oriented economy to an energy-efficient pattern. Some studies advocate that the price reform could be an alternative way to reach the same target. However, our evidence shows that the price increase would have very limited effect. Moreover, if most of the price inflation falls on the household users, their benefits will be damaged, just as experienced by the West.

Although the price increase is welcomed by the power firms in China, it's found that there is no direct link between the price and the capacity. In fact, the Chinese power firms earn higher profit through higher outputs in the context of the fast growing economy. Because the price and outputs of the power firm are still controlled by the state, the only way for the Chinese power firm to take up larger market share is to have larger share of supply capacity. Such arrangement encourages the competition in the capacity in China's power generation industry. It could be especially true in the economic-booming period. But, it normally takes around two years to finish the construction of a new power plant. The on-going economic downturn would eventually lead to an undesired result, where the newly-built supply capacity would become excessive and idle, and it could be difficult for the investment to earn sufficient return.

Overall, this study intends to present a view of the pro and con of both the plan mechanism and the market mechanism. With our data and international comparison, it extends and challenges the current prevailing view about the Chinese power supply. The Chinese reformed plan system is effective in terms of promoting small users' benefits, economic growth, and the power supply. The study reminds the policy maker of the risks and problems of the electricity market in the West, which are ignored by most of the Chinese studies about the power supply. Thus, it intends to provide the meaningful and helpful implications for the market-oriented reform of the Chinese power supplies in the future.

Chapter 2. The Overview of the Electric Power Industry in China

2.1. Introduction

As the second largest power producer in the world, China produced over 3.4 billion MWh electric power in 2008, and consumed the equivalent. The Chinese electricity sector, which was dominated by the coal-fired plants, has expanded dramatically for about three decades to power its fast growing economy.

The state has reformed the electricity sector by opening its entry to the market and commercialise state-owned power companies. Although the restriction upon capacity investment has been removed, the output and price of the electricity are still on the hand of the government. Furthermore, the grids have been separated from the power generation, the vertical unbundling has not yet finished.

This chapter attempts to provide a comprehensive overview about the Chinese power sector, with the discussion and implication for the policy makers about the market-oriented reform in the power generation and transmission sectors in the next step. It covers a wide range of topics, including the reform history, the power generation, the power transmission, the electricity price control and the conflicts between the coal and electricity prices, on the basis of the previous studies, the historical events, the latest news and the fresh data.

This chapter is structured into seven parts. The first part is the introduction herein. The second part reviewed the history of the electric power sector reform in China. The third part describes the current status of the power generation sector, and the ownership of the generation capacity. The fourth part describes the power transmission sector, with the reference to the special distribution of the energy sources in China. The fifth part is about the governmental control of the electricity price. The sixth part is about the coal supply and the price conflicts between the coal and power producers. The last part presents the summary and conclusion.

2.2. The electric power sector reform in China

Since the 1980s, the state planner has committed to carry out a gradual reform to establish the market mechanism in the electricity sector. However, there are different models of power supply system in the world, even in the western countries. We should notice that there is no best or universal model in management of power supply. All countries keep on evolving their power supply system gradually, in order to match up the technology advances and the environmental changes. Among those different models, England was the one of the pilots to carry out the vertical unbundling reform of its electric power sector. Thus, it has been chosen as the benchmark to compare with the market-oriented reform in China throughout this study.

Table 2.1 Bundling and Unbundling in the Western Countries		
Separation of Transmission and Generation	Separation of Distribution and Retail	Country
Complete Separation	Completed Separation	England and Wales (UK)
		Spain
		Netherlands
		Sweden
		Italy
		New Zealand
	Internal Separation	Norway
		Finland
		Denmark
		Belgium
		Portugal
		Northern Ireland (UK)
		Australia
	Integrated	Chile
		Argentina
Internal Separation	Internal Separation	Greece
		Scotland (UK)
		Austria
		Ireland
	Integrated	United States (1)
		France
		Germany
		Luxemburg
		Japan

Source: Nanbu, T., (2003), "System Technology and Market Mechanism: System Design of the Electric Power Liberalisation", *Tokyo: Tokyo University Press*, pp.39.

Notes: 1) Distribution could be different in different states.

The electric power sector in China has experienced a series of reform, since the establishment of the new republic. According to Yeoh and Rajaraman (2004), there are four periods in the history of the Chinese power industry, which take it from the plan mechanism towards the market-oriented reforms.

Stage 1 (between 1949 and 1985)

A British, R.W. Little, founded the first power plant in China in 1882[2]. Before 1949, the Chinese electricity industry was invested by various investors, including private, government and foreign funds, but most of the electric assets were held by foreigners (Yang, 2006). Since 1949, the Chinese Communist Party has come to power and all of the industries were owned and managed by the government, under the "centrally planned" economy of the Soviet model. The electric power industry was not an exception. Between 1949 and 1978, it became "a vertically integrated state-owned utility" (Yang, 2006). The Ministry of Electricity in the central government was the highest controller and was supported by "the regional, provincial, municipal, and county power bureaus" (Yeoh and Rajaraman, 2004). It means that the power generation, transmission, distribution and retail are all planned, managed, regulated and owned by the central government.

The government also set "the directive price" by different catalogues for the end users, such as the illuminating price, non-industrial price, the common-industrial price, and the big-industrial price. The price setting procedures were opaque (Yang, 2006). The price only covered the operational costs and the asset depreciation of the plants and the grids (Wang, 2006), and it is irrelevant to the supply-and-demand equilibrium. The "on-grid price" and the profit didn't exist, as they were not allowed under the framework of the plan economy.

As the power supply could only be funded by the central government, the insufficient governmental investment resulted in the national-wide power shortages for a long period. Besides that, the electric power industry was also suffered by the syndrome of the plan economy, such as the low productivity, and the management dilemma. After 1978, China started the economic reform, which multiplied the seriousness of the power shortages. After 7 years, the government eventually decided to launch the reform of the electric power industry, so as to provide sufficient power supplies for

[2] "The history of the early development of the electric light in China, starting from Shanghai", http://info.lamp.hc360.com/2009/08/10114957376.shtml, visited on August 3, 2010.

the booming economic development.

Stage 2 (between 1985 and 1997)

Since 1985, the state has issued a series of policies to encourage the investment into the power sector to increase the capacity of the generation and the output of the electricity. During this period, the reform was characterised by the following features:

1) First, the state issued the notice of "Provisional Regulations on Promoting Fund-Raising for Investment in the Power Sector and Implementing Different Power Prices" to sweep the restrictions upon the market entry. Since then, besides the central government, the local governments, the private and foreign investors were all allowed to invest into the power sector, and the independent power producers (IPPs) were then created.
2) The new "guidance price" were introduced, which not only covered the operational costs and depreciation, but also included a certain profit margin for the generator. The price could be set on the basis of the particular situation of each plant, which is known as the "one-price-for-one-plant" scheme. Such pricing arrangement is treated as a kind of incentive for the plants to provide more outputs. But, the old "directive price" was not immediately cancelled at the same time.
3) The taxation rebate was allowed, as preferential condition.

Overall speaking, this reform achieved great success, as the development of the electric power sector started to accelerate in China. From 1985 to 1997, the total output of the power supply increased by around 2.7 times in China[3].

Stage 3 (between 1997 and 2002)

In order to separate the administrative authority from the enterprise, the Ministry of Electricity was replaced by the State Electric Power Corporation. The administrative authority of the Ministry of Electricity was transferred to the State Economic and

[3] The calculation is based on the data from the National Bureau of Statistics of China.

Trade Committee, while the managerial responsibility together with most of its assets was completely transferred to the State Electric Power Corporation (SEPC). Thus, the State Electric Power Corporation became a tycoon of power supply in China. It held almost all of the regional power generators throughout China, except those in Guangdong, Hainan, Inner Mongolia and Tibet. It also held all the transmission and a large proportion of the distribution networks in this country. It means that the State Electric Power Corporation played the roles of both the generator and the grid. But, some independent power producers still existed, outside of the State Electric Power Corporation. The structure of the power supply system during that period can be simplified into the chart Figure 2.1:

As the independent power producers were separated from the networks controlled by the State Electric Power Corporation, it implies that the concept of the "on-grid price" was forming. Actually, any new plant built after 1997 started to use the so-called "average on-grid price" over its useful life, which covered the operational costs, the interests, the taxation and also the reasonable return on capital. But, those prices still needed the government approval, just as the "directive price" and the "guidance price" before. The State Electric Power Corporation even conducted an experiment on the separation of the power plants from the grids with the competitive on-grid price in Zhejiang, Shandong, Shanghai, Liaoning, Jilin, and Heilongjiang provinces. But the experiment was eventually halted by the central government in 2000, as it couldn't overcome "the problem that both the power plants and the grids are owned by the same provincial power companies" (Liu and Zheng, 2010).

Stage 4 (after 2002)

In 2002, the State Council of China issued a decree of "System Reform Plan of Electricity Industry", of which the objectives were "to break the monopoly, introduce competition, improve the efficiency, reduce the costs, improve the pricing mechanism, optimising the resources allocation, promote the power development, push forward the establishment of the national-wide grids, and construct a healthy electricity market under the governmental supervision.” (The Chinese electricity industry report 2005). In order to achieve those objectives, this reform fell on two points, i.e. first, the split between the generator and the grid; and second, the introduction of the competitive on-grid price.

In December 2002, the State Electric Power Corporation was further divided into two state-owned grid companies, and five state-owned power producers (Figure 2.2). In May 2003, the State electricity Regulator Commission was established as the national regulator of the power industry, so as to separate the administrative authority from the regulating. Thus, the aim of separating the generator from the grid was largely achieved. The on-grid price between the independent power producers and the grids formally came into being and finally replaced the “guidance price” and the “directive price”. However, as the power transmission, distribution, and retails were still controlled by the grids, there were no transmission price and the distribution price. The two grids were criticised as the regional monopolies without sufficient cross-regional transmission facilities.

The on-grid price and the end price were still set by the government. As to the plants, the price is set as “one-price-for-one-plant”. The end price was classified by different catalogues, and would be very different among different classification and region. In 2005, the on-grid price was split into “capacity tariff” and “volume tariff”, to avoid the boosting the fuel costs (China Electric Power Yearbook 2006). However, such arrangement was suspended later on, as the power stations soon colluded together and then bid a high price that the grids companies couldn’t afford (Wang 2006).

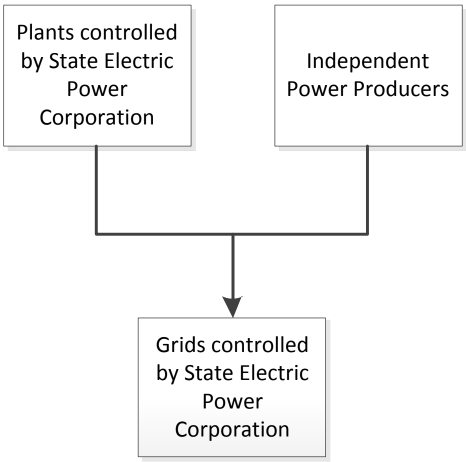

Figure 2.1 The Relationship between the State Electric Power Corporation and the Independent Power Producers

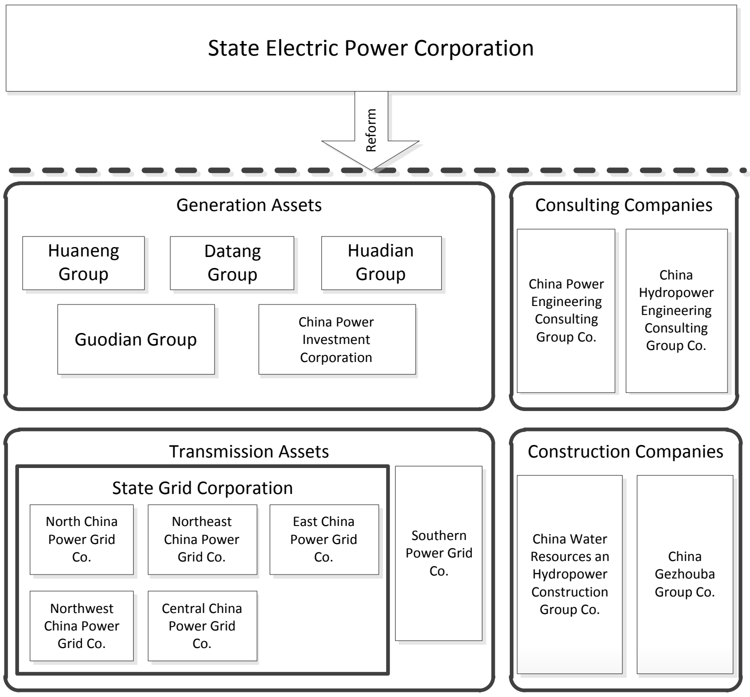

Figure 2.2 The Separation of the State Electric Power Corporation in 2002

Source: Ni (2005)

So far, the electric power sector in China has achieved a series of great success. The private and foreign investments are allowed to flow into the power sector, so that the social resources could be effectively utilised for the power supply. The power generation and the network are separated. And the on-grid price and the end price are formed, which promotes the efficiency and profitability of the power producers.

The administrative authority and the managerial responsibility are also separated, which is an important step to build up a market-economic supervision system.

The reformed plan system of the power industry in China is different from the former soviet one. The former soviet system was a full planning system. Both supply and demand were planned according to information provided by the firm. In contrast, demand for power is not planned and it is observable information from market by the state. The state plans aggregate output according to the expected market demand, and then divides the aggregate output to individual firms according to their capacity. The firm has an incentive to report true capacity that determines how much it can produce. The capacity is not planned. In short, the state plans outputs for the firm according to market demand and capacity, and the firm decides capacity. The price is determined according to the bargain between an individual firm and the state rather than the bargain between the producers and the buyers.

If demand in excess of the plan appears, the firm with spare capacity can be called to produce more either the plan price or at a negotiable price between the firm and the grid, or between the local government of the firm in the region and the local government of the end users.

As the Chinese power firms has established modernised corporate governance, the incentive for the power firms is to seek more profits through producing more planned outputs. The plan output is linked with capacity, and capacity is set by the firm. So firms compete with capacity and the state provides planed output according to capacity at the firm level and market demand at an aggregate level. If the firm makes a loss, it can be covered by a higher price to some extent. But the management will lose their profit-linked bonus. Also, the management faces the risk of replacement by the government for performance failure. This profit-oriented incentive also can help reduce the agency costs of the management in the power firms.

For the cost information, the distortion is limited. The accounting and auditing practice in China is similar with the UK. The accounting transactions are recorded according to General Accepted Accounting Practice, which compatible to the International Accounting Standards. There are also the independent audit firms to perform the annual financial auditing for the firm. So, it's less likely for firms to make serious and widespread information distortion in China. In another aspect, the total costs can be inflated due to the high cost strategy. However, this does not mean every item of costs to be infected. In the thesis, it is informed that the overhead costs, such as depreciation, are overstated when compared with the UK companies. For material costs, this is decided by the market and the price of coal is not subject to the choice of the power producing firms.

For the investment into the power generation sector, the funds mainly come from the loan of the banks in line with normal commercial norm. The decision of the loan falls in the hand of bank itself. The bank will assess the projected return of the new plant, according to the size of the capital, the plan price, the output, the construction period and etc. The bank can decline the loan application for a new power plant which is small and inefficient. To get more output allocation from the state, the investors have to build large and efficient power plant, which constitutes the competition in the capacity expansion.

Both state banks and power corporation are ultimately owned by the state. The ownership is separated from the management that is responsible for profitable operation for owners.

The separation can be ensured to a large extent by introducing a legal system to regulate owners of the firm on one hand, and by restructuring owners into a mixed set of state and private investors on another. This modern corporate-governance can help operational independency of banks from the state effectively.

Although the entry and investment into the power industry is free, it’s unlikely for the investors to build up new small inefficient coal-fired power plants at the moment. The government also has the plan to shut down the small inefficient coal-fired power plants in recent years. This is partly required by environmental protection to reduce pollution, and partly by economics of scale.

However, such market-oriented reform still has a long-way to go. The transmission and distribution are all owned by the grids and haven’t separated. The price and the output are still under the governmental control. The national-wide wholesale market has not been built for the price competition and free trades. Wu and Fu (2005) claimed that “the greatest challenge in the restructuring of China’s power industry is to ensure that the market rules send the right signals to ensure a proper level of generation investment”. Simply speaking, the Chinese power industry has not cleaned its heavy red colour of the plan economy.

2.3. The power generation and consumption in China

The basics of the Chinese power supply

So far, China has been the second largest electric power producer and consumer in the world. In 2008, Chinese power producers supplied around 3,433 billion kWh electric power (National Bureau of Statistics of China), equal to 83% of the US power supply, or 880% of the UK power supply (International Energy Agency).

Table 2.2 The Capacity and Production of the Chinese Power Supply

Year	Capacity Growth	Power Supply Growth	Capacity Growth to Power Supply Growth
1991	**9.85%**	**9.05%**	**1.09**
1997	**7.48%**	**5.09%**	**1.47**
1998	**9.07%**	**2.07%**	**4.38**
1999	**7.75%**	**6.51%**	**1.19**
2000	6.88%	10.98%	0.63
2004	12.60%	14.79%	0.85
2005	**15.36%**	**13.16%**	**1.17**
2006	**22.34%**	**14.54%**	**1.54**
2007	14.68%	14.87%	0.99
2008	**12.69%**	**5.45%**	**2.33**
Average	10.36%	10.02%	**1.24**

Source: Calculated on the data from National Bureau of Statistics of China

Since the 1985, the development of the power supply in China has run on the fast tracks. As shown on Table 2.2, during the period from 1991 to 2008, the average growth rate of both the capacity and the generation is around 10%. However, the growth of the capacity exceeds the generation in recent years. For example, the ratio of the capacity growth to the generation growth was 1.17 in 2005 and then reached up to 2.33 in 2008. In 1998, such ratio was even 4.38. The interesting thing is that 1998 was the hard time of the Asian financial crisis, and 2008 was on the first stroke of global economic downturn. It means that the power supply is more sensitive to the economic fluctuation than the capacity expansion in China. It also clearly indicates that the capacity built in recent years would be too much for the gloomy economy in the foreseeable future.

Table 2.3 The Mix of the Chinese Power Supply (2008)

	Total	Hydro	Coal-fired	Nuclear and other
Capacity (MW)	803,800.00	165,360.00	620,170.00	18,270.00
%	100.00%	20.57%	77.15%	2.27%
Output (billion kwh)	3,433.40	563.30	2,779.30	90.80
%	100.00%	16.41%	80.95%	2.64%

Source: National Bureau of Statistics of China

China heavily replies upon the coal-fired plants for its power supply. In 2008, China had a total generation capacity of 803,800 MW, of which 77% was coal-fired plants. Actually, the coal-fired plants produced over 80% of the total power in China. The hydro is the second important energy source for the power generation. In 2008, around 16% of the power generated in China came from the hydro power. From 1990 to 2008, the capacity of the coal-fired plants increased by six times, and coal-fired power generation increased by around 5.6 times.

Table 2.4 The Mix of the Power Supply in the UK and US (2008)

	Total	Hydro	Coal-fired	Gas	Nuclear and others
UK					
Generation	100%	1%	31%	46%	22%
Capacity	100%	5%	30%	35%	30%
US					
Generation	100%	6%	48%	22%	24%
Capacity	100%	8%	31%	40%	22%

Source: the UK data from the Digest of the United Kingdom of Energy Statistics 2009; the US data from the Electric Power Annual 2008

Such kind of structure of the power generation in China is very different form the Western countries. In the West, the gas-fired plant plays a very important role in the field of the power supply. In the UK, the gas-fired and coal-fired plants produced 46% and 31% of the total power supply respectively in 2008. In the US, the power generated by gas-fired plants also took up around 22% of the total power supply in the same year. Compared to China, the structure of the power supply in the West is much more diversified.

Obviously, such heavy reliance upon and rapid growth of the coal-fired power plants in China indicate that the state planner failed in diversifying the power supply in terms of different generation technologies, and also failed to meet up its commitment of implementing more clean-energy facilities in the environmental protection issue.

According to Dubash (2003), around 32% of the CO_2 and 24% of the NO_x emission in the world came from the electricity sector in China in 1998.

According to Rosen and Houser (2007), "the annual sulfur dioxide (SO_2) emissions, the principal cause of acid rain, have grown by 30 percent since 2000", and caused "over $60 billion in direct economic damage in 2005". According to Liu and Zheng (2010), only 15% of the Chinese power plants have installed the flu gas desulphurisation (FGD) system in 2006, and even fewer are in operation. According to Rosen and House (2007), over half of the FGD capacity was built in 2006, after the state issued an incentive policy to allow the plants to pass the cost of the installation and operation of FGD equipment to the grids. Besides, the full commitment to the Kyoto protocol is regarded as an important step for China to amend its profile of the greenhouse gas emission. The state planner should put the International Emissions Trading (IET), the Clean Development Mechanism (CDM) and the Joint Implementation (JI) into the consideration of the approval of the new plant in China. Thus, the environmental costs can be effectively recognized in the total cost of the power generation.

The power demand and economic development in China

In 2009, China consumed around 3.6 billion MWh electric power and created around 12,439 billion Yuan industrial value added. However, the growth of the power consumption has been decreased from 15.15% in 2006 to 6.77% in 2009. And the growth of the industrial value added dropped to 14.72% in 2009 from 21.88% in 2006. It clearly shows that the recent economic downturn has an adverse effect on industrial activities in China and hence the demand for power.

Table 2.5 The Power Consumption and the Industrial Value Added

	2005	2006	2007	2008	2009
Power Consumption (Billion MWh)	2.5	2.8	3.2	3.4	3.7
Growth		15.15%	10.82%	8.76%	6.77%
Industrial Value Added (Billion Yuan)	7,072.98	8,620.42	9,502.02	10,842.72	12,439.31
Growth		21.88%	10.23%	14.11%	14.72%

Source: the Development Research Centre of the State Council

Normally, the consumption and supply of the electric power are almost equal to each other at an aggregate level. But, at a provincial aggregate level, the situation becomes complex, due to the transmission among different regions. In order to measure the power sufficiency, we divide the power production by the power consumption of each province, as shown in Table 2.6. If the ratio is larger than one, it means that the province is a net exporter of power. If the ratio is smaller than one, it means that the province is a net importer of power. If the ratio is close to one, it means that the province is mainly reliant on its own power supply. In 2007, the ratio of self-sufficiency of twenty provinces falls in the range of 0.85 to 1.25. It means that most of the provinces are of the power self-sufficiency. However, certain large municipalities and the economy-advanced provinces have lower self-sufficiency of power, while the energy-rich provinces normally turn to be a net exporter of the power. For example, Shanghai has an industrial value added per capita of 24,050 Yuan in 2007, and the ratio of the power self-sufficiency was only around 0.68. In Guizhou, the industrial value added per capita was only 1,960 Yuan, but the ratio was as high as 2.13.

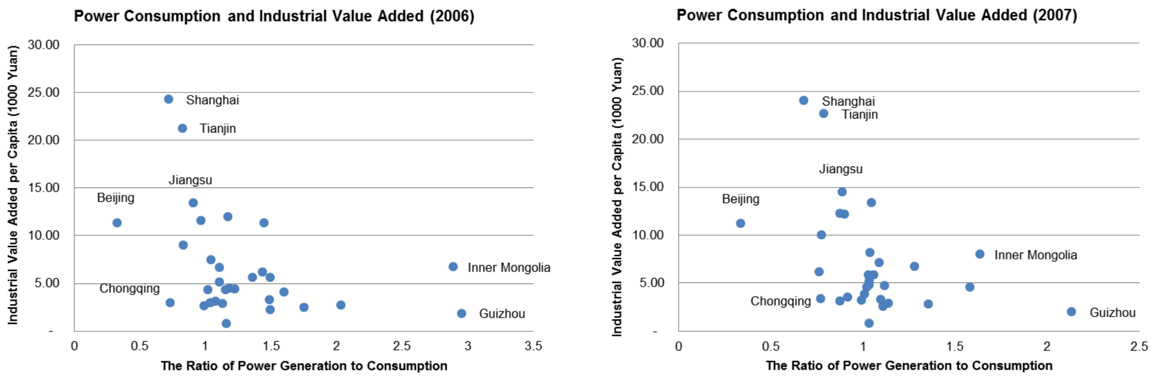

Figure 2.3 The Power Consumption and the Industrial Value Added

Source: The provincial data of the industrial value added, the power generation and power consumption from the Development Research Centre of the State Council; the population data from National Bureau of Statistics of China.

Table 2.6 The Power Self-sufficiency and the Industrial Value-Added at Provincial Level in China				
	2006		2007	
Province	Power Generation to Consumption	Industrial Value Added per Capita (1000 Yuan)	Power Generation to Consumption	Industrial Value Added per Capita (1000 Yuan)
Beijing	0.32	11.32	0.34	11.17
Tianjin	0.83	21.25	0.79	22.63
Hebei	1.49	5.63	0.76	6.14
Shanxi	1.43	6.16	1.28	6.69
Inner Mongolia	2.89	6.73	1.63	7.99
Liaoning	0.83	8.99	0.78	10.00
Jilin	1.10	5.15	1.06	5.83
Heilongjiang	1.11	6.64	1.09	7.10
Shanghai	0.72	24.27	0.68	24.05
Jiangsu	0.91	13.40	0.89	14.49
Zhejiang	0.97	11.55	0.90	12.18
Anhui	1.13	2.86	1.10	3.24
Fujian	1.04	7.44	1.04	8.19
Jiangxi	0.99	2.66	0.88	3.08
Shandong	1.17	11.98	1.05	13.34
Henan	1.18	4.50	1.04	5.18
Hubei	1.60	4.05	1.58	4.57
Hunan	1.08	3.12	0.92	3.55
Guangdong	1.45	11.36	0.88	12.22
Guangxi	1.49	2.24	1.11	2.55
Hainan	1.75	2.43	1.14	2.86
Chongqing	0.73	2.98	0.77	3.39
Sichuan	1.49	3.29	1.01	3.83
Guizhou	2.95	1.84	2.13	1.96
Yunnan	2.03	2.69	1.36	2.80
Tibet	1.16	0.74	1.03	0.83
Shaanxi	1.15	4.30	1.12	4.74
Gansu	1.04	2.95	0.99	3.20
Qinghai	1.22	4.36	1.04	4.79
Ningxia	1.02	4.30	1.02	4.57
Xinjiang	1.36	5.58	1.03	5.82

Source: The provincial data of the industrial value added, the power generation and power consumption from the Development Research Centre of the State Council; the population data from National Bureau of Statistics of China.

Another interesting finding is that the average electricity price would be higher in the province with higher economic power efficiency. For example, in 2007, the average end price of Shanghai was 0.66 Yuan/kWh in Shanghai, while the industrial value added per unit of power consumed was 4.16 Yuan/kWh. But, in the same year, the electricity price in Qinghai was only 0.30 Yuan/kWh, and the economic power efficiency was around 0.93 Yuan/kWh only. Therefore, it means that the economic-advanced provinces would attract the power supply from other provinces with higher end prices, in order to balance their lower power self-sufficiency.

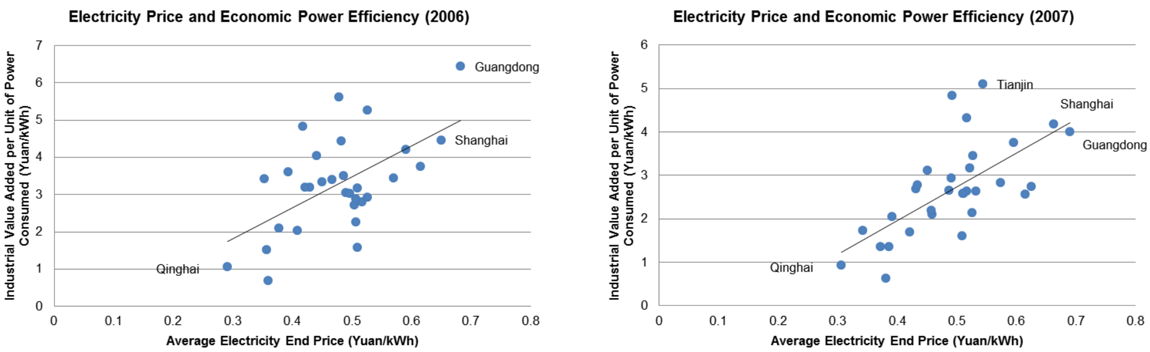

Figure 2.4 The Electricity End Price and the Economic Power Efficiency

Source: The provincial data of the industrial value-added, the electricity end price the power generation and power consumption are obtained from the Development Research Centre of the State Council.

Table 2.7 The Electricity End Price and the Economic Power Efficiency at Provincial Level in China

Province	2006		2007	
	Industrial Value Added per Unit of Power Consumed (Yuan/kWh)	Average End Price (Yuan/kWh)	Industrial Value Added per Unit of Power Consumed (Yuan/kWh)	Average End Price (Yuan/kWh)
Beijing	2.93	0.53	2.74	0.63
Tianjin	5.27	0.53	5.10	0.54
Hebei	4.05	0.44	2.11	0.46
Shanxi	2.03	0.41	1.68	0.42
Inner Mongolia	3.41	0.35	1.73	0.34
Liaoning	3.18	0.51	3.16	0.52
Jilin	3.51	0.49	3.44	0.53
Heilongjiang	4.44	0.48	4.32	0.52
Shanghai	4.46	0.65	4.17	0.66
Jiangsu	4.22	0.59	3.74	0.59
Zhejiang	3.44	0.57	2.82	0.57
Anhui	2.72	0.50	2.57	0.51
Fujian	3.04	0.49	2.93	0.49
Jiangxi	2.88	0.51	2.63	0.52
Shandong	5.61	0.48	4.83	0.49
Henan	3.19	0.43	2.68	0.43
Hubei	2.79	0.52	2.63	0.53
Hunan	3.04	0.50	2.57	0.51
Guangdong	6.44	0.68	4.00	0.69
Guangxi	3.33	0.45	2.19	0.46
Hainan	3.76	0.62	2.55	0.61
Chongqing	2.26	0.51	2.14	0.53
Sichuan	3.40	0.47	2.64	0.49
Guizhou	2.10	0.38	1.35	0.39
Yunnan	3.61	0.39	2.05	0.39
Tibet	1.59	0.51	1.60	0.51
Shaanxi	3.19	0.42	2.78	0.43
Gansu	1.52	0.36	1.36	0.37
Qinghai	1.06	0.29	0.93	0.31
Ningxia	0.68	0.36	0.63	0.38
Xinjiang	4.83	0.42	3.10	0.45

Source: The provincial data of the industrial value-added, the electricity end price the power generation and power consumption are obtained from the Development Research Centre of the State Council.

The ownership of the Chinese power producers

As the entry restriction upon the power sector was removed in the first wave of the reform, the ownership structure of the power generation became diversified, due to the massive and various investments. The private firms and the foreign-invested plants have been allowed to operate in China since then. In 2004, there are 2,956 power companies (over 4,000 power plants) in the power generation sector, according to the statistics of the Bureau of National Statistics of China. However, 75.78% of those plants are small plants with the installed capacity below 50MW. As the power plant in small size normally has lower thermal efficiency, a large number of small and medium-sized plants will definitely lower down the overall thermal efficiency of China. In order to improve its overall thermal efficiency, China has to shut down the massive small plants and build more large plants to supply the power. By the end of June 2009, China has closed down 7467 small generators, with a total capacity of 54 million kW[4].

Table 2.8 China's "Big Five" in 2006

	Huaneng	Datang	Huadian	Guodian	CPI	Total
Value of Asset (million RMB)	285,572	226,616	196,100	187,972	181,165	1,077,425
Market Share (%)	12.90%	10.23%	8.86%	8.49%	8.18%	48.66%
Installed Capacity (million KW)	57.18	54.06	50.05	44.45	35.50	241.24
Capacity Share (%)	9.17%	8.67%	8.02%	7.13%	5.69%	38.68%
Total Generation (TWH)	2,820.35	2,516.21	1,995.11	2,259.10	1,725.04	11,315.81
Generation Share (%)	9.90%	8.83%	7%	7.93%	6.05%	39.71%

Source: Qing Zhang, Regulatory Framework for the Electricity Industry in China (PPT presentation)

As mentioned above, the monopoly of the State Electric Power Corporation has already been broken down, after continued reform. In 2006, the "big five" generators only took up around 38.7% of the total capacity and 39.7% of the total power generation. It's interested that the concentration in both the capacity and generation in China is much smaller than the West, given the whole industry is under the plan system. For example, in Italy, the biggest five power companies took up 68.7% of total capacity (European data from Eurostat).

[4] http://www.chinatibetnews.com/guonei/huanbao/2010-06/07/content_481668.htm, visited on August 9, 2010.

The reason why the Chinese power industry is less concentrated than those European countries might be that most European countries are much smaller. Compared to the US, the top ten power companies only take up around 23.72% of the total capacity[5].

Table 2.9 The Power Generation Capacity by Ownership (2007)

	2007 Year End		Net New Capacity installed 2004-2007	
	GW	% of Total	GW	% of Total
Big Five	304	43	138	42
Local Governments	288	40	131	40
Central government agencies	79	11	40	12
Private/foreign	43	6	20	6

Source: Kroeber (2007)

Furthermore, we could find that the Chinese power supply actually is based on "two pillars". One pillar refers to those "big five" power corporations, which are controlled directly by the central government. They took up around 43% of the total capacity at the end of 2007. Another important pillar refers to those plants controlled by the local government, which accounted for 40% of the total capacity. The rest capacity can be attributed to the other ownership, such as the central government agencies, the private and foreign investments.

During 1990s, China experienced the honeymoon with the foreign-invested power companies (Woo, 2005). The state planner arranged several institutional arrangements for the foreign-direct-investment into the Chinese power sector, such as "the cooperative joint ventures, wholly-owned foreign ventures, equity joint ventures, build-operate-transfer (BOT) projects, build-operate-own (BOO) projects, commercial loans, and stock and bond investments in existing Chinese power enterprises" (Turner, 1997). By June 1998, there were 24 foreign invested plants with a total capacity of 4.9 GW in operation, and another 12 plants with a total capacity of 9.0 GW under construction (Blackman and Wu, 1998).

[5] It's calculated by the Form EIA-860 Annual Electric Generator Report 2009, from US Electricity Information Administration.

Woo (2005) found three reasons why China attracted the foreign investment into its power sector. The first reason was to seek the foreign capital, because of the tight fiscal budget of China in late 1980s and early 1990s. The second one was to transfer the advanced generation technology from the developed countries. Actually, over 40% of the foreign invested plants were larger than 300 MW (Blackman and Wu, 1998). The third reason was to introduce the competition, so as to increase the economic efficiency of the power generation sector.

However, the foreign investments started to quit the Chinese market since 2002. Blackman and Wu (1998) claimed that the "the central government intentionally put in place of three "barriers" to FDI, i.e. ownership restrictions, rate of return restrictions, and project approval requirements -- in order to limit foreign ownership of strategic infrastructure and, perhaps more important, to limit local control of FDI." Thus, by 2007, the private and foreign invested plants only accounted for 6% of the total capacity in China, which was rather insignificant. According to Wee and Wee (2003), "despite the promising opportunities generated by China's tremendous power development needs, reports show that many foreign investors are either substantially scaling back operations in the industry or avoiding new exposure to Chinese power projects."

2.4. The power transmission in China

The basics of the power transmission in China

After 2002, the two grids companies were split off from the State Electric Power Corporation, i.e. the State Grid Corporation of China (SGCC) and the South China State Grid Corp (SCSG). Again, the State Grid Corporation consists of five regional grid companies. It means that the power network in China actually has been divided into six regional grids. Those grids are playing a dominating role in the transmission, distribution, wholesale and retail of the electric power. Interestingly, the power shortages in China are found to be characterised by both the regional and seasonal features (Liu and Zheng, 2010). For example, the power plants in the north need to operate at full capacity in winter to meet the peak demands for heating, while the power shortages occur in the south and the east in summer when demand for air conditioning is soaring.

Table 2.10 The Regional Power Grid Companies and Their Service Territories

Grids	Territory
State Grid Corporation of China	
- North China Power Grid Co.	Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia (part), Shandong
- Northeast China Power Grid Co.	Liaoning, Jilin, Heilongjiang, Inner Mongolia (part)
- East China Power Grid Co.	Shanghai, Jiangsu, Zhejiang, Anhui, Fujian
- Central China Power Grid Co.	Jiangxi, Henan, Hubei, Hunan, Chongqing, Sichuan
- Northwest China Power Grid Co.	Shanxi, Gansu, Qinghai, Ningxia, Xinjiang
South China State Grid Corporation	Guangdong, Guangxi, Hainan, Guizhou, Yunnan

Source: Ni (2005)

So far, China has already had the largest power network in the world[6]. In 2007, the total length of the circuit of the transmission facility in China exceeded 1.1 million kilometres. However, it doesn't mean that China owns an advanced and powerful network to transmit the electricity anywhere easily within its territory. Unlike the rapid development of the generation sector, the lack of investment in grid assets has harassed China's electric power industry for a long time. By 2007, the circuit above 220kv only took up 29.7% of the total length in China. The high-voltage and the extra-high-voltage facilities are even less.

Although China has successfully promoted the rapid expansion of power supply capacity, it's a not easy to achieve a similar success in the power transmission sector. As the end prices are planned by the government, the profits of the grids would be easily eroded in front of the increasing on-grid price, which is linked to the coal price.

[6] "The Prospect of the Chinese Power Network", http://www.zdoy.cn/news/w10186232.asp?lanid=9561&n=1&o=4, visited on August 5, 2010.

Thus, it could be difficult to attract investments into the transmission sector.

Another reason could be the regional barrier to the establishment of a unified nation-wide power transmission system, which could not be easily offset by the local and private incentives and initiatives (Liu and Zheng, 2010). Actually, the interconnection only took up 1% of the total length of the transmission network in 2007. Definitely, it would make the nationwide transmission in difficulty.

Table 2.11 The Length of the Transmission Circuit of Chinese Grids in 2007

Unit: km	Total	750kv	500kv	330kv	220kv	Above 220kv	Below 220kv
Whole Country	1,106,345	141	96,574	15,493	216,159	328,367	777,978
Interconnection	11,099	0	10,899	0	200.00	11,099	0

Source: Chinese Electricity Yearbook 2007, page 743.

Fortunately, this situation has been change recently. It's the first time for the investment into the grids exceeds the power generation, due to the stimulus package of 4000 billion RMB unleashed by the government (Southern Grid Network 2009) in 2009.

The distribution of the energy resources and the generation capacity

The coal is the most important energy source in China. Over 80% of the power and 70% of the total energy is supplied from coal (Liu and Zheng, 2010). Actually, China is the largest coal producer in the world, and its coal reserve is sufficient to sustain its economic growth for more than 100 years, according to the estimation by Fairley (2007). However, the coal reserves as well as other energy resources are distributed unevenly in China. The northern China has 64% of the coal reserves, and the south-western China has over 70% of the hydro reserves (See Table 2.12). However, major power users are in the eastern coastal areas of China. Thus, it should be the best option to generate the power in the resource-rich areas and then transmit it to the high-demand areas.

Table 2.12 The Regional Distribution and Structure of the Energy Resources in China

Region	Total (%)	Coal (%)	Hydro (%)	Oil and Gas (%)
North	43.9	64	1.8	14.4
Northeast	3.8	3.1	1.8	48.3
East	6	6.5	4.4	18.2
Middle	5.6	3.7	9.5	2.5
Southwest	28.6	10.7	70	2.5
Northwest	12.1	12	12.5	14.1

Source: http://www.sgcc.com.cn/dlkp/dlhb/kpzs/sbdssjbzs/61091.shtml

Although the nationwide transmission network was established in 2005, the facilities of the grids are far from the adequacy. As mentioned above, China only implemented 11,099 kilometres interconnection of the network among those six regions in 2007. Within the State Grid Corporation of China, there were eight 500 KV AC lines, three +/- 500 KV DC lines, and 120 KV DC line, with 12660 MW transmission capacity. And there was only one +/- 500 KV DC line with 3000 MW transmission capacity between the State Grid Corporation of China and the South China State Grid Corporation. Obviously, such network facilities are too weak to undertake the long-distance transmission of the power. And, the transmission ability between two state-owned grids was especially vulnerable.

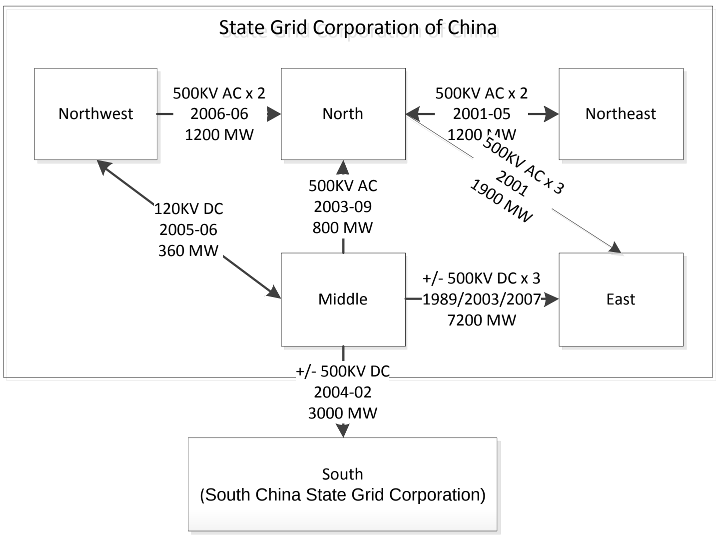

Figure 2.5 The Grid Interconnection in China (2007)
Source: Liu and Zheng (2010)

Actually the power transmitted among different regions is very limited, due to the inadequacy of the long-distance transmission facilities. In 2006, only 2.03% of the total power generated in China was transmitted among the different grid regions. It also implies that the power demand in China is largely satisfied by the local supply, rather than the pooling of the whole country.

Table 2.13 The Power Transmitted between Regions in China

Unit: billion kwh	2006	Percentage of the total power generated
From Northeast to North	3.26	0.11%
From Middle to East	23.81	0.84%
From North to East	11.15	0.39%
From Middle to South	19.67	0.69%
Sum	57.89	2.03%
Total power generated	2850.00	100.00%

Source: The report of the analysis and advice of the development of the Chinese grids in 2007

In another aspect, it means that the power plants have to be built in the high-demand areas, rather than concentrated in the energy-rich areas. For example, the northern region owns over 64% of coal reserves, but only has 13% of the coal-fired capacity and 14% of the coal-fired power. The south-western region has 70% of hydro reserves, but only produces 15.7% of the hydro power. On the contrary, the eastern region has only 6.5% coal reserves, but has over 14.5% coal-fired capacity and 14.5% of coal-fired power. It obviously shows that the capacity distribution doesn’t overlap with the distribution of the energy sources in China. And China allocates more capacity for the coastal regions, where the industry is concentrated.

Table 2.14 The Distribution of the Regional Installed Capacity and the Power Generation of China (2007)

	Installed Capacity					
Unit: %	Total	Coal-fired	Hydro	Nuclear	Wind	Other
State Grid Co. of China	45.09%	45.65%	42.31%	36.41%	48.00%	21.52%
North	10.45%	13.08%	1.47%	0.00%	9.15%	1.20%
Northeast	4.52%	5.02%	2.57%	0.00%	20.28%	2.18%
East	13.30%	14.50%	7.96%	36.41%	7.38%	14.30%
Middle	12.47%	9.69%	24.59%	0.00%	0.22%	1.05%
Northwest	3.81%	3.35%	5.72%	0.00%	10.97%	2.79%
South China State Grid Co.	10.35%	8.70%	15.38%	27.17%	4.01%	56.96%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
	Power Generation					
Unit: %	Total	Coal-fired	Hydro	Nuclear	Wind	Other
State Grid Co. of China	45.09%	45.84%	42.16%	34.21%	47.73%	32.13%
North	11.75%	13.92%	0.47%	0.00%	9.35%	1.93%
Northeast	4.67%	5.29%	1.44%	0.00%	19.68%	1.82%
East	13.39%	14.25%	5.81%	34.21%	6.76%	23.47%
Middle	11.21%	8.64%	27.99%	0.00%	1.09%	0.99%
Northwest	4.08%	3.74%	6.45%	0.00%	10.84%	3.93%
South China State Grid Co.	9.81%	8.33%	15.67%	31.59%	4.54%	35.73%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Source: Chinese Electricity Yearbook 2008

Again, the local power demand will be satisfied by the local suppliers, rather than the power transmitted from other regions. In order to measure the reliance upon the local supply, we calculate the ratio of the power consumption to the power generation for each of those six regions. If the ratio is larger than one, it means that the power is transmitted from other regions to the particular region. If the ratio is less than one, it means that the particular region is transmitting the power to others. Actually, we find that the ratio of each region is close to one. It means that all the six regions heavily rely upon the local power supply, rather than the power transmitted between different regions. Although China has almost kept its balance of power consumption and production within each region, it has some imbalance between provinces as we have shown in Table 2.6.

Table 2.15 The Regional Power Consumption and Power Generation

	Power Consumption	Power Generation	Power Consumption /Power Generation
Unit	Billion kwh	Billion kwh	
State Grid Co. of China	2,581.99	2,544.24	1.01
North	712.05	662.80	1.07
Northeast	261.75	263.54	0.99
East	798.28	755.49	1.06
Middle	582.84	632.47	0.92
Northwest	223.38	229.94	0.97
South China State Grid Co.	564.13	553.60	1.02

Source: Chinese Electricity Yearbook 2008

The provincial level of imbalance between power consumption and production can cause a structural shortage of power supply in a region due to a low transmission capacity. For example, there is only one trunk transmission line linking the coal-rich area in the north and the industrial area in the south (Kroeber, 2008). One of the direct solutions for such problem is to transport the coal from the northern and western provinces to the eastern part of this country, through railway, road, and freight. However, it would put significant burden on the existing transportation system, increase the fuel costs and also result in the instability of supply. Those are just the unique problems harassing the independent power producers in the coastal regions (Woo, 2005). Liu and Zheng (2010) believed that it could be one of the reasons for the power shortages in China. Kroeber (2008) had the similar understanding and claimed that the inadequate investment into transmission sector is the very reason for China facing “the electricity shortfall of at least 5% nationwide”, “although China has adequate generation capacity”.

The projected development of the grids in China

Obviously, the development of the long-distance power transmission cannot be slid over. The central government determined to build a unified national grid system to ease the less optimism of the capacity distribution and also the localised electricity shortages after 2010. The unified national grid would be based on the middle grid, and connected with other regions around. According to Liu and Zheng (2010), three regional "corridors" of the grids will also be built, i.e. northern, central and southern corridors, and they will transmit the electric power nationwide from the west to the east. The integrated national grid will also allow the electricity to be sold nationwide at the market determined rates. According to Liu and Zheng (2010), the State Grid Corporation of China would spend 800 billion RMB from 2006 to 2010 to upgrade its network facilities, which was expected to "increase the sale of electricity to 2,200 billion kilowatt-hours during the same period". According to Lou and Gui (2007), the Chinese government is aiming to remove such bottleneck of the transmission in the current five-year plan with the "1.25 trillion" RMB investment into the network facilities. Obviously, the state will accelerate the development of the grids in the near future.

The critical technology for China to build the nationwide grid is the Ultra High Voltage (UHV) transmission system (Liu and Zheng, 2010). The UHV system can be classified into the UHVDC and the UHVAC again. The UHVDC and UHVAC refer to the ±800KV direct currency and 1000KV alternating currency respectively. So far, a pilot UHV transmission line, called Jindongnan-Nanyang-Jingmen (JNJ), has been put into operation since 2006. The JNJ line connects the North China Power Grid with the Central China Power Grid from the Shanxi Province to Henan Province with a total length of 640 kilometres. According to Liu and Zheng (2010), the State Grid Corporation of China announced the a further investment of 600 billion RMB to build another 15 UHV projects before 2020, in order to link the newly built hydro power plants in the southwest to the industrial and residential regions in the east.

Table 2.16 The Completed, Under construction, and Proposed UHV projects in China

Project	Distance (km)	Voltage (kV)	Capacity	Start Year	Completion Year
JNJ	654	1000 (AC)	6000 MW	2006	2009
YG	1438	±800 (DC)	5000 MW	2006	2010
XS	1907	±800 (DC)	6400 MW	2007	2010
JS	2096	±800 (DC)	7200 MW	2009	2012
NG	1500	±800 (DC)	6000 MW		2015
LG		1000 (AC)			2030
YG		1000 (AC)			2030

Sources: Liu and Zheng (2010)

Notes: JNJ: Jindongnan-Nanyang-Jingmen; YG: Yunnan-Guangdong; XS; Xiangjiaba-Shanghai; JS: Jinping-Sunan; NG: Nuozhadu (Yunnan)-Guangdong; LG: Lijiang (Yunnan)-Guangdong; YG: Yongping (Yunnan)-Guangdong

The UHV system is regarded as having strong ability of the long-distance transmission with high energy efficiency. The implement of such technology could significant reduce the number of the required transmission corridors. It would be also helpful in environmental protection issue. The UHV system is also a fundamental factor to build up a nationwide electricity wholesale market in the future. But, Liu and Zheng (2010) also pointed out that the implement of the UHV network would be contradict with the institutional reform plan to break the monopoly set by the central government in 2002. According to the spirit of the reform plan, the regional grids under the State Grid Corporation of China will be converted to "the independent share-holding companies" to attract the further investment. A unified UHV grid would be expected to reinforce the relationship between the transmission and distribution and make it even more difficult to separate the transmission and distribution functions apart. The massive investment required for the nationwide UHV projects may also drain out the social resources from improving the interconnection between different regional grids. However, the fragment market may also result in the less economy-of-scale. The best option to balance those issues would be "the UK model", where the grid changed its role as the electricity pool to the electricity transporter merely.

2.5. The electricity price control in China

The price control of the electric power

A series of reform actions brought the Chinese electric power sector into a kind of transitional status, which is different from the traditional plan mechanism, but still far away from the liberalised market system.

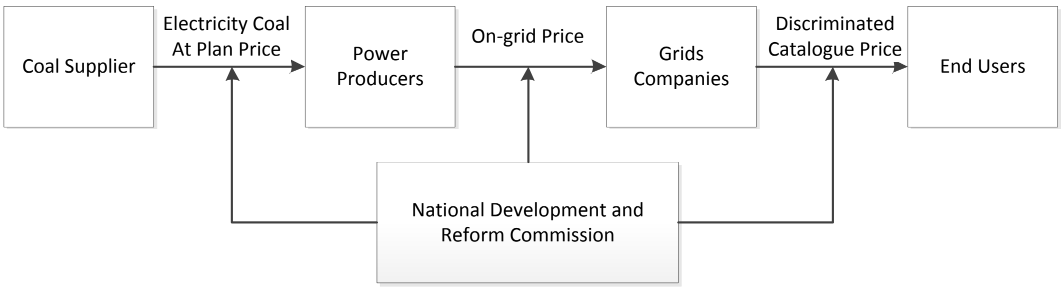

Figure 2.6 The Supply Chain of the Coal-fired Power Plants in China

Under such institutional mechanism, the National Development & Reform Commission (NDRC) plays an important role in the supply chain of the electric power. The electricity coal refers to the coal supplied to the power producers by plan. The on-grid price refers to the price between the independent power producers and the two state-owned grids companies. The catalogue price refers to the price between the grids and the end users. The price of the electricity coal, the on-grid price and the catalogue price are all controlled by the NDRC. Besides that, the output of the individual power producer is also set by the government. But, it should be noticed that, the coal supplier is not fully under the plan mechanism and also can sell the coal on the market freely at the market price. The industrial end users on the supply chain are opened to the market competition. Moreover, the diversified investments are allowed to participant in capacity build. Overall speaking, the government still takes significant intervention into the supply chain of the electric power, although not every aspect any more. Thus, the transitional Chinese power industries are still painted with the colour of plan mechanism heavily, The state planner designed and then adjusted the structure and arrangements of the existing system to maintain the balance between the development, stability, and reform (Ngan 2009). The biggest conflict in the supply chain of the electric power is the inflation of the coal price (Lin, 2004). According to Liu and Zheng (2010), “the conflicts between the market coal and the plan electricity intensified due to the virtual elimination of the plan coal when the National Annual Coal Price Negotiating Conference was cancelled, since 2007”.

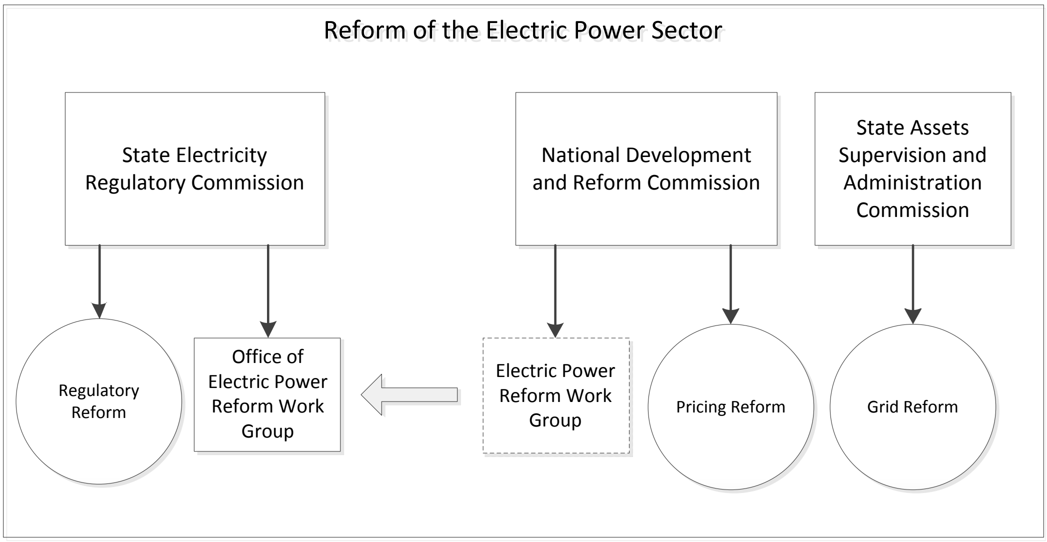

Figure 2.7 Institutional Bodies involved in the Reform of the Electric Power Sector in China
Source: Liu and Zheng (2010)

To solve this problem, the state also intends to reform the power sector by setting up reform work place shown in Figure 2.7. However, the electricity price reform has encountered several obstacles in the middle of the way. The relevant interest groups are reluctant to give up their existing privileges and dominant power in the pricing reform (Liu and Zheng, 2010). For example, the state-owned grids refuse to their monopolistic position in the power sector, and the NDRC is reluctant to give up the job of price setting. Zhao (2009) also mentioned that the provincial governments are not willing to lose the control and authority over the power producers as well.

According to Liu and Zheng (2010), there are three institutional bodies involved in the reform of the electric power sector. The National Development & Reform Commission is taking the charge of the pricing reform. The State Assets Supervision & Administration Commission is taking the charge of the grids reform. And the State Electricity Regulatory Commission is taking the charge of the regulatory reform. In order to coordinate the work with those bodies, the Electric Power Reform Work Group was established in 2002 under the National Development & Reform Commission, and transferred to the jurisdiction of the State Electricity Regulatory Commission later on. Obviously, under such dispersed structure, it could be very difficult for the State Electricity Regulatory Commission to implement the reform directly, smoothly and efficiently. Such kind of thing looks especially weird in a socialist country governed by a communist party. Thus, it's necessary to establish a centralised and strong reform body to carry out the further steps of the electric power reform.

The features of the electricity price scheme in China

As mentioned above, the planned electric power sector is designed to provide a growing, stable and affordable power supply to fuel the economic development in China. It should be noticed that the plan price of the electricity takes important functions in this system. And the electricity price scheme has several unique features, shown as the following:

1) **The "dual-track" system of the coal price**

   From 1993 to 2007, the Chinese coal industry implemented a so-called "dual-track" price scheme. The coal supplied to the market directly would be charged at the market price, while the "electricity coal" supplied to the power producers would be charged at the plan price. Normally, the plan price is lower than the market price by around 21% (Energy Data 2005). Such "dual-track" system is originally designed to help lower down the electricity price. However, it's obvious that the coal producers are reluctant to fulfil the state plan of supplying the electricity coal to the power producers. Thus, the power producers have to purchase the coal from the market at the market price from time to time, so as to satisfy the rapid growth of the power demand. However, the "on-grid" price of the electricity is also under the plan of the government, which could be too low to cover the full market price of the coal. In one hand, such arrangement effectively restricted the inflation of the fuel cost and hence the electricity price of the power producers. In another hand, it also became an incentive to the power companies to build more capacity to obtain more quota of the electricity coal under the plan. Thus, the periodical power shortage and the excess capacity would co-exist in China.

2) The discriminated electricity price

Currently, the state planner categorises and sets eight different "catalogue prices" for the end power users in China. Those catalogue prices are the household price, the illuminating price (non-household), the non and common industry price, the big industry price (as "the industry price"), the commercial price, the agricultural price, and irrigation price for the poor areas and wholesale price (only applied to the local grids and certain very large enterprises). The state planner has several considerations in setting the catalogue prices. The first one is the affordability. For example, the users in poor areas may only need to pay twice as low as the common household users, and the agricultural users are paying much lower price than the industrial users. From 2000 to 2004, the industrial price increased by around 23%, while the agricultural price only increased by 11%. In another hand, the average price would be higher in the economic-developed coastal provinces and relatively lower in the poor regions in the western part of the country. For example, in 2006, the average end price in Guangdong was 2.87 Yuan/kWh, while it's only 0.58 Yuan/kWh in Qinghai. Lam (2004) studied the cross-sectional data in 1998 and found out that the regional income level in China has the positive relationship with the regional average catalogue price. The second consideration is the benefits of the small consumers. Fortunately the state planner keeps the household price at the same level with the industrial price. However, in the West, the household users' benefits could be sacrificed to keep the competitiveness of the industrial users. The third consideration is the energy efficiency. The end price is also set to in a way to encourage the energy-saving industries, and suppress the energy-consuming ones. For example, the state planner implemented the discriminated price for the cements, steel, and aluminium industries, so as to encourage the energy efficiency improvement of those industries.

3) The cost-oriented pricing

In China, the basic composition of the electricity price includes the cost, the taxation and the regulated profit margin. Lam (2004) found that there was a positive relationship between the catalogue price and the generation cost. Actually, the "one-price-for-one-plant" policy has been applied to most of the power plants in China for long time. The ex-factory price is based on the cost and the technology of a particular plant, such as the fuel cost, the transport cost, the labour cost. After 2004, the unified "pole on-grid prices" are issued and applied to the newly-built plants. The pole prices are set by the state on the basis of the average cost of the plants by the different types and regions. Nevertheless, the pole price is still a kind of cost-based price. Therefore, the individual plants in China are selling the electricity at different prices, which reflects their general cost condition in a particular region. The plan price is part the strategy of the economic development of China (Chapter 4), since the power supply is critical to the industrialisation of the country. The state has a strict control over cost-pass-through from power firms to the grid firm. Usually, it allows 70% of an increase in fuel or coal cost to be passed through to the grid firm or the end-user price.

2.6. The coal supply for the power generation in China

The supply and consumption of the coal in China

As the coal-fired power plants consist of over 77% of the total capacity in China, the coal supply is critical to the power sector and even the economic development.

Table 2.17 The Outputs of Coal in China

	Output		Net Imports/(Exports)	
	1000 Tonnes	Growth (%)	1000 Tonnes	% out of the output
1995	1,360,731		-26,982	-1.98%
1996	1,396,699	2.64%	-33,268	-2.38%
1997	1,387,531	-0.66%	-28,717	-2.07%
1998	1,332,029	-4.00%	-30,711	-2.31%
1999	1,363,997	2.40%	-35,766	-2.62%
2000	1,384,185	1.48%	-52,886	-3.82%
2001	1,471,527	6.31%	-87,469	-5.94%
2002	1,550,400	5.36%	-72,638	-4.69%
2003	1,834,899	18.35%	-82,931	-4.52%
2004	2,122,611	15.68%	-68,050	-3.21%
2005	2,349,518	10.69%	-45,553	-1.94%
2006	2,528,551	7.62%	-25,167	-1.00%
2007	2,691,643	6.45%	-2,171	-0.08%
2008	2,802,000	4.10%	-5,094	-0.18%

Source: China Energy Statistical Yearbook 2009

From 1980 to 2008, the coal output in China increased dramatically from 620 million tonnes to 2,802 million tonnes, by around four times. From 1995 to 2008, the compound annual growth rate of the coal output is around 9.64% in China. The interesting thing is that China still has a minor net export of the coal for many years, although the electricity coal is in tight supply from time to time. The net coal export reached up to around 5.9% of the total output in 2001, and then dropped to 0.08% in 2007. The self-sufficient rate of the coal supply in China is much higher than the UK. In 2008, over 71% of coal supplied in the UK can be attributed to the net imports (DUKES 2009).

Table 2.18 The Distribution of the Coal Outputs in China (2008)

Region	%	Region	%	Region	%	Region	%
Shanxi	23.02%	Sichuan	3.39%	Gansu	1.44%	Guangxi	0.16%
Inner Mongolia	17.92%	Hebei	2.91%	Jilin	1.42%	Zhejiang	0.00%
Shaanxi	8.62%	Yunnan	2.87%	Jiangxi	1.18%	Guangdong	0.00%
Henan	7.60%	Xinjiang	2.40%	Jiangsu	0.87%	Tianjin	0.00%
Shandong	4.90%	Liaoning	2.32%	Fujian	0.84%	Shanghai	0.00%
Anhui	4.16%	Hunan	2.20%	Qinghai	0.46%	Hainan	0.00%
Guizhou	4.04%	Chongqing	1.67%	Hubei	0.38%	Tibet	0.00%
Heilongjiang	3.48%	Ningxia	1.54%	Beijing	0.21%		

Source: China Energy Statistical Yearbook 2009

As mentioned above, the coal reserves in China is distributed unevenly. From the table above, we could find that the Shanxi, Inner Mongolia, Shaanxi, Henan, Shandong are top five coal-producing provinces in 2008, which altogether account for 62.44% of the total coal output in China. Most of the coal outputs are produced in the western and northern part of China. And the economic-advanced coastal provinces produce a few coal, such as Zhejiang, Guangdong, Tianjin, and Shanghai. Thus, the coal is mainly shipped from the west to the east and from north to the south in China (Ma, Oxley and Gibson, 2009).

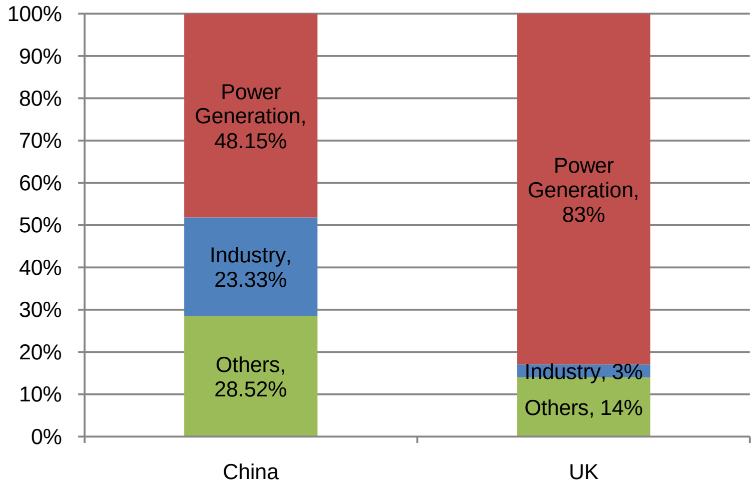

Figure 2.8 The Coal Consumption by Usage in China and the UK (2008)
Source: Chinese data from the China Energy Statistical Yearbook 2009; the UK data from the Digest of the United Kingdom Energy Statistics 2009

In China, the power generation sector consumes the largest proportion of the coal supplied. In 2008, over 48% of the coal was supplied to the power plants in China. Then another 23% of the coal was used in the industries directly. In the UK, the percentage of the coal used for power consumption is even higher. It was 83% in 2008. But the UK industries only consumed 3% of the coal directly. Thus, it implies that the UK imports the coal mainly for the purpose of power generation, while China uses its domestic coal for the electricity generation and also the industrial production.

Table 2.19 The Percentage of the Energy Production of China and the UK (2008)

	Coal	Oil	Natural Gas	Primary electricity
China	81.03%	11.28%	4.32%	3.37%
UK	15.87%	39.04%	40.07%	5.94%

Source: Chinese data from the China Energy Statistical Yearbook 2009; the UK data from the Digest of the United Kingdom Energy Statistics 2009

In another aspect, the coal is the most important energy resource in China, as it accounted for over 80% of the total energy production in 2008. But in the UK, the coal only took up 15.87% of the total energy, below the natural gas and the oil. Thus, it reveals another fact that the Chinese economic development is relies upon the supply of coal, and such reliance is much heavier than any other kinds of energy sources.

Table 2.20 The Concentration and Ownership of the Chinese Coal Industry

Concentration ratio	2000	2001	2002	2003	2004	2005	2006	2007	2008
CR4	9.54	13.56	13.71	14.65	15.59	17.47	18.3	18.85	20
CR8	14.71	20.8	20.78	21.59	23.31	24.5	25.41	26.18	27.9
Production share (%)									
Central government	53.82	55.95	50.49	47.25	47	47.61	48.01	48.15	52.27
Local government	19.44	20.18	18.88	16.25	14.86	13.55	13.72	13.41	14.72
Township	26.94	23.87	30.63	36.8	38.14	38.84	38.27	38.44	33.01

Source: Liu and Zheng (2010)

Notes: CR4 means four-firm concentration ratio, CR8 means eight-firm concentration ratio.

Despite of the rapid growth, the Chinese coal industry has a much fragmented market concentration. In 2008, the four-firm concentration ratio was only 20, and the eight-firm concentration ratio didn't exceed 30%. Compared to the situation in the UK, the top-five firms accounted for over 79% of total output of coal in 2004[7]. Nevertheless, the Chinese coal industry becomes more and more concentrated, as the CR8 rose by around 13.19% from 2000 to 2008. As the market concentration of the coal sector is smaller than the power generation sector, it implies that the large power producers should have greater bargaining power than the coal producers in the coal price negotiation. However, with the consolidation of the coal market, the bargaining power of the power producers is losing.

However, we noticed that the largest UK coal producer is much smaller than the Chinese one. In 2009, the top coal producer in the UK, UK Coal, produced 6.9 million tonnes of coal (around 40% of total output in the UK), while the top coal producer in China, Shenghua, produced 328 million tonnes of coal (around 10% of the total output in China). The output of the former one only equals to 2.1% of the

[7] Concentration ratios for businesses by industry in 2004, http://www.statistics.gov.uk/articles/economic_trends/ET635Mahajan_Concentration_Ratios_2004.pdf, visited on August 13th, 2010.

latter one. In 2009, the top US produced 189.2 million tons of coal, represents 17.6% of the total coal production. The total coal production in the US was 1.075 billion tonnes, equal to 35% of China[8]. This indicates that the market size matters for the concentration of the industry.

From Table 2.16, we also can find that the importance of the small coal mines owned by township had been increasing dramatically over the past ten years, because of the growing demand for the coal from the Chinese industries. From 2000 to 2007, the production share of the small coal mine increased from 26.94% to 38.44%. Actually, over 90% of them are small coal mines[9].

Table 2.21 Coal Mine Accidents and Deaths in China

Year	Number of accidents	Deaths	Death rate per million tons of coal
2000	2,863	5,798	5.8
2001	3,082	5,670	5.11
2002	4,344	6,995	4.93
2003	4,143	6,434	4
2004	3,639	6,027	3.01
2005	3,341	5,986	2.73
2006	2,945	4,746	1.99
2007		3,770	1.44
2008		3,210	1.18
2009	1,616	2,631	0.89

Source: State Administration of Work Safety, http://www.minesandcommunities.org/article.php?a=1155

However, there are lots of headaches associated with the small coal mines, such as the inefficiency of production, the coal mine accidents, the poor corporate governance, and the damages to the environment. From Table 2.17, we could find that China is suffering heavy casualties in the coal production. During the period from 2002 to 2004, more than six thousands of workers died in the coal mine accidents each year. It should be noticed that over 73% of the deaths come from the accidents in the small

[8] Major U.S. Coal Producers, http://www.eia.doe.gov/cneaf/coal/page/acr/table10.html, visited on 19th March, 2010.

[9] Coal power in China, http://en.wikipedia.org/wiki/Coal_power_in_China, visited on August 13th, 2010.

coal mines[10]. It's justified to say that the coal supply in China is not only paid by money, but also by lives.

Table 2.22 Number of Mines Remaining in Shanxi at the End of 2010

City in Shanxi Province	Number of mines
Taiyuan	50
Yangquan	50
Jincheng	118
Xinzhou	63
Lvliang	100
Yuncheng	18
Datong	71
Changzhi	95
Suozhou	65
Jinzhong	110
Linfeng	127
Total	867

Source: http://xz.daynews.com.cn/2009/0329/article_44868.html

Therefore, in recent years, the state plans to close and restructure the small coal mines, to improve the overall safety records, the corporate governance, and also the production efficiency. As the largest coal-producing province, Shanxi should be the first one to restructure the regional coal mines to bring down the death toll of the coal mine accidents. The state plans to consolidate the output capacity to build up large mines with safer and better facilities. It's planned to establish three enterprise groups with the output capacity over 100 million tonnes, four groups with the output capacity over 50 million tonnes, and ten groups with the output capacity over 10 million tonnes. The coal mines with the output capacity below 900 thousand tonnes, and the coal companies with the output capacity below 3 million tonnes are all ordered to be closed. Thus, the total coal mines have been reduced from 4,878 in 2003 to 2,598 in 2008, and only 1,000 mines will remain at most by the end of 2010[11]. From the point of view of the whole country, more than 12 thousands small coal

[10] http://cn.chinagate.cn/economics/2009-01/20/content_17156964.htm, visited on August 13th, 2010.
[11] http://xz.daynews.com.cn/2009/0329/article_44868.html, visited on August 14th, 2010.

mines have been closed since 2005[12]. According to Table 2.17, the death toll has been reduced to 2,631 in 2009, by around 63% since 2002. And the death rate per million tonnes of coal was only 0.89, which was the lowest record in the past ten years. However, it's reasonable to expect the raise of the coal price in future, as the state is building dominant coal suppliers who would naturally and easily gain the market power under the market mechanism, if in the absence of proper regulation.

The reform of the coal price in China

Generally speaking, the reform of the coal industry in China experienced five stages towards a market mechanism[13].

[12] http://msn.biz.smgbb.cn/MsnFinance/postPage/2009/09/18/posting_common_7c7c0b4a-c0c2-4d97-8f50-9b492bb155c8_1.shtml, visited on August 13th, 2010.

[13] http://xcyszx.blog.163.com/blog/static/316139200912562623264/, visited on August 14th, 2010.

Table 2.23 The Timeline of the Coal Price Reform in China

Period	Pricing mechanism	Pricing regime
1949 – 1992 Stage 1	**Plan mechanism**	1) Ministry of Coal Industry; 2) State Pricing Bureau
1993 – 1997 Stage 2	**Dual-track system** Gradual introduction of the market price with the exception of the electricity coal, of which the price was set by the state planner.	1) State Development and Planning Committee; 2) Annual Electricity Coal Convention; 3) The government coordination
1998 – 2001 Stage 3	**Dual-track system** Further development of the market mechanism	
2002 – 2006 Stage 4	**Dual-track system** 1) Market price with gradual abolishment of the state guidance price 2) Encouraging the meetings between the supply and the demand sides	National Development and Reform Commission
2007 – 2008 Stage 4	The abandonment of the National Annual Coal Price Negotiating Conference	
2009 – Stage 5	The cancelation of the 2010 Coal TV Conference	

Source: http://xcyszx.blog.163.com/blog/static/316139200912562623264/

Until 1992, the quota and the price of the coal output are in the hand of the government, i.e. the Ministry of Coal Industry and the State Pricing Bureau. After 1992, the market-oriented reform of the coal industry was launched in China, and the power of the Ministry of Coal Industry was transferred to the State Development and Planning Committee. The market price of coal was also introduced into practice, in order to tie in with the price reform at that time. But, the plan price of the electricity coal was retained. The price of the electricity coal was negotiated on the Annual Electricity Coal Convention, under the guidance price set by the State Development and Planning Committee, with the governmental coordination. Such kind of the pricing mechanism is known as dual-track system. From 1998 to 2001, the state carried out further development of the market mechanism in the coal industries. In the stage four, the state guidance of the electricity coal was relieved gradually and the negotiated price between the supply and demand sides was encouraged by the government. However, the government still took significant effect upon the negotiation between the supply and demand sides upon the price of the electricity coal, where the price cap would be put to restrict the sudden jump of the price of the electricity coal. During this period, the National Development & Reform Commission took the regulatory responsibility. In 2007, the "National Annual Coal Price Negotiating Conference" was abandoned, and replaced by the coal TV conference instead, which was cancelled by the NDRC two years later. Since 2009, the market price has been fully applied to the coal industry, and the government declared the cease of the control over the price of the electricity coal.

Table 2.24 The Price of the Coal and Electricity in China (1997-2004)

	1997	1998	1999	2000	2001	2002	2003	2004
Average market coal price (Yuan/Tonne)	166	160	142	140	150	167	178	206
Average electricity coal price (Yuan/Tonne)	137	133	121	120	123	137	145	161
Differences (Yuan/Tonne)	*29*	*26*	*21*	*19*	*27*	*30*	*33*	*44*
Differences %	*21.17%*	*19.55%*	*17.36%*	*15.83%*	*21.95%*	*21.90%*	*22.76%*	*27.33%*
Average electricity price (Yuan/kWh)				0.37	0.38	0.40	0.43	0.46
Growth of the average electricity coal price %		*-2.92%*	*-9.02%*	*-0.83%*	*2.50%*	*11.38%*	*5.84%*	*11.03%*
Growth of the industrial electricity price %					*2.15%*	*6.04%*	*5.70%*	*7.29%*

Source: the coal price from Lin, Dong and Li (2004), and the electricity price from the Electricity Market and Electricity Prices Monitoring Report 2005

Such decentralised and market-oriented reform of the coal industry attempts to foster a free competitive environment to boost the coal supply to support the rapid economic growth in the past two decades. However, it's reasonable to expect a great rise in the coal price for the power generators if the governmental price control would be fully removed. As mentioned above, the guidance price of the coal was gradually abolished since 2002. And it clearly shows that the growth of the electricity coal price jumped from 2.50% in 2001 to 11.38% in 2002. In another aspect, because of the governmental control, the growth of the electricity price from 2001 to 2004 was always lower than the coal price, despite of the coal-power linkage. For example, in

2002, the former one was lower than the latter one by 5.34%. Actually, the market coal price is lower than the electricity coal price by around 21% on average, due to the government control. If the government loses the control over the price of the coal supplied to the power producers, it's very likely that the power generators would face considerable pressure of the fuel price hikes immediately. According to the National Bureau of Statistics of China[14], over 40% of the power producers made losses in early 2008, when the coal industry achieved an average profit growth of 66.8%. Moreover, the State Grid Corporation of China only achieved a profit of 9.66 billion RMB in 2008, i.e. a sharp decrease of 75% from 2007, and would face a further loss of 45 billion RMB in 2009, due to the conflicts between the coal price and the electricity price[15]. That's why Lin (2004) advocated the full lift of the price control over the on-grid price and the end price, so as to pass the inflation of the coal price to the electric power users and then secure the profit of the entire electric power sector.

The current issue and future's actions

In order the deal with the conflicts between the coal industry and power industry, there are several options that could be considered by the state:

1) The monitoring of the coal price and the regulator's intervene

The regulator will intervene to the market if the coal price grows to an unacceptable level that will treat the survival of power companies. On December 17th, 2009, the NDRC cancelled the 2010 coal TV conference, which was interpreted as a major step towards a thorough coal market. However, in March 2010, the NDRC announced the new of pushing the build of the pricing indexes of the electricity coal. It implies that the government attempts to strengthen, rather than to loose, the monitoring of the coal price, although the NDRC emphasised that coal price should be determined by the direct negotiation and agreement between the supply and demand parties.

[14] http://info.electric.hc360.com/2008/04/11084363228.shtml, visited on August 15th, 2010.
[15] http://news.qq.com/a/20090313/000054.htm, visited on August 15th, 2010.

Actually, there was no substantial agreement has been reached between December 2008 and June 2009, because of the conflicts of the coal price. Thus, the NDRC raised the non-residential prices of electricity by around 5.4% from November 2009 to relief the losses of the grid companies[16]. In the early 2010, the coal supply shortages stroke China, and it pushed the NDRC to intervene the coal price negotiation again. It's reported that the agreed coal price in 2010 would be 30 Yuan/Tonne higher than the corresponding figure of last year on average (Liu and Zheng, 2010). The massive closure of the small coal mines could be the reason for such coal supply shortage. It also implies that the governmental intervene would be still essential for the coal industry and electricity industry at the current stage of reform.

2) The integration of the power and coal producers

The integration of the power and coal industries could be another possible option to deal with the conflicts of the coal price. The so-called Huai-Hu Model is a good example. The Shanghai Power Company, which is a subsidiary of China Power Investment Corporation (known as "CPI"), established the Huai-Hu Coal-Electricity Corporation, a joint venture with the Huainan Mine Group[17]. The new joint venture also includes the Tianji Power Plant and the Tianji Coal Mine. The whole group achieved remarkable performance, while other power producers were suffering losses because of the hikes of the coal price (Liu and Zheng 2010). The China Power Investment Corporation was inspired from this Huai-Hu Model, and takes a series of projects of the vertical integration, such as the coal, electric power, the aluminium. The China Power Investment Corporation also extends the investment into the railway and freight industries to achieve greater profitability.

3) The changes of the electric power structure

The best way of lowering the price of the electricity coal should be from the demand

[16] http://uk.reuters.com/article/idUKTOE5BE04K20091215?pageNumber=2&virtualBrandChannel=0, visited on August 15th, 2010.
[17] http://energy.people.com.cn/GB/8862669.html, visited on August 15th, 2010.

side. The power companies should reduce usage of the coal for the power generation, by shifting the future's investment from the conventional coal-fired plants to the clean energy resources, such as the hydro power, nuclear power and wind power. It would effectively eliminate the bargaining power of the coal producers. Unfortunately, the capacity share of the hydro and nuclear power declined from 24.31% in 1998 to 22.85% in 2008. One of the reasons could be the construction period. The coal-fired plant would only take about two to three years to complete, while the hydro and nuclear plant would take seven to eight years.

2.7. Summary

Through the overview of the Chinese power sector, it clearly shows that the state has been taking a series of reform towards a market-oriented electric power sector gradually. At the moment, the Chinese electric power sector is not the same with the traditional plan mechanism. In the current transitional period, the market behaviour and the state plan are mixed together in order to secure a stable, fast growing and affordable electric power supply for its fast economic development.

For the past three decades, the Chinese power industry has been featured by free investment and the plan price. The "welcome policy" over investment is designed to attract the social resources for the capacity expansion of the power generation to create a solid support and foundation for its industry-oriented development. The plan price is designed to promote outputs of the industries at the lowest possible costs, and also to protect the household benefits in China. Perhaps, these two fundamental phenomena in the power sector explain the concept of "socialism with Chinese characteristics".

There are several implications from the investigation into the Chinese power sector. First, the investments into grids facility are relative insufficient, compared to the investments into the generation sector. So, more investments into the power sector are needed to ease the problem of the capacity allocation, resulted from the uneven distribution of the energy resources. Second, a certain degree of the vertical and horizontal integration could be necessary, in terms of gaining the economy-of-scale for the whole industry. Third, the relief of the price cap on the on-grid and end electricity price could easily save the profit of the power sector from the coal price inflation. However, such kind of the action would again damage the benefits of the end users obviously. So, it should be carefully designed, where the governmental monitoring and intervene would be required during such process.

So far, the Chinese power supply looks healthy, and has good performance in the capacity expansion, the stability of the supply, and the protection of consumer's welfare. However, new challenges remain for the Chinese power producers, such as the environmental concerns, the conflicts of coal and electricity prices, the production efficiency, and the potential strikes by the global economic risks. Thus, it's important to understand the industrial background of the Chinese power sector for future.

Chapter 3. The Cost and Price Structure of the Chinese Power Supply

3.1. Introduction

In the early 1990s, China started to restructure its plan supply of electricity in aim of developing a competitive electricity market. Power generators have been separated from the grids and became independent power producers. In 2002, the Big 5 power company groups in China were created and their subsidiaries are listed either domestic or overseas stock markets respectively to attract private capital investment. Electricity supply in China increased by 2.36 times in capacity and 2.65 times in output respectively, during the period from 1990 to 2005. By the year 2004, China became the second largest electricity producer just behind the US in the world. In 2004, OECD and China together produced 70.72% of the fossil-fuel electricity and 69.50% of the total electricity of the world (Electricity Information 2006, IEA).

However, compared with the electricity market in the UK, known as British Electricity Trading and Transmission Arrangements (BETTA), the electricity sector in China has still been controlled by state plan at present. Unlike many other liberalised industries in China, electricity prices and production have still been controlled directly by the National Development and Reform Commission (NDRC) of China in Beijing and its provincial offices throughout China.

It's a consensus for economists that a plan economy would not be helpful for technology progress, leading to production inefficiency and the relatively higher costs of goods supplied, especially the institutional costs and expenses. By contrast, the market promotes competition and thereby stimulates innovation, improve productivity and cost efficiency. However, such positive expectation may not appear if market fails, in particular, when market is highly concentrated and the firms abuse their market power. In particular, market failure can damage total outputs and technology progress.

It seems to be true in the natural monopolistic sector, such as electricity industry. The high electricity prices would damage the end-users' benefits and the inadequate liquidity would result in the even fatal problem, for example, the closure of the wholesale market. By the previous studies, the negative influences of the abused market power have already been identified in the electricity market. Before the failure of California's electricity market, Borenstein and Bushnell (1999) predicted that "large firms" in California's electricity market "might have an incentive to restrict output to raise price" with their simulation. After the failure of California's electricity market in 2001, Chi-Keung Woo (2001) in his study concluded that "if electricity market reform is not done in an environment of surplus capacity, many sellers and easy market entry, it will not yield the desired outcome of reliable service at low and stable prices." Besides, Bimanis and his fellows (2003) studied the reform of Virginia's electricity market and declared that one of the four major electricity producers in Virginia "withheld a significant amount of power" and so "the market clearing price was extremely high".

Not only does the US electricity market suffer the problem of high electricity prices charged by the dominant participants in the market, but also the European countries have the similar problem. Sweeting (2004) directly pointed out that "generators exercised increasing market power in the England and Wales wholesale electricity market in the second half of the 1990s despite declining market concentration." Ofgem also reported the cases of the abuse of the market power in 1997/98. The two biggest power generators, i.e. National Power and PowerGen, were found that "significantly increased the price at which they offered their coal-fired station into the Pool over the period May to July 1999". All those show the fact that the liberalised market may be lost its expected effectiveness and drive the price higher than what it should be.

Nevertheless, most previous studies (Woo, 2001; Cocker, Lundberg, 2005; Bradley, Yang, 2006; Sweeting, 2007; Wang, 2007; Yao, Liu, Wu, 2007; Cai, Jiang, 2008) share the common belief that the effective system of the electricity sector should provide reliable electricity supply at the affordable prices with the high energy efficiency. In order to achieve those objectives, it doesn't matter for the regulator of the electricity industry to choose a reformed plan-supply mechanism or market supply via competition, as long as the supply is more effective and efficient.

Through the comparison of the price structure between China and the European power plants, this chapter attempts to address the question whether the reformed plan-supply mechanism or the market supply is more superior and effective in terms of the achievement of those objectives described above. With the lesson learnt from the European electricity market, our arguments are made for advantages and disadvantages of market supply, when compared with Chinese reformed plan supply.

This chapter includes six parts. The first part is the introduction of this chapter. The second is review of previous studies and the background of both the European and China electricity supply. The third is the comparison of both the household and the industrial electricity prices between the OECD countries and China, so as to reveal problems of the wholesale electricity market. The fourth attempts to figure out the market problem from the point of view of the structure of the electricity sectors in both the UK and China. The fifth is the comparison of the decomposed cost between the UK and Chinese cases. The last part concludes and reveals the implication for the further reform of the Chinese electricity sector.

3.2. Background, existing literature and current arguments

The reform of the Chinese electricity sector has been carried out since the 1980s. Some studies draw the outline of the background and the history of Chinese electricity market (Li, Dorian, 1995; Andrews-Speed, Dow, 2000; Hafsi, Tian, 2005; Xu, Chen 2006; Yao, Bin, Wu 2006; Hang, Tu, 2007; Yang, 2008). Wu and Li (1995) also advocated the liberalisation of the electricity industry in China, so that the tariffs would be able to increase to a sufficiently high level to attract more investment and also improve the energy efficiency. From the point of view of the reform history, Hafsi and Tian (2005) made a general conclusion that the reform of Chinese electricity industry "cannot be separated from the transformation of the whole country", where privatisation and liberalisation should be introduced. Wang (2007) also argued that the plan economy of the Chinese electricity sector, which suppressed the prices of electricity coal, should be removed, so that the price of the electricity coal can be increased freely according to the demand and supply equilibrium on the market. However, in order to ascertain the further steps to build the market-oriented reform in Chinese electricity sector, the lessons from the European countries cannot be ignored.

With a belief in China thatmarket can be the panacea to cure all the problems in the economy, the study of the California electricity market gives the belief with different experience that the market mechanism may also fail (Woo, 2001; Hogan, 2002; Woo, Lloyd, Tishler, 2003). In the California case, the extremely high prices followed by the rolling blackouts stroke the whole energy system in the region. So far, the deregulation of the electricity market in the UK has been the most stable reform in the OECD countries, although it's not perfect. Some studies tried to prove that the new design of the wholesale market in the UK would meet the original expectation to remove the problems found in the previous periods. In 2003, Ofgem declared the observed drop of the wholesale electricity prices by 40% after the introduction of the

NETA in 2001, and attributed it to the market competition promoted by the decentralised trading arrangement and many other various reasons, such as falling fuel prices, less demand and cheap investment expenditures (National Audit Office, 2003). The report of Ernst and Young (2006) also declared the observed instant fall of the generation cost and the spark spreads, which implies the decreasing electricity prices in the wholesale market after 2001.

However, it may be too early to draw the conclusion that the UK full-liberalisation-oriented reform is successful, as the wholesale price in the UK increased again after 2002. In other words, it means that the new design of the wholesale market may not be able to meet its original expectation to provide the reliable supply at the low price. Green and McDaniel (1998) declared that the additional cost of the market reform would be transferred from the generators to the end users through the electricity prices. Some other researches tried to explain the problem from the point of view of the market power which has prevailed in the UK electricity for a long time. Wolak and Patrick's argued (1996) that in order to maximise the gains, the dominant large firms would increase the electricity pool price by declaring the unavailable supply in certain periods. Sweeting (2007) measured the market power by the comparison between system marginal price and estimated bench mark marginal cost. The evidence shows that the abuse of the market power would become even more serious when the market concentration varies. Besides, Ofgem (1999) also reported the case of the abuse of the market power by the two dominant players in 1999, in which this was found by comparing the electricity prices with the previous period.

As to the retail market, Thomas (2003) studied the UK electricity sector before and after the introduction of the NETA, and found that the reform of the UK electricity market didn't protect the benefit of the small consumers as expected. Although the UK small consumers have the right to change their retailers, the high switch costs hindered those small consumers, and the small consumers were also unable to exerted sufficient pressure to the retailers to gain the fair price of the electricity. Thomas also estimated the price for small consumers in the UK and found that it should be 30% lower than the actual price. Graham (2006) also made the plausible conclusion that the reform of the UK electricity market didn't make the disadvantaged consumers worse than before, which implies that the reform has not significantly improved the small consumers' benefits at least. In OXERA's report (2004), both the wholesale and the retail prices were investigated through the comprehensive comparison of the aggregated data between the UK and the G7 during the period from 2003 (historical figures) to 2009 (projected figures). And they found that the generation cost has a great influence on the inflation of the wholesale price in the UK, and the introduction of the competition would raise the cost of the retailers. It argues that the other G7 countries except the UK would face the high inflation of the retail price in the future, because the competition in the retail market in the UK had been relatively high.

A series of studies by Pollitt proved that the privatisation of the power sector without proper regulation would harm the outputs of other industries. With the social cost-benefit analysis, Newbery and Pollitt (1997) studied the UK electricity market reform and declared that the power generators could "gain more than the cost reduction" after the introduction of the Electricity Pool, but "the consumers and government lose". Domah and Pollitt (2001) admitted that "for the first few years following privatisation, real prices, profits and costs in the industry rose", and after the implementation of the strict regulation, "prices have now fallen sharply and there have been substantial reductions in costs and more recently in profits." By 2005, Jamasb and Pollitt (2005) carried out the comprehensive studies on aggregated data of the EU electricity sectors, and declared to observe the overall decline trend in the wholesale prices, which is consistent with the expected gains from the EU electricity market reform.

Arguments drawn from studies above may be partial and limited since they are made on the basis of the UK and other OECD experience that has a common feature — a market-based approach. It would be interesting if we can make international comparison of UK experience with the Chinese experience that takes a very different approach to manage power supply. Through the comparison of the cost and price structures among different countries under different economies over a certain period, it will be able to draw a new view of the electricity industries through this West-East comparison. And then it will provide us with something meaningful for further thinking about how to reform our power industry on both the Chinese and Western side.

3.3. Overview of the Chinese power supply with reference to the UK

3.3.1. The electricity supply in China with reference to the UK

In 2009, the gross consumption of electricity in China reaches 3643 TWh, which has increased by 27.43% since 2006. Unlike China, the UK electricity supply is much smaller. The gross power consumption in the UK was only equivalent to 13.3% of the Chinese power consumption in 2006 and 9.8% in 2009, which means that the difference of the electricity supply between China and the UK would become bigger.

Over the past two decades, the fluctuation of the UK power supply is much flatter than China. Since 1990, China achieved remarkable economic development, where its average annual GDP growth is around 10%. In 1992, the GDP growth in China was soaring to 14%. During this period, Chinese power supply achieved an average annual growth at 9.8%, with two peaks of growth. In 1992, the Chinese power supply reached its first peak of growth at around 11.3%. After that, it started to drop and then reached the lowest level at 2.8% in 1998. In 2002, the Chinese electricity industry entered the fourth stage of the reform, and the electricity supply growth started going up again, and reached the second peak of growth at 16% in 2003. In the same year, China also achieved strong GDP growth, i.e. at around 10%. By contrast, the UK economic growth is around 2% over the past two decades, while the UK power supply growth is only 0.78% on average and never exceeded 5%. In 2009, the real GDP and the power supply growth of the UK dropped by 4.9% and 5.5% respectively. Obviously, the growth of the power supply in China is much faster than the UK. It also indicates that the reform carried out in China has been successful in stimulating the supply of the power to the economy.

Table 3.1 The Comparison of Electricity and GDP Growth between China and the UK

	Gross Power Consumption				Real GDP			
	China		UK		China		UK	
Year	Index	Annual Growth	Index	Annual Growth	Index	Annual Growth	Index	Annual Growth
1990	100.00		100.00		100.00		100.00	
1991	108.74	8.74%	102.47	2.47%	109.20	9.20%	98.64	-1.36%
1992	121.05	11.32%	101.88	-0.57%	124.71	14.20%	98.83	0.20%
1993	134.24	10.90%	102.97	1.06%	142.17	14.00%	101.13	2.33%
1994	148.93	10.94%	104.66	1.64%	160.79	13.10%	105.59	4.41%
1995	160.88	8.02%	108.02	3.21%	178.36	10.93%	108.61	2.86%
1996	172.77	7.39%	112.83	4.45%	196.19	10.00%	112.18	3.28%
1997	181.12	4.83%	112.54	-0.26%	214.44	9.30%	115.66	3.10%
1998	186.16	2.78%	114.79	2.00%	231.16	7.80%	119.83	3.61%
1999	197.49	6.09%	116.97	1.90%	248.73	7.60%	123.99	3.47%
2000	216.24	9.49%	120.05	2.63%	269.63	8.40%	128.84	3.91%
2001	236.32	9.29%	121.06	0.84%	292.03	8.31%	132.01	2.46%
2002	264.28	11.83%	121.22	0.13%	318.61	9.10%	134.78	2.10%
2003	305.46	15.59%	122.39	0.97%	350.48	10.00%	138.58	2.82%
2004	352.65	15.45%	123.10	0.58%	385.90	10.10%	142.40	2.76%
2005	400.30	13.51%	124.46	1.11%	426.05	10.40%	145.33	2.06%
2006	458.85	14.63%	123.26	-0.96%	475.49	11.61%	149.46	2.84%
2007	525.04	14.43%	122.58	-0.55%	537.36	13.01%	153.97	3.02%
2008	554.40	5.59%	122.18	-0.32%	585.98	9.05%	155.06	0.71%
2009	584.71	5.47%	115.45	-5.51%	636.96	8.70%	147.43	-4.92%

Source: the Chinese power data from the National Bureau of Statistics of China, the UK power data from the Department of Energy and Climate Change of the UK; The real GDP from the UN data.

Note: Year 1990 = 100; The gross power consumption equals to the power consumption of all industries plus the transmission losses

3.3.2. The installed capacity in China with reference to the UK

The total capacity of Chinese power plants was 442,387.3 MW in 2004, composed of 105,242 MW hydro generators, 329,483 MW coal-fired generators and 6836 MW nuclear generators. The total capacity has increased by 50,964 MW, with an annual growth of 13.2%, since 2003 (the hydro power capacity increased by 10,344 MW, 13.02%, coal-fired power capacity increased by 39,700 MW, 13.7%). In 2004, the capacity of hydro, coal-fired and nuclear power took up 24.6%, 73.72% and 1.55% of the total installed capacity respectively (Chinese Electricity Statistics 2005). The coal-fired power capacity takes the major part out of the total capacity of electricity generation.

By contrast, the capacity mix of the UK power plants was much diversified than Chinese power plants. In 2004, the gas-fired, the coal-fired generators and the nuclear plants took up 33%, 37% and 16% of the total generation capacity in the UK, while the coal-fired plants took up 74% of the all installed capacity in China. There is almost no gas-fired power station in Chinese power supply.

Over the past 10 year's development, the mix of the power capacity in the UK has been changed a lot, but in China, the coal-fired power plants still dominated in electricity generation. In the UK, the CCGT out of the total installed capacity increased from 18% in 1996 up to 33% in 2005, by around 2 times during the 10 years. And the proportion of the UK conventional generators reduced from 45% in 1996 to 37% in 2005. However, the proportion of the coal-fired plants against the total capacity in China kept unchanged around 76% over the 10 years.

Table 3.2 The Comparison of Generation Capacity Mix between China and the UK

	China				UK				
Unit: MW	Total	Hydro	Coal-fired	Nuclear and others	Total	Hydro	Coal-fired	CCGT (Gas-fired)	Nuclear and others
1996	236540	55580	178860	2100	68860	4101	31276	12052	12986
1997	254240	59730	192410	2100	68140	4099	31243	12252	13016
1998	277290	65070	209880	2340	68312	4115	29587	14618	13064
1999	298770	72970	223430	2370	70245	4115	29711	16110	13073
2000	319320	79350	237540	2430	72193	4115	29034	19349	12603
2001	339490	83010	253010	3470	73382	4136	29034	20517	12603
2002	356570	86070	265550	4950	70369	4092	26568	20260	12357
2003	391400	94900	289770	6730	71465	4055	26991	22037	11969
2004	440700	108260	324900	7540	73277	4058	27054	23783	11969
2005	508410	116520	384130	7760	74041	4061	27235	24373	11969
Unit: %	Total	Hydro	Coal-fired	Nuclear and others	Total	Hydro	Coal-fired	CCGT (Gas-fired)	Nuclear and others
1996	100%	23%	76%	1%	100%	6%	45%	18%	19%
1997	100%	23%	76%	1%	100%	6%	46%	18%	19%
1998	100%	23%	76%	1%	100%	6%	43%	21%	19%
1999	100%	24%	75%	1%	100%	6%	42%	23%	19%
2000	100%	25%	74%	1%	100%	6%	40%	27%	17%
2001	100%	24%	75%	1%	100%	6%	40%	28%	17%
2002	100%	24%	74%	1%	100%	6%	38%	29%	18%
2003	100%	24%	74%	2%	100%	6%	38%	31%	17%
2004	100%	25%	74%	2%	100%	6%	37%	32%	16%
2005	100%	23%	76%	2%	100%	5%	37%	33%	16%

Source: the Chinese data from the National Bureau of Statistics of China, the UK data from the DTI.

3.3.3. The supply structure of electricity in China with reference to the UK

The total electricity generated in China increased up to 3255.9 TWh, by 13.68% for 2007. In 2007, the hydro plants, the coal-fired plants and the nuclear plants generated the electricity of 486.7 TWh, 2698 TWh and 62.6 TWh respectively, with the growth rate of 16.80%, 14.45% and 15.29% respectively. There was no significant drop of the proportion of the electricity generated by the coal-fired plants over the 10 years. And in 2007, the coal-fired power plants still took up 82.9% of the electricity supplied in China.

Unlike China, the significant change of structure of the power generation in the UK has taken place for the past 15 years. In 1990, coal-fired power stations generated 77% of the electricity in the UK. Another 21% of total electricity was generated by nuclear power stations. However, in 2005, coal-fired power stations only maintained 39% of the total electricity generation and 38.6% of the electricity is supplied by gas power stations. The nuclear power stations still hold 19%, which is almost the same with 14 years ago.

The utilisation of the generators in China is slightly higher than in the UK, in which in 2004 the average load factor in the UK and China was 54.7% and 56.6% respectively. For efficiency in coal-fired power stations, according to the data from Wang (2005) and DTI's website, in 2004, the coal-equivalent consumption rate of the UK and Chinese coal-fired power plants was 346 g/kWh and 376 g/kWh respectively, in which the UK had been slightly better than its Chinese counterpart.

Table 3.3 The Comparison of Electricity Supply Mix between China and the UK

	China				UK				
GWh	Hydro	Coal-fired	Nuclear & other	Total	Hydro	Coal-fired	Nuclear	CCGT (Gas-fired)	Total
1990	126,300	495,000	0	621,300	7,082	234,101	58,664	280	300,128
1991	124,800	552,700	0	677,500	6,071	233,325	62,761	607	302,764
1992	131,500	622,700	0	754,200	7,046	221,265	69,135	3,358	300,804
1993	150,700	683,100	2,600	836,400	5,673	193,969	80,979	23,195	303,816
1994	166,800	747,000	14,100	927,900	6,451	185,021	79,962	37,553	308,987
1995	186,800	807,300	12,800	1,006,900	6,286	183,567	80,598	49,458	319,909
1996	186,900	878,100	14,300	1,079,300	5,340	174,665	85,820	68,962	334,787
1997	194,600	925,200	14,400	1,134,200	6,227	147,664	89,341	90,874	334,106
1998	204,300	938,800	14,600	1,157,700	7,540	149,001	90,590	98,162	345,293
1999	212,900	1,004,700	15,500	1,233,100	8,958	135,262	87,672	119,553	351,445
2000	243,100	1,107,900	17,500	1,368,500	8,609	147,394	78,334	126,428	360,764
2001	261,100	1,204,500	18,300	1,483,900	7,339	147,192	82,985	129,875	367,392
2002	274,600	1,352,200	27,400	1,654,200	8,584	141,013	81,090	139,433	370,120
2003	281,300	1,579,000	44,900	1,905,200	7,141	153,213	81,911	139,190	381,454
2004	328,000	1,807,300	51,700	2,187,000	9,410	145,289	73,682	151,331	379,713
2005	395,200	2,018,000	61,500	2,474,700	9,621	150,519	75,173	147,920	383,232
%	Hydro	Coal-fired	Nuclear & other	Total	Hydro	Coal-fired	Nuclear	CCGT (Gas-fired)	Total
1990	20.33%	79.67%	0.00%	100%	2.36%	78.00%	19.55%	0.09%	100%
1991	18.42%	81.58%	0.00%	100%	2.02%	77.06%	20.91%	0.20%	100%
1992	17.44%	82.56%	0.00%	100%	2.35%	73.56%	23.04%	1.12%	100%
1993	18.02%	81.67%	0.31%	100%	1.89%	63.84%	26.98%	7.73%	100%
1994	17.98%	80.50%	1.52%	100%	2.15%	59.88%	26.64%	12.51%	100%
1995	18.55%	80.18%	1.27%	100%	2.09%	57.38%	26.85%	16.48%	100%
1996	17.32%	81.36%	1.32%	100%	1.78%	52.17%	28.59%	22.98%	100%
1997	17.16%	81.57%	1.27%	100%	2.07%	44.20%	29.77%	30.28%	100%
1998	17.65%	81.09%	1.26%	100%	2.51%	43.15%	30.18%	32.71%	100%
1999	17.27%	81.48%	1.26%	100%	2.98%	38.49%	29.21%	39.83%	100%
2000	17.76%	80.96%	1.28%	100%	2.87%	40.86%	26.10%	42.12%	100%
2001	17.60%	81.17%	1.23%	100%	2.45%	40.06%	27.65%	43.27%	100%
2002	16.60%	81.74%	1.66%	100%	2.86%	38.10%	27.02%	46.46%	100%
2003	14.76%	82.88%	2.36%	100%	2.38%	40.17%	27.29%	46.38%	100%
2004	15.00%	82.64%	2.36%	100%	3.14%	38.26%	24.55%	50.42%	100%
2005	15.97%	81.55%	2.49%	100%	3.21%	39.28%	25.05%	49.29%	100%

Source: the Chinese data from the National Bureau of Statistics of China, the UK data from the DTI.

3.3.4. Summary

By comparing the structure of the power supply between the UK and China, it seems to suggest that environmentally there are no much differences between the two economies. China has 16% of its power supply from renewable sources, such as hydro power, and the UK has only 3.27%. The lower part of power supply from renewable energy is supplemented by nuclear energy in the UK, taking a quarter of total UK power supply. By contrast, China only has 2.5%, but growth of power supply from the nuclear energy has been higher, and we expect that it will increase further over time. China does not develop gas-fired power technology, which is right, because China has rich coal resources that enable the nation to obtain low-cost energy to power its economic growth at a low cost. Moreover, China that sticks with coal can reduce world reliance on gas and so be good to remain stable demand for gas, which can benefit the stability of price or cost of power for gas energy. In this sense, we argue that the structure of power supply is very much affected by the resources of an economy. In particular, the resource impact is more significant when the size of an economy is large.

3.4. Electricity supply of price comparison: OECD versus China

The market-oriented reform in the European countries was pioneered by the UK experiment of the Electricity Pool in 1991, where the liberalisation and privatisation were introduced in the electricity sector. It's globally believed that the market competition would be the magic cure for the problems caused by the notorious centralised plan economy. However, as mentioned by the previous study, the market may also fail in restricting the abuse of the market power asserted by the dominant firms in the industry. The figures and tables blew present the household and the industrial prices in the OECD member countries and China, during the period from 2000 to 2004. By comparison, it will show a relative level of electricity prices in China, against other market economies. It will also reveal the different market environments between the liberalised market and planned supply.

In different countries, the end-use electricity prices could be classified into various categories by different measurements. However, the household and industrial prices of the electricity are prevailing and comparable among most countries in the world. In OECD, the household price is referred to the retailing price of the electricity for small consumers, and the industrial price is referred to the wholesale price set among the power generators, retailers and large consumers. In China, the household price and the industrial price are all referred to the catalogue prices. The two electricity prices could vary from each other, because of the structure of the electricity industries. The two electricity prices in different countries may also be different, due to various reasons, such as competition, production costs and regulation.

3.4.1. Household electricity prices

Compared with the OECD members, the electricity for household consumers in China is one of the cheapest out of the 30 selected countries. During the period from 2000 to 2004, the household price of OECD Europe on average is around 2.5 times as much as the price in China. Before 2002, the electricity for household use in China was the second cheapest one to Norway. In 2003 and 2004, the household price in China was the lowest, while the price in Denmark became the highest out of those countries. In 2004, the household electricity tariff in China was 0.4467 Yuan/kWh, i.e. only 19.1% of the price in Denmark which was 2.3423 Yuan/kWh, 39.1% of the price in the UK which was 1.1422 Yuan/kWh, and 44.6% of the average price of the OECD members which was 1.0015 Yuan/kWh.

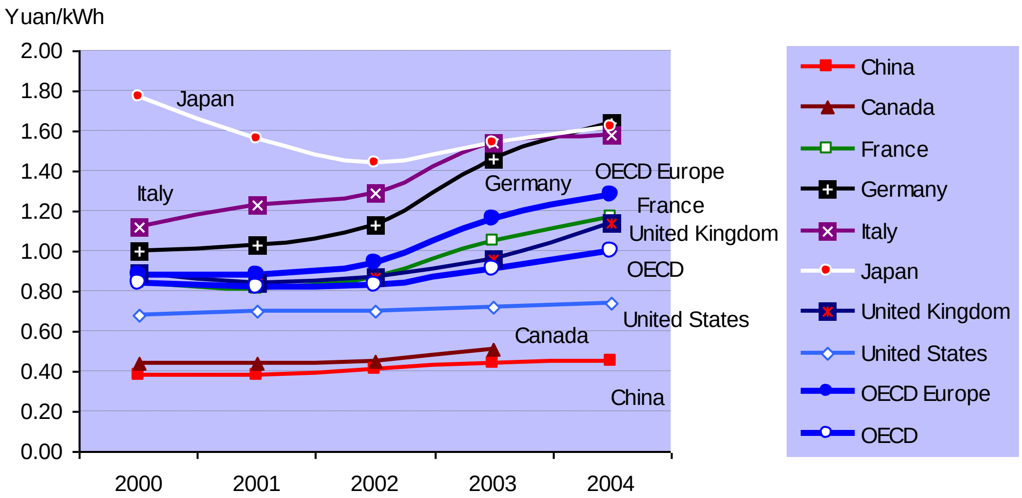

Figure 3.1 Household Electricity Prices (nominal) in OECD and China

Source: 1) The OECD data of the electricity prices are collected from IEA, Electricity Information 2006; 2) the Chinese data are collected from Electricity Market and Electricity Prices Monitoring Report 2005; 3) The data of exchange rate are collected from DataStream.

Besides, the growth of the household price in China was one of the lowest out of the 30 selected countries during that five-year's period. As shown in Figure 3.1, from 2000 to 2004, the household electricity price in China increased by 17.86%, only above Japan (-8.43%), Korean (-5.97%) and United States (9.73%). Such a growth rate of China was smaller than many other countries, such as the UK at 28.67%, Hungary at 110.73%, Norway at 115.58%, and Slovak at 167.95%. It's also below the growth rate of the OECD Europe (46.2%) and OECD total (19.78%).

Compared with those European countries, China had a relatively low level and also a low growth rate of the household electricity. As shown in Figure 3.1, unlike China, some European countries, such as Denmark and Netherland, had both a high level and a high growth rate of the household price. It implies that the difference of the household price between China and those European countries would become larger.

The prices could also be expressed by using each country's purchase power parity conversion factor. The purchasing power parity (PPP) conversion factor, known as the real exchange rate, takes into account the element of the differences in the relative prices of products and services in different economies, which could provide a better measure to compare the real value of the outputs of different countries. The prices of the 30 countries are converted into the Chinese Yuan equivalents by multiplying the PPP conversion factors provided by the International Monetary Fund.

When considering the PPP factors, the household electricity price in China becomes one of the highest out of the group of those countries, only next to Denmark after 2002. In 2004, the household price in China was the second highest at a level of 0.45Yuan/kWh. In 2004, the household electricity price in Denmark reached an equivalent level of 0.57 Yuan/kWh. As shown in Table 3.5, in 2004, the average household prices of the OECD Europe and OECD total were equivalent to 0.31 Yuan/kWh and 0.24 Yuan/kWh, i.e. 68.9% and 53.3% of the household price in China respectively. In the same year, the household price in the UK ranked the 14th highest out of the 30 countries, at a price of 0.28 Yuan/kWh, which was 37.8% lower than the price in China.

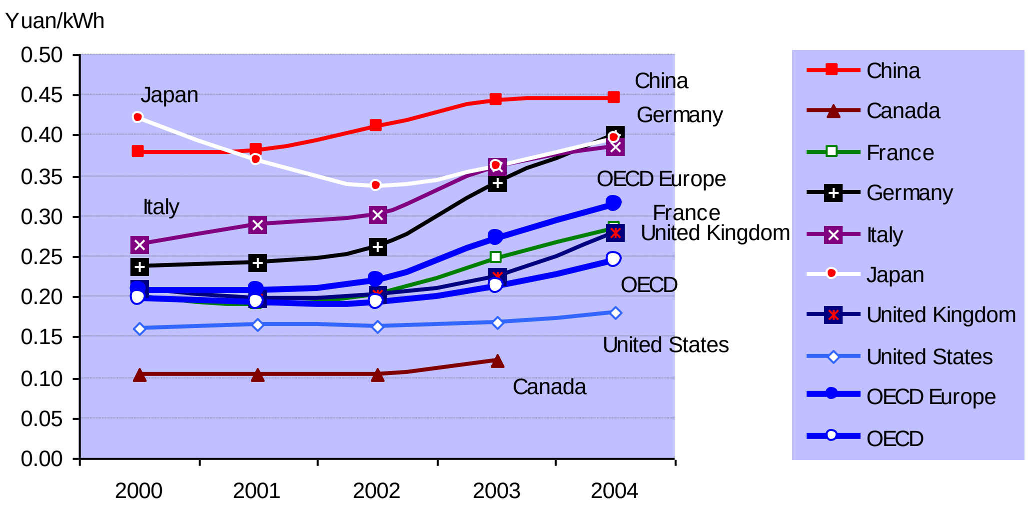

Figure 3.2 Household Electricity Prices (by Purchase Power Parity) in OECD and China

Source: 1) The OECD data of the electricity prices are collected from IEA, Electricity Information 2006; 2) the Chinese data are collected from Electricity Market and Electricity Prices Monitoring Report 2005; 3) The data of exchange rate are collected from DataStream; 4) the Purchase Power Parity conversion rates are collected from the International Monetary Fund, "World Economic Outlook Database April 2007".

As shown in Figure 3.2, the household price in China was not cheap relative to both the purchasing power of consumers and their income level. It also implies that the burden of power for the household users in China was much heavier than most other countries in the world, although the electricity price in China was low in a nominal term.

3.4.2. Industrial electricity prices

As shown in Figure 3.3, the electricity for the industrial use in China was still one of the lowest out of those selected countries. In 2004, the industrial price in China was round 49% of the average price of the OECD Europe and 38% of the average price of the OECD total. In 2004, the industrial price in the UK (0.5545 Yuan/kWh) was 1.21 times of China (0.4570 Yuan/kWh). The industrial prices in Italy and Japan were the two highest out of those OECD members during the five-year's period. In 2004, the Italy (1.3326 Yuan/kWh) and Japan (1.0512 Yuan/kWh) industrial prices were 2.92 and 2.30 times of the price in China. However, the industrial price in some other countries were lower than China, such as South Korea (0.4387 Yuan/kWh), New Zealand (0.4221 Yuan/kWh), Norway (0.3559 Yuan/kWh), United States (0.4387 Yuan/kWh) and France (0.4138 Yuan/kWh).

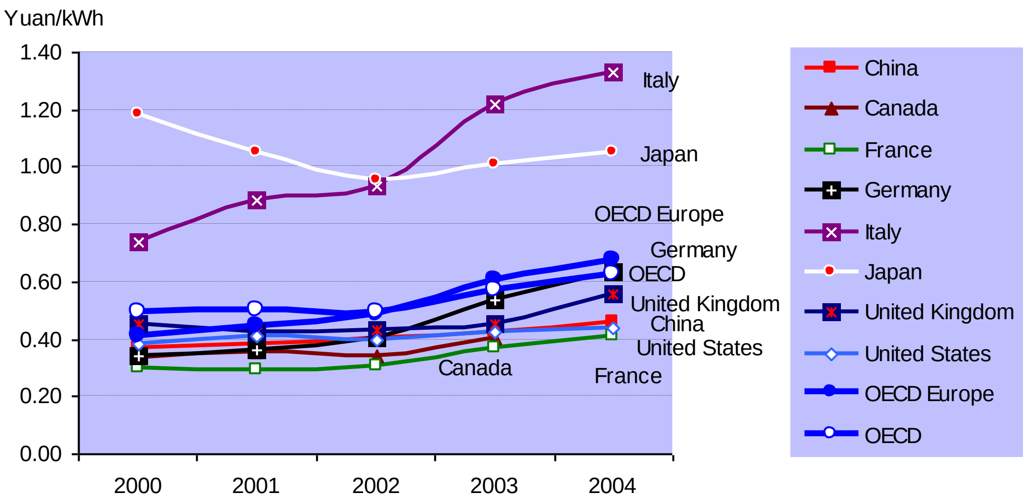

Figure 3.3 Industrial Electricity Prices (Nominal) in OECD and China

Source: 1) The OECD data of the electricity prices are collected from IEA, Electricity Information 2006; 2) the Chinese data are collected from Electricity Market and Electricity Prices Monitoring Report 2005; 3) The data of exchange rate are collected from DataStream.

From 2000 to 2004, the industrial prices in all those countries increased except Japan, of which the industrial prices decreased by 11.21%. The industrial prices in China and UK increased by 22.85% and 21.79% respectively during that period. The growth of the industrial prices in China was also below the growth rate of the OECD Europe (63.97%) and the OECD total (26.64%). This implies that the growth rate of the industrial price in China was still kept at a relatively low level.

Jamasb and Pollitt (2005) in their studies upon the Electricity Market Reform in the European Union point out that "the overall trend of price decline … is not inconsistent with the anticipated benefits of the implementation of the Electricity Directives." However, their view might be contradictory to the fact that the nominal industrial and household prices of the OECD Europe increased by 63% and 40% respectively during the period from 2000 to 2004. In the UK, the pioneer of the liberalisation of the electricity market, the industrial and household prices inflated by 21% and 29%

during that period. Those evidences indicate that the liberalisation of the electricity market in Europe actually didn't meet its expectation of a slow increase in the price. Compared with the OECD members, China had the relatively lower household and industrial prices in nominal term, and also the smaller inflation rate of the electricity prices, when compared to the UK and OECD average. Moreover, our comparison shows that the industrial prices in China was much closer to the OECD members, we find no evidence that the Chinese manufacturing industry enjoys a lower power cost than their Western counterpart.

3.4.3. Comparing the household price with the industrial price

Table 3.7 shows the ratio of the household to industrial prices. If such ratio is larger than one, it implies that the domestic price is higher than the industrial price or vice versa. The average ratio in China during the five years is only around 1.01, the lowest one among the 30 countries. It means that the two prices in China were almost the same during that period. It indicates that the social benefits of the household users in China are protected by the Chinese plan pricing scheme. However, it's exactly a reverse phenomenon in the Western countries, where the benefits of the large industrial users are protected at the expense of the small household users.

In contrast, Denmark had the highest ratio in 4 years. In 2004, its ratio reached up to 2.95, which means that the household price was almost three times as much as the industrial price. The ratio in the UK has been around 2 for the five years, which implies that the household consumers would pay twice as much as the industrial consumers for the electricity. In 2004, the average ratios of OECD Europe and OECD total were 1.89 and 1.59 respectively, both higher than the ratio of China.

Such ratio of the OECD Europe shrank from 2.12 to 1.89 over the five years, which implies that the two prices started to get close with each other. However, in the UK, the ratio enlarged from 1.95 to 2.06, which indicates that for the household as the group of small users, their benefits have not been well cared by the market liberalisation.

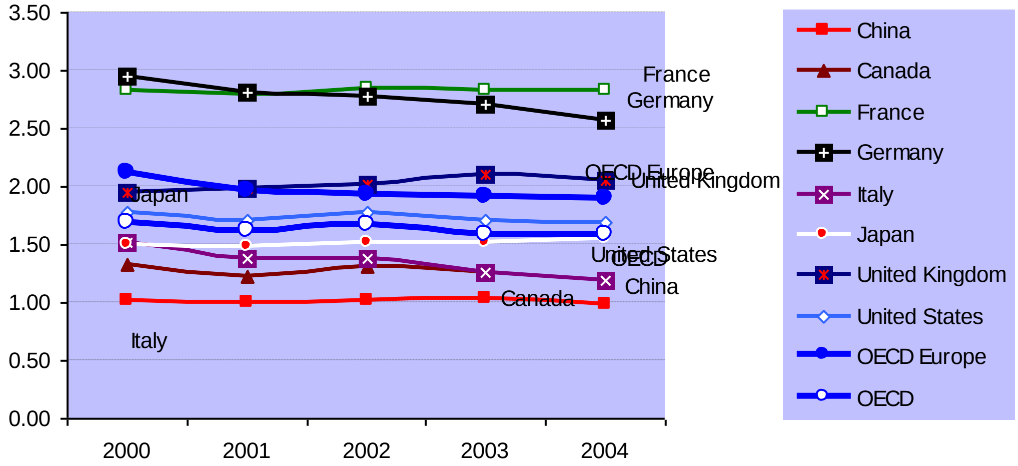

Figure 3.4 Household to Industrial Electricity Prices of OECD and China

Source: 1) The OECD data of the electricity prices are collected from IEA, Electricity Information 2006; 2) the Chinese data are collected from Electricity Market and Electricity Prices Monitoring Report 2005; 3) The data of exchange rate are collected from DataStream.

3.4.4. Summary

From the historical data presented in Table 3.4 and 3.6, it's clearly shows that electricity prices in China stayed at the relatively lower level when compared with the OECD countries in a nominal term. It also reveals a fact that the household electricity price was as low as the industrial price in China. Pun-Lee Lam (2004) argued that "electricity prices in China were highly subsidized and below the average total costs of generation and transmission." If it were true, it would imply that the grid would be subsidised by the Chinese government in order to protect the small users' benefit. We will address this point in a few pages later.

In another aspect, household prices relative to industrial prices were still high in European countries. In the UK, such big difference between the two electricity prices continued even after the introduction of NETTA (New Electricity Trading and Transmission Arrangements) in 2001. A large number of the small electricity consumers in the UK paid much higher prices when compared with the industrial users. Despite the introduction of market competition, the household users couldn't enjoy the lower price as same as the industrial users. Such problem would indicate certain kind of the ineffectiveness of the electricity market in the UK. It implies that the market reform in the UK didn't achieve the Pareto improvement, at least, not in the power market.

However, if measured by the purchase power parity, the electricity price in China was higher than other countries (Table 3.5). It means that compared with the OECD member countries, it could be more expensive for the users in China in terms of the affordability of electricity. In order to mitigate the affordability problem for low income households, the government subsidises them directly by cutting price down at almost more than 2 times of the industrial price.

The comparison of costs between China and the UK indicates that, first, the Chinese industries do not pay cheaper electricity than Western industries. Secondly, the Chinese non-commercial users like households are charged for use of electricity at discriminated prices according to income or affordability. The plan price serves income discrimination rather than balancing demand and supply for effective resources allocation.

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Table 3.4 Electricity Prices for Household of OECD and China

	Household Electricity Prices in Yuan/kWh		Average Rank in Descending Order
	2000-2003	2004	2000-2004
Denmark	1.77	2.34	1
Japan	1.58	1.62	2
Netherlands	1.29	1.83	3
Italy	1.29	1.58	4
Germany	1.15	1.64	5
Portugal	1.08	1.45	6
Austria	1.07	1.46	7
Belgium	1.09	N/A	8
Spain	0.99	1.26	9
Ireland	0.93	1.43	10
Switzerland	0.97	1.18	11
Luxembourg	0.94	1.22	12
France	0.89	1.17	13
United Kingdom	**0.89**	**1.14**	**14**
Turkey	0.77	0.92	15
Finland	0.73	1.02	16
Hungary	0.65	1.13	17
United States	0.70	0.74	18
Poland	0.67	0.85	19
Greece	0.65	0.89	20
Slovak Republic	0.59	1.11	21
Mexico	0.67	0.74	22
New Zealand	0.59	0.99	23
Korea	0.62	0.65	24
Czech Republic	0.57	0.80	25
Australia	0.53	0.74	26
Norway	0.44	0.57	27
Canada	0.46	N/A	28
China	**0.40**	**0.45**	**29**
Sweden	N/A	N/A	NA
OECD Europe	0.96	1.28	
OECD	0.85	1.00	

Source: 1) The OECD data of the electricity prices are collected from IEA, Electricity Information 2006; 2) the Chinese data are collected from Electricity Market and Electricity Prices Monitoring Report 2005; 3) The data of exchange rate are collected from DataStream.

Note: 1) The "e" means that the figure is estimated by linear method; 2) The "NA" means that the figure is not available; 3) The taxation is included in the electricity price.

Table 3.5 Electricity Prices for Household of OECD and China, measured by Purchase Power Parity

	Household Electricity Prices in Yuan/kWh measured by PPP 2000-2003	2004	Average Rank in Descending Order 2000-2004
Denmark	0.42	0.57	1
China	**0.40**	**0.45**	**2**
Japan	0.37	0.40	3
Netherlands	0.30	0.45	4
Italy	0.30	0.39	5
Germany	0.27	0.40	6
Austria	0.25	0.36	7
Portugal	0.25	0.35	8
Belgium	0.26	N/A	9
Spain	0.23	0.31	10
Ireland	0.22	0.35	11
Switzerland	0.23	0.29	12
Luxembourg	0.22	0.30	13
France	0.21	0.28	14
United Kingdom	**0.21**	**0.28**	**15**
Turkey	0.18	0.22	16
Finland	0.17	0.25	17
Hungary	0.15	0.28	18
United States	0.17	0.18	19
Poland	0.16	0.21	20
Greece	0.15	0.22	21
Slovak Republic	0.14	0.27	22
Mexico	0.16	0.18	23
New Zealand	0.14	0.24	24
Korea	0.15	0.16	25
Czech Republic	0.13	0.20	26
Australia	0.12	0.18	27
Norway	0.10	0.14	28
Canada	0.11	N/A	29
Sweden	N/A	N/A	N/A
OECD Europe	0.23	0.31	
OECD	0.20	0.24	

Source: 1) The OECD data of the electricity prices are collected from IEA, Electricity Information 2006; 2) the Chinese data are collected from Electricity Market and Electricity Prices Monitoring Report 2005; 3) The data of exchange rate are collected from DataStream; 4) the Purchase Power Parity conversion rates are collected from the International Monetary Fund, "World Economic Outlook Database April 2007".

Note: 1) The "e" means that the figure is estimated by linear method; 2) The "NA" means that the figure is not available; 3) The taxation is included in the electricity price.

Table 3.6 Industrial Prices of OECD and China (USD/KWh)

	Industrial Electricity Prices		Average Rank in Descending Order
	2000-2003	2004	2000-2004
Japan	1.05	1.05	1
Italy	0.94	1.33	2
Turkey	0.73	0.83	3
Switzerland	0.60	0.70	4
Portugal	0.59	0.77	5
Denmark	0.58	0.79	6
Ireland	0.58	0.79	7
Austria	0.31	0.79	8
Hungary	0.49	0.74	9
Mexico	0.46	0.64	10
Netherlands	0.48	N/A	11
Slovak Republic	0.42	0.69	12
United Kingdom	**0.44**	**0.55**	**13**
Germany	0.41	0.64	14
Czech Republic	0.40	0.55	15
Finland	0.38	0.60	16
Australia	0.40	0.50	17
Korea	0.41	0.44	18
Greece	0.39	0.52	19
United States	0.40	0.44	20
Poland	0.39	0.50	21
China	**0.40**	**0.46**	**22**
Spain	0.38	0.50	23
Belgium	0.40	N/A	24
Canada	0.36	N/A	25
France	0.32	0.41	26
New Zealand	0.28	0.42	27
Norway	0.25	0.36	28
Luxembourg	N/A	N/A	N/A
Sweden	N/A	N/A	N/A
OECD Europe	0.49	0.68	
OECD	0.52	0.63	

Source: 1) The OECD data of the electricity prices are collected from IEA, Electricity Information 2006; 2) the Chinese data are collected from Electricity Market and Electricity Prices Monitoring Report 2005; 3) The data of exchange rate are collected from DataStream.

Note: 1) The “e” means that the figure is estimated by linear method; 2) The “NA” means that the figure is not available; 3) The taxation is included in the electricity price.

Table 3.7 Household to industrial electricity prices of OECD and China

	Household to Industrial Electricity Prices		Average Rank in Descending Order
	2000-2003	2004	2000-2004
Denmark	3.10	2.95	1
France	2.82	2.82	2
Germany	2.81	2.57	3
Belgium	2.75	N/A	4
Spain	2.57	2.53	5
Austria	3.11	1.84	6
Netherlands	2.38	N/A	7
New Zealand	2.14	2.35	8
United Kingdom	**2.01**	**2.06**	**9**
Finland	1.93	1.71	10
Portugal	1.83	1.88	11
United States	1.74	1.70	12
Poland	1.73	1.72	13
Norway	1.72	1.60	14
Ireland	1.65	1.80	15
Greece	1.68	1.70	16
Switzerland	1.61	1.67	17
Japan	1.50	1.54	18
Korea	1.51	1.49	19
Czech Republic	1.43	1.47	20
Slovak Republic	1.39	1.61	21
Mexico	1.46	1.17	22
Hungary	1.33	1.54	23
Australia	1.33	1.48	24
Italy	1.39	1.19	25
Canada	1.28	N/A	26
Turkey	1.06	1.11	27
China	**1.02**	**0.98**	**28**
Luxembourg	N/A	N/A	N/A
Sweden	N/A	N/A	N/A
OECD Europe	1.98	1.89	
OECD	1.64	1.59	

Source: 1) The OECD data of the electricity prices are collected from IEA, Electricity Information 2006; 2) the Chinese data are collected from Electricity Market and Electricity Prices Monitoring Report 2005; 3) The data of exchange rate are collected from DataStream.

Note: 1) The "e" means that the figure is estimated by linear method. 2) The "NA" means that the figure is not available. 3) The taxation is included in the electricity price.

3.5. The market structure of China's power supply with reference to the EU and the UK

As a further measure to liberalise the electricity market in European Union, the Electricity Pool in the UK was introduced in 1991. After that, the members in the European Union started to open their electricity markets one after another. In February 1997, the EU Directive 96/92/EC came into force, which required all of EU members to deregulate their electricity markets and allow all the customers to choose their suppliers no later than the year 2007. In 2003, according to the figures of the International Energy Agency, the electricity amounted 320 TWh was traded in all of Western European electricity markets. By the year 2004, within the European Union, 13 regional electricity exchange markets have been established, such as NETA in England and Wales, Powernext in France, EEX in Germany, GME in Italy and the cross-board Nord Pool in Scandinavia. Moreover, those regional markets are still under the continued development to achieve the ultimate objective of building up an integrated pan-European market.

3.5.1. The market structures and reform in EU

In general, each existing regional electricity market in the EU can be divided into two parts, i.e. the wholesale and retail market. The two markets are opened to the different participants. And the electricity in the different two markets would be traded at different prices. Besides, the generation, transmission, and distribution of the electricity are separated to some extent, so that the competition on the market could be encouraged.

(a) The UK electricity market structure

The electricity market in the UK is a kind of typical example. The UK wholesale market, known as British Electricity Trading and Transmission Arrangement (BETTA), was established in April 2005. Unlike the previous Electricity Pool, which was criticised for its non-transparency (Powell 1993), the centralised pricing mechanism has been removed from the market under BETTA. As shown in Figure 3.5, the commodity of the electricity could be traded within and between the power generators, large customers and the regional retailers directly, which would promote the competition in the market. In the wholesale market, the cheap industrial price is prevailing.

The retail market in the UK is constituted by small customers and the retailers. The small customers have the right to choose their electricity suppliers (the retailer). However, according to the estimation by OFGEM, the costs of the businesses in the industry could be up to £580 million, including “adapting their operating procedures and IT systems to the new wholesale arrangements”, and the additional operational costs for the participants annually would be up to £30 million (National Audit Office UK, 2003). It obviously shows that such wholesale and retail markets are not built up without costs, and these additional trading costs will be ultimately paid by the users of electricity. For those small customers can only buy the electricity from the 7 regional retailers, rather than the power generators directly, because they are lack of the access to the wholesale market. Such kind of arrangement makes the prices in the retail market higher than the wholesale market, which costs more for the small customers.

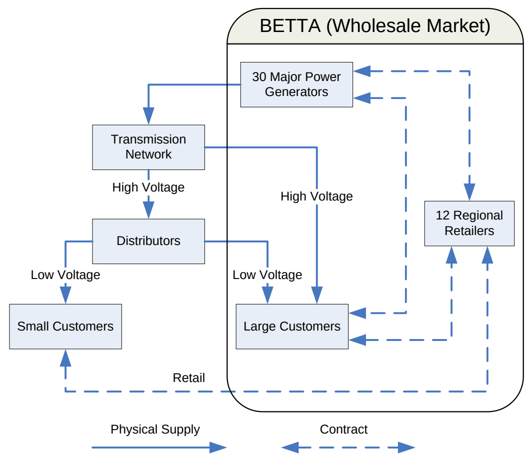

Figure 3.5 Electricity Industry Structure in the UK
Source: Based on the information from "The Digest of United Kingdom Energy Statistics 2006"

Moreover, the additional transaction costs of "market trading" may also reduce the economic welfare as a whole (Green and McDaniel 1998). The overall effect of the reform of the electricity industry in the UK could be unambiguous, just as the plausible conclusion made by Graham (2006) that "the introduction of privatisation and greater reliance on market mechanisms has not made the material position of disadvantaged consumers worse as regards these industries".

(b) The comparison between France and UK electricity market

In contrast to the UK market, the French electricity market started to be liberalised in the year 2000 and adopted a similar structure in the UK. The market is divided into a wholesale and retail part as well. However, there are still some differences between the UK and France electricity market. By the year 2004, 100% of the market in the UK has been opened to the competition, while in France only 68% of the market has been opened to the traders and industrial users. In 1999, all customers in the UK were able to choose their electricity retailers, which enhanced the market competition (DUKE 2007). As a result, since April 2002, the price controls upon the 12 regional retailers in the UK have been lifted. In contrast, from July 2004, the traders and industrial users in France, who don't renegotiate their contracts with their suppliers, are still able to buy the electricity at the prices set by the government. At the end of the year 2004, around 50% of the customers chose to enjoy the state regulated prices. The most important reason for Energy Regulation Commission (CRE) to delay the full market liberalisation has been the higher concentration of the electricity generation sectors in France. In 2003, EDF (Electricite de France) took up around 80% of the electricity market in France, although other 20 competitors enlarged their market share up to 18.5% of the eligible electricity market. When compared with France, the concentration ratio of the electricity production and distribution sectors in the UK is much smaller. In the year 2004, the top five businesses took up 55% of the total output in the UK market. The total number of the major power producers also has grown up since the liberalisation, from 7 in 1990 to 30 in 2006. Compared with the electricity market in the UK, the French market has not been opened to the full competition, due to its monopolistic structure. In contrast, the concentration of the electricity generation sector in China is much smaller than the UK. There are big 5 central-government-owned power companies taking around 40% of total electricity supply in China and the rest is shared by local-government-owned power firms and a few non-state owned firms.

(c) The liberalisation of the wholesale market

Does the liberalisation drive down prices in the wholesale market? In 2003, OFGEM observed around 40% of the wholesale price decline during the period from 1998 to 2001, and then declared that the reasons would be the decentralised trading mechanism and many other factors "such as falling fuel prices, a large margin of capacity over demand and increased competition in generation ownership." (National Audit Office, 2003) Moreover, according to the report issued by Ernst & Young in 2006, the decreased generation costs and spark spreads, and the improved capacity utilisation and labour productivity were observed, alongside the liberalisation of the electricity market. They also found the fall in the prices due to the increasing competition.

As shown in Figure 3.3, from 2000 to 2002, the wholesale prices in the UK indeed dropped 6.4%. However, such prices decline didn't last for long and started to increase again after the year 2002. By 2004, the wholesale price in the UK has increased by 28.3%. Besides, Sweeting (2007) also declared that, despite the reduced market concentration, the power generators exerted considerable market power upon the England and Wales wholesale electricity market, in the late 1990s. The increase of the wholesale price also happened in other European markets. The wholesale prices in France, Germany and Italy increased by 32%, 89% and 81% during those four years respectively (Figure 3.3). It is clear about the viewpoint that the unbundling of the electricity generation, transmission and distribution could impair the overall industrial outputs under some circumstance (Meran 2004). A huge rise in price raises a question about the introduction of fully-liberalised market in the power sector to protect small consumers' benefits in the long run.

(d) The impact of the competition upon the power generators

Although a long-term price trend remains ambiguous, the effect of competition upon the short-term profit margin of those generators is clear. After the introduction of the NETA in the UK, some power generators encountered the financial difficulties and were unable to recover their capital costs. Such decline of the profit margin of the market competitions would eventually become the driver for the horizontal and vertical market integration. On the contrary, in the era of the Electricity Pool, the power generators could "gain more than the cost reduction" (Newbery and Pollitt 1997). As mentioned in DTI's report (DUKE 2007), "since the late 1990s, there have been commercial moves toward vertical re-integration between generators, electricity distribution and/or electricity supply businesses." Such integration was also observed in Germany during the process of market liberalisation and it has driven the electricity prices increasing dramatically (Green 2006). Green in his paper (2006) concluded that "If a formerly regulated industry is liberalised, the increase in competition raises the rewards to size. Mergers are generally the easiest way to make a company larger." The tactic collusion between the power producers may eventually lead to the growing prices and then damage the benefits of other market participants. However, Green (1996) argues that such mergers would take effect on the retailing market, rather than "the competition in generation itself", because of the use of the long-term contracts, which are normally as long as 15 years in the UK.

(e) The small customers on the retail market

Table 3.8 Indicative Cost Breakdown for Household and Industrial & Commercial Customers (2002)

	Percentage of Price (%)		Costs and Prices (¥/kWh)		Percentage Difference between Household and I&C
	Household	I&C	Household	I&C	
Generation	40	60	0.35	0.26	26%
Transmission	3	5	0.03	0.02	18%
Distribution	25	24	0.22	0.10	53%
Retail (supply)	26	11	0.23	0.05	**79%**
Other	6	0	0.05	0.00	100%
Price	100	100	0.87	0.43	**51%**

Sources: 1) "Gas and Electricity Price Projections", OXERA, 2004, 2) "The New Electricity Trading Arrangements in England and Wales", National Audit Office, 2002-2003: 9 May 2003, Page 19-20, 3) "Electricity Information 2006", IEA and 4) the calculation is based upon the information above.

To the retail market, there is no doubt that the small end-users have to pay much higher than the large consumers. The retail price not only includes the cost of the power generation, transmission and distribution, but also the mark-up of the suppliers. As shown in Table 3.8, the costs of retailers (suppliers) take up 26% of the household prices on average, which will be passed on to the small users, while the retail costs only take up 11% of the industrial prices. Compared by the unit cost between the household and industrial prices, the unit distribution and the retail costs undertaken by the household users are higher than the industrial users by 53% and 79% respectively. And even the unit generation and transmission costs of the household tariff are higher than the industrial one by 26% and 18% respectively. Eventually, it results in the average household price higher than the industrial & commercial price by 51%.

Although the small customers have the right to change the retailers, the high trading costs make them unable to join in the wholesale market to buy the cheap electricity.

Besides, the concentration of the retailing market increased during the process of the liberalisation. Before the liberalisation of the retail market, 14 regional electricity retailers provided the services in their franchise area at controlled price. However, after 2001, there are only 7 electricity retailers on the competition market. When the small customers choose the retailers, they find that actually they won't have many choices.

On the other hand, because of the market liberalisation, the market exchange costs will occur, which will be passed onto the end-users, especially the small users. Domah and Pollitt (2001) observed "the per-unit revenue of the distribution and supply business increased by an average of 22%", compared to the pre-privatisation-period level, at the early stage of the reform of the regional electricity companies in the UK. Unlike the large consumers, the small customers have limited ability to avoid the increasing prices of the retailed electricity. Due to various reasons, over 60% of the customers haven't changed their retailers by 2002 (National Audit Office, 2003). In Germany, only 5% of the small users have changed their retailers since the liberalisation (Reisch, Micklitz 2006). Eventually, those additional transaction costs will largely passed onto the small customers.

Combined with the factor of the increasing fuel prices, it's almost impossible for the small users to benefit from market liberalisation in the retail sales of electricity. From Figure 3.1 in the previous part, it clearly shows that the household prices increased by 28% in the UK and was almost 2 times as much as the industrial prices. The retail market in the UK clearly fails to promote benefits for the group of small users of electricity.

3.5.2. Market structure and reform in China

As shown in Figure 3.6, the Chinese electricity industry remains under a reformed planning system. Currently, unlike many other industries in China, the electricity industry is still heavily regulated by the government via plan. The competition has not yet been introduced in selling power, but in capacity expansion, after decades of economic reform.

(a) The independent power producers in China

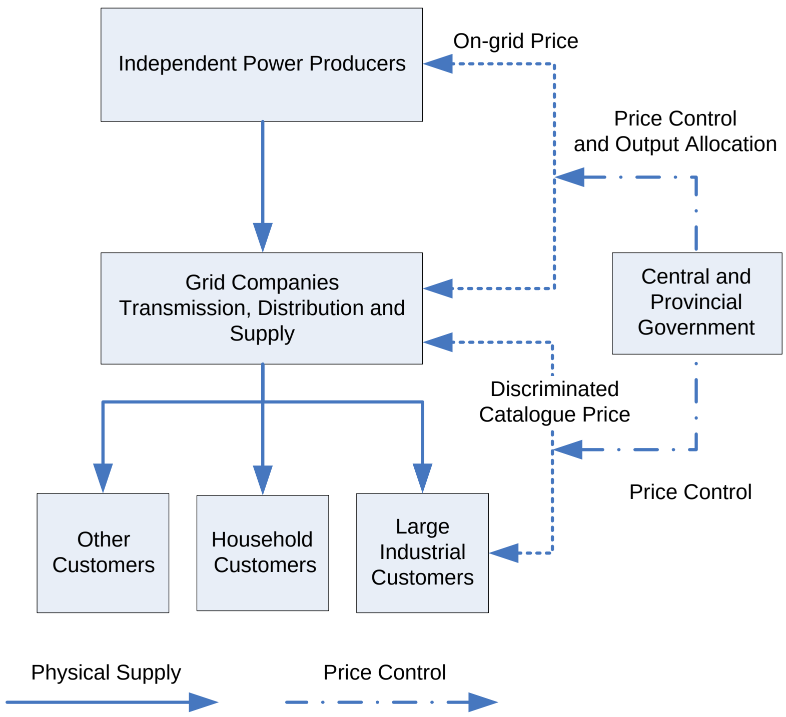

Figure 3.6 Electricity Industry Structure in China

Source: Based on the information from "Bing Wang, An imbalanced development of coal and electricity industries in China, Energy Policy 35 (2007) 4959–4968" and Chinese Electricity Market and Tariffs Monitoring Report 2005, and author's own observation

By 2004, the majority of the power generators have been separated from the grids and became independent power producers, although some studies (Ring and Read 1996) believe that vertical integration of the generation and transmission could achieve the perfect coordination. In 2004, the grids only held 2% of the total capacity in China (Capgemini 2005). "The internal transfer prices" and the "on-grid prices" apply to the grid-owned and the independent power producers (IPPs) respectively. At present, both the price and production volume for each power plant are set by the government. The on-grid price, paid by the grid companies to the IPPs, is calculated by various rules and specific formula which is set up by the state, in order to take into account variable costs, fixed capital costs and the profit margin for those IPPs. Under such state arrangement, the "on-grid" prices of those individual power plants, which could be different from each other, sell their output to the grid company at the agreed plan price that is what we observe so-called "on-grid price" in China.

(b) The catalogue prices in China

Table 3.9 Catalogue Prices in China

¥/MWh	2000	2001	2002	2003	2004
Big Industrial Uses 1)	372	380	NA	426	457
Common & Non-Industrial Uses 2)	430	520	NA	583	614
Household Uses 3)	379	380	NA	443	447
Lighting Uses (non-household) 4)	500	590	NA	620	776
Commercial Service Sector Uses 5)	670	690	NA	754	643
Agricultural Sector Uses 6)	329	330	NA	359	365
Irrigation Uses in Low-income Regions 7)	146	150	NA	156	166
Sales in excess of Plan 8)	328	330	NA	351	374
Average	376	396	410	435	458

Source: Electricity Market and Electricity Prices Monitoring Report 2005

Notes: The catalogue 1) applies to the one, of which the capacitor exceeds 315 kV, 2) applies to the one, of which the capacitor is below 315 kV, the government departments and the public services providers, 3) applies to the residents, kindergartens, schools and rest homes, 4) applies to the users of the signal lamp, the street lamp, the arc lamp and the neon light, 5) applies to the business services providers, 6) applies to those involved in the farming activities, 7) applies to the low-income counties, and 8) refers to the prices of the traded electricity in excess of plan.

Although the power generation has been separated, the power transmission, distribution and supply are still bundled together, of which those roles are taken by the two grid companies in the nation. The prices of the electricity sold to the end-users can be classified into several catalogues, big industrial use, non-industrial use, commercial use, domestic use, lighting use, agricultural use, poor counties irrigation use, and retails. Those catalogue prices will be different from each other. As mentioned in the previous section, the prices of the industrial and domestic use in China are very close, compared with the situation of other countries. From Table 3.9, it shows that the price of the poor counties irrigation use is the lowest all the time and only around 25% of the commercial-use price. From 2000 to 2004, the price of the industrial use increased by 23%, while the agriculture-used price only raised by 11%. It clearly shows that, under the price control, the prices of the domestic use, the agricultural use and the poor counties irrigation use are subsidised, in a form of "price-cut" rather than "cash-back". It's kind of evidence of which electricity prices are used to serve income distribution for the social justice.

(c) The controlled coal prices for the power generation in China

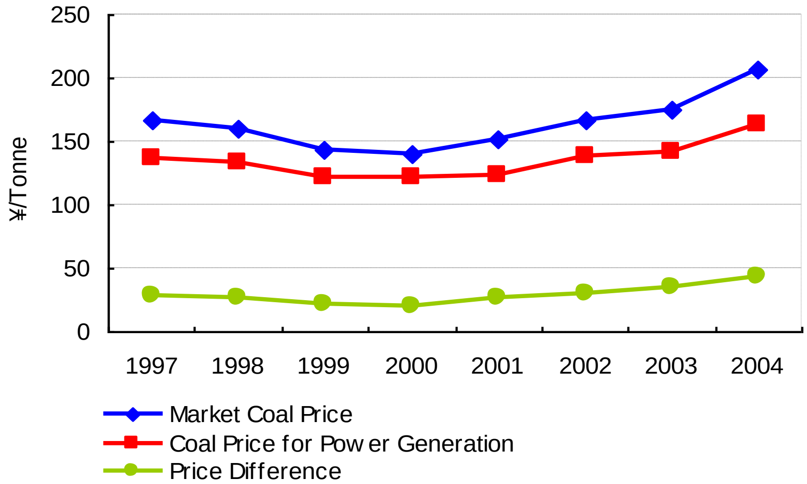

Figure 3.7 The Gap between the Average Market Coal Prices and Electricity Coal Price in China

Source: Energy Data 2005

Not only are the electricity prices under the control, but also the prices of the coal for the power generation are regulated as well. Although the coal market has been liberalised since 1993, the prices of the coal for the electricity generation (so called electricity coal) are still set by the government. As shown in Figure 3.7, from 1997 to 2004, the market prices of the coal is higher than electricity coal with a similar trend of price movement. During that period, the two coal prices increased by 24% and 18% respectively. However, the prices of electricity coal are lower than the market prices by 28.95 Yuan/Tonne, i.e. around 21% on average. In the year 2004, the gap between the two prices jumped up to 43.92 Yuan/Tonne, i.e. by 27%. It implies that the prices of the electricity coal were suppressed heavily by the government, in order to relieve part of the cost pressure for the power plants.

3.5.3. Summary

Both in the European countries and China, the reforms of the electricity industries have been carried out through the vertical unbundling. The vertical separation of the European electricity industries has been implemented in depth, and the competition has also been introduced into both the wholesale and retail markets. In contrast, China only has the power generators split off from the grid companies. And so far, there is neither the wholesale nor the retail electricity market has been fully liberalised in China.

In both China and the UK, the electricity prices and the fuel costs grew up in recent years. However, from the comparisons above, it clearly shows that neither the market competition nor planned economy can absolutely drive down the growing prices incurred by the inflated fuel costs. Fortunately, under such planned economy mechanism in China, the inflation of the electricity prices has been limited indeed and the benefits for the small and poor consumers are protected effectively.

3.6. Supply costs and price: China versus the UK

As identified in the previous section, the liberalised UK market has a relatively higher retail prices for end users. Moreover, the overall price in the UK on average is higher than the price level in China in absolute term. Also, the UK electricity price is generally higher than other OECD member states. In order to explain why such price difference between the two countries exists, we choose China Power International Development (CPID) Ltd, as one of largest power companies in China, which is listed in Hong Kong stock market and its 5 coal-fired power plants to compare with the UK largest coal-fired power company, Drax Group.

Both CPID and Drax engage in the coal-fired power generation and have the close output capacity. CPID, which is one of the big five power generation companies in China, owned 10 coal-fired power plants with the total output capacity of 4860MW and produced 26GWh electricity, i.e. 1.04% of the total output throughout China, for the year 2005. The Drax Group, the largest coal-fired power station in the UK, has 6 generators with the total output capacity of 3960MW. In 2005, it provided 23GWh electricity and met 7% of the total demand in the UK electricity market.

3.6.1. The comparison method

In 2004, the captured average prices of CPID and Drax were 203.07 Yuan/MWh and 391.49 Yuan/MWh respectively. In 2005, the revenue from generation achieved by Drax was 1.96 times as much as the sales of CPID. However, the net profit of Drax was 6 times higher than CPID, which shows that Drax would be more profitable than CPID.

Table 3.10 Sales and Profit Comparison between CPID and Drax in 2005

	CPID	Drax
Revenue (Yuan)	6,437,607,787.55	12,671,116,213.44
Operational Profit (Yuan)	944,309,891.17	5,285,119,833.65
Net Profit (Yuan)	629,659,415.86	4,210,205,475.38
Operational Profit Margin (%)	15%	42%
Net Profit Margin (%)	10%	33%

Source: Annual Report 2005 of CPID and Drax

The unit cost and the percentage of the cost against the price are calculated to identify the levels of the costs of CPID and Drax. However, due to effects of the exchange rates and the Producer Price Index (PPI), such direct comparison may have a limit in precisely defining the operational costs of the power plants in a straight comparable term. So our comparison shall be regarded as indicative rather than decisive.

For the comparison, we take a formula below to calculate the difference of unit costs of China from the UK in a percentage term:

$$D_{cu} = \frac{U_c - U_u}{U_u} \times 100\%$$

D_{cu}: Percentage difference of the unit cost (price or unit profit) between the Chinese and UK power plant

U_c: Unit cost (price or unit profit) of the Chinese power plant,

U_u: Unit cost (price or unit profit) of the UK power plant

In this paper, the Drax will be selected as the benchmark, and the five Chinese plants together with the parent company of CPID will be compared to it, respectively. If the price (unit cost) of the Chinese power plant is lower than the UK plant, the percentage difference of the price (unit cost) will be less than 0%. If the two plants have the same price (unit cost), the percentage difference of the price (unit cost) equals to 0%. If the percentage difference of the price of the plant is lower than the percentage difference of its unit cost, it implies that the unit cost of that power plant would be relatively higher (not as low as "it should be"), compared to its current price level.

Form the Appendix 3.3 and Appendix 3.4, it shows that both in 2004 and 2005, the price percentage difference between CPID and Drax (-33.72% in 2004, -54.71% in 2005) is lower than the percentage differences of the unit fuel costs (-33.6% in 2004, -49.07% in 2005), the unit labour cost (-30.69% in 2004, -33.15% in 2005), the unit depreciation and amortisation (14.63% in 2004, 1.75% in 2005), and the unit institutional & managerial costs (-22.98% in 2004, -38.56% in 2005), except the percentage differences of the unit administrative expenses (-95.64% in 2004, -90.27% in 2005) and the unit interest paid (-92.05% in 2004, -94.13% in 2005).

An interesting point is that the Chinese plants have every cost lower than their English counterpart except depreciation cost. This may reflect (1) the Chinese firm manipulates by setting up higher cost that has no cash implication to business but helps strengthen its bargaining with the state for a high plan price, or (2) China has an industrial policy that encourages technology upgrading by providing the firm with tax favourable arrangement such as high depreciation rate before corporate tax.

3.6.2. The fuel cost and energy efficiency

Table 3.11 Percentage of the Fuel Cost against the Total Cost of CPID and Drax

	2004	2005
CPID	67%	70%
Drax	57%	65%

Source: Annual Report 2004 and 2005 of CPID and Drax

The fuel cost is the largest part of the total generation cost. As shown in Table 3.11, in 2005, the fuel costs of CPID and Drax take up 70% and 65% of the total generation costs respectively. Compared with Drax, the fuel costs of CPID took larger proportion of the total costs. However, the unit fuel cost of CPID (150.46 Yuan/MWh) was smaller than Drax (295.41 Yuan/MWh) by 49.1% in the same year.

The unit fuel cost is determined mainly by the coal price and the thermal efficiency. During the period from 2000 to 2004, both the coal prices in the UK and in China increased by 34.38% and 34.22% respectively. The main reason for such cheaper coal price in China could be attributable to the price control set by the government. Although the coal industry has been partially liberalised in 1993, the coal price for the power generation is still regulated by NDRC in the central government. As mentioned in the previous section, the coal price for the electricity generation is normally lower than the Chinese market price by 30 to 100 Yuan per tonne.

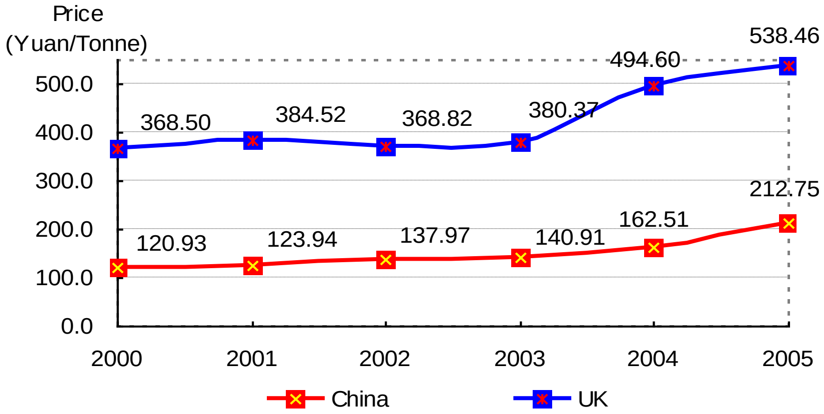

Figure 3.8 The Comparison of the Coal Prices (Nominal) for Electricity Generation between the UK and China

Source: China Electric Power Yearbook 2005, Energy Data 2005 and IEA Electricity Information 2007

In China, the increasing coal prices inevitably deteriorate the profit margin of the coal-fired power stations. From 2000 to 2004, in China, the industrial and domestic electricity prices only increased by 22.85% and 17.86%, both lower than the rise in the coal prices that were increased by 34%. Such situation eventually creates the issue of the new regulations to link the coal and electricity prices in the year 2005.

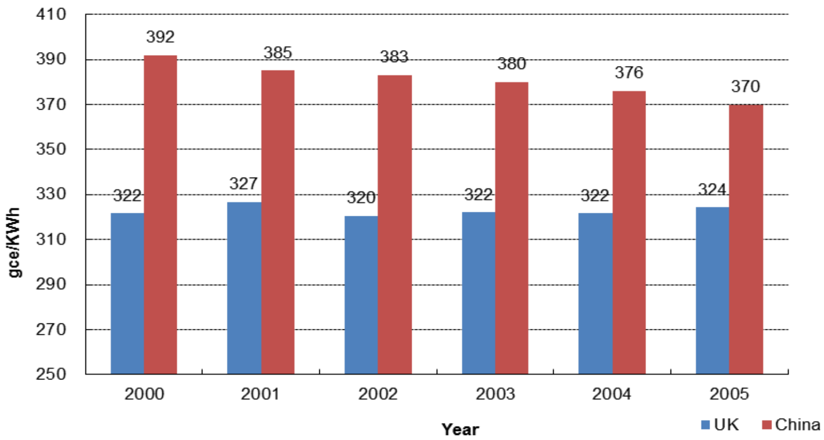

Figure 3.9 The Comparison of Energy Efficiency between UK and Chinese Power Plants

Source: The Chinese data are collected in from Xie, Shaoxiong (2002), "Review of Assumptions as to Changes in the Electricity Generation Sector in Nautilus Institute's Clean Coal Scenarios Report", and Wang, Qingyi(2005), "Energy Data 2005". The UK data are collected from DTI's website.

In the UK, in recent years, the coal-fired power plants couldn't avoid the pressures of the coal price increases too. After 2000, over 43% of the annual coal consumption in the UK relied upon the imports from overseas. In 2004, the prices of the steam coal for electricity generation sharply increased by 30%, which made the coal costs higher than the gas costs in the UK. Such price fluctuation led to the abandonment of the coal-fired power generation in the UK in 2004. From 2003 to 2004, the UK coal-fired capacity increased by around 0.23%, but the power supplied by the coal-fired capacity dropped by around 5.17%, which resulted in a decrease in the coal-fired load factor by around 5.39% (DUKES 2006).

One of the reasons for the higher overall energy efficiency in the UK could be the wide use of the combined cycle gas turbine (CCGT) technology. In 2004, the over 41% of the electricity was supplied by CCGT, of which the thermal efficiency was up to 47%, i.e. higher than the coal-fired stations by over 11%. Another reason could be the large number of the small coal-fired power stations in China, of which the thermal efficiency is low. In 2004, the small (installed capacity below 50MW) and medium-sized (installed capacity between 50MW and 300MW) power producers took up 75.78% and 21.11% of the total power producers in China (Capgemini 2005). In 2005, the large coal-fired power plants (of which the installed capacity is above 1 million kW) had the aggregate capacity of 14.625 million kW, which only took up 2.6% of the total capacity of the all-sized coal-fired power plants in China. But the large plant in China could also achieve a high thermal efficiency. For example, the thermal efficiency of Pingwei plant was 38.57% in 2005. And the small and old power plants in the UK could only reach a low thermal efficiency, such as Uskmouth. So, the closure of the small thermal power plants and investing in large-size of new plants, for example CCGT, would help compare the thermal efficiency for both China and the OECD countries.

Generally speaking, the overall energy efficiency of the UK is still higher than China, but the gap is closing. In 2004, the overall thermal efficiency in the UK and China was 38.2% and 32.55% respectively. In 2006, the average energy efficiency of the power generation in China reached up to 33.34%, equivalent to the 1980s level in the UK. However, since 1962, the gap of the energy efficiency between Chinese and UK power plants has been narrowed sharply, by over 50%.

Table 3.12 The Energy Efficiency Comparison between UK and Chinese Power Plants

	Unit	2000	2001	2002	2003	2004	2005
OECD (Power Generation)	%	37.17	36.10	37.43	37.75	37.84	
Overall UK power plants[1)]	%	38.2	37.59	38.33	38.14	38.2	37.89
Combined cycle gas turbine stations (UK)	%	46.6	46.7	46.8	46.4	47.0	49.0
Coal fired stations (UK)	%	36.2	35.8	36.3	36.5	36.2	35.9
Nuclear stations (UK)	%	37.3	37.3	37.6	38.1	37.9	38.2
Drax (UK)[2)]	%						38.0
Uskmouth (UK)[3)]	%					28.7	29.9
Overall China Power Plants (Supply)	%	31.23	31.80	31.96	32.21	32.55	33.08
Shanxi Shentou (Supply)	%				32.2	32.5	32.5
Liaoning Qinghe (Supply)	%				31.7	31.3	30.5
Pingdingshan Yaomeng (Supply)	%				35.8	35.7	35.8
Jiangsu Changshu (Supply)	%				35.3	35.5	35.8
Anhui Pingwei (Supply)	%				36.1	36.4	37.0
CPID (Supply)	%				35.7	35.9	35.6
Shanxi Shentou (Generation)	%				35.51	35.65	35.55
Liaoning Qinghe (Generation)	%				35.01	34.68	33.56
Pingdingshan Yaomeng (Generation)	%				38.76	38.60	38.73
Jiangsu Changshu (Generation)	%				37.05	37.27	37.60
Anhui Pingwei (Generation)	%				37.81	37.93	38.57
CPID (Generation)	%				37.84	37.91	37.86

Source: 1) The Chinese data are collected in from the paper "Xie Shaoxiong, Review of Assumptions as to Changes in the Electricity Generation Sector in Nautilus Institute's Clean Coal Scenarios Report", and author and Prof. Guy Liu's survey of CPID's annual report 2004 and 2005; 2) The UK data are collected from DTI's sheet file18945. 3) Calculation based on the data from IEA, "Electricity Information 2006", Table 13.

Note: 1) gross calorific value basis. 2) Drax is the most efficient coal-fired power plant in the UK, which implies that the thermal efficiency of other UK coal-fired plants won't exceed Drax. 3) The thermal efficiency of Drax is the baseload efficiency, calculated by the energy out to energy in.

As shown by the selected samples, in 2005, both CPID and Drax achieved the energy efficiency around 38%. However, in 2005, the average price of the natural coal purchased by CPID (239.21 Yuan/Tonne) is lower than Drax (510.61 Yuan/Tonne) by 42.58%. Considering the fact that the fuel costs of CPID is lower than Drax by 49.07%. This explains why fuel takes more weight in total costs of the UK firm than its Chinese counterpart, given that both have a similar level of the thermal efficiency.

The gap of the thermal efficiency between the OECD average and China is not so obvious either. In 2004, the average thermal efficiency of OECD was 37.84%, higher than China by around 5.2%. However, the thermal generation efficiency of CPID was 37.91%, i.e. at the same level with the OECD average.

The percentage difference of the price between the two is smaller than the percentage difference of the fuel cost. It could be interpreted as, because of the price control in China, the Chinese power plant couldn't transfer the increase in the fuel cost into the price as much as the UK counterpart. However, it would encourage those Chinese power producers to improve their energy efficiency, such as building large plant and implementing new technology, in order to suppress their overall fuel costs.

3.6.3. The fuel cost pass-through

As described above, the power generators in the UK and China expose themselves to the risks of the operational costs growth, which is mainly due to an increase in fuel costs. However, such increases may be transferred to the electricity price, and then paid by the end users. In order to measure how much increases in the fuel costs have been passed through into the electricity price, the ratio of a change in the electricity price to a change in coal price is calculated by the following formula, under the assumption of other costs remaining unchanged:

If such ratio is below 1, it means that an increase in the fuel costs can be partly passed through to the electricity price. It also indicates that the inflation of the fuel price would be absorbed partly by the end users and partly by the generators. If such ratio is equal to 1, it means that the increase in the fuel price is fully passed to the electricity price. If such ratio is larger than 1, it means that the electricity prices increased more than the fuel prices.

Table 3.13 The Comparison of the Electricity Price and Coal Price in China and the UK

Year	Industrial Electricity Price[1)] (¥/KWh)		Electricity Price Changes (%)		Coal Price for Electricity Generation (¥/Tonne)		Coal Price Changes (%)		The Price Changes of Electricity to Coal	
	China	UK	China	UK	China	UK	China	UK	China	UK
2000	0.3720	0.4595	NA	NA	120.93	368.50	NA	NA	NA	NA
2001	0.3800	0.4210	2.15%	-8.38%	123.94	384.52	2.49%	4.35%	0.86	-1.93
2002	0.4030e	0.4302	6.04%	2.19%	137.97	368.82	11.32%	-4.08%	0.53	-0.54
2003	0.4259	0.4530	5.70%	5.29%	140.91	380.37	2.13%	3.13%	2.67	1.69
2004	0.4570	0.5521	7.29%	21.87%	162.51	494.60	15.33%	30.03%	0.48	0.73
2005	NA	NA	NA	NA	212.75	538.46	30.92%	8.87%	NA	NA

Source: 1) "Electricity Information 2006", IEA, 2) Energy Data 2005, 3) Electricity market and Electricity Prices Monitoring Report 2005

Notes: 1) Taxation included 2) “e” means the estimated figure.

In Table 3.13, the price changes of the fuel and the electricity in the UK and China, from 2001 and 2004, are calculated and compared. In 2001, when the NETA was introduced, the ratio of UK was -1.93. It indicates that, in 2001, the introduced competition in the UK wholesale electricity market indeed led to the decline of the electricity price by 8.38%, when the coal price increased by 4.35%. However, such situation didn’t last long. In 2002, although the coal price dropped by 4.08%, the electricity price grew up by 2.19% and led to a ratio of -0.54. Such ratio increased up to 1.69 in 2003 and then shrank to 0.73 in 2004.

As to China, such ratio only exceeded 1 in 2003, because of the cap for the price increase set by the NDRC in May, 2003[18]. In 2004, the ratio went down to 0.48, which means that over 50% of the increase of the fuel price didn’t pass to the electricity prices. However, in the same year in the UK, less than 30% of the fuel

[18] “The Notice from the NDRC about Improving the Work of the Negotiation of the Contract of the Electricity Coal in 2003”, http://policy.mofcom.gov.cn/section/claw!fetch.html?id=g000022228, visited on 20th December, 2008.

price increase was absorbed by the power generators themselves, which results in the great jump in the electricity price by 21.87%. It clearly shows that, in the long-term, the introduced competition in the UK didn't work as effective as expected by the market regulator. The fuel price increases were passed much more to the end users in the UK than in China.

However, an increase in the fuel price may not be equal to the increase in the unit costs of fuel. In order to ascertain the influence of the unit fuel cost upon the electricity price, a similar ratio is calculated, by dividing the electricity price change by the unit fuel cost change.

From Table 3.14, our firm-to-firm comparing example shows that in 2005, the ratio of Drax as the largest coal-fired power station in the UK is above 1, i.e. 1.14, while the ratios of all the five subsidiaries and the parent company of China Power International Development Ltd are below 1. It indicates that the power plants in China absorbed a part of the fuel costs growth, while the UK peer passed all of the increase in the fuel costs to its electricity prices. This example of comparison sheds some light on the difference between plan and market in effectively regulating the firm in passing its cost through to consumers.

Table 3.14 The Comparison of the Electricity and Coal Prices of CPID and Drax 2004-2005

	Electricity Price (¥/MWh)		Unit Fuel Cost (¥/MWh)		Electricity Price Changes (%)	Unit Fuel Cost Changes (%)	Ratio of Electricity Price Change to Unit Fuel Cost Change
	2004	2005	2004	2005			
Shanxi Shentou	134.39	162.93	68.95	92.04	21.24%	33.48%	0.63
Liaoning Qinghe	203.84	253.01	126.84	173.41	24.12%	36.72%	0.66
Pingdingshan Yaomeng	195.59	227.70	120.40	148.72	16.42%	23.52%	0.70
Jiangsu Changshu	275.08	290.49	164.92	177.00	5.61%	7.32%	0.77
Anhui Huainan	248.16	267.16	125.69	156.52	7.66%	24.52%	0.31
CPID[1)]	241.23	247.34	137.44	150.46	2.53%	9.47%	0.27
Drax	363.93	546.17	205.32	295.41	50.08%	43.88%	1.14

Source: Annual Financial Reports 2004 and 2005 of China Power International Development Ltd and Drax.

Notes: 1) CPID is referred to the parent listed company, the China Power International Development.

3.6.4. The labour cost

Unlike the fuel cost, both in China and in the UK, the labour cost only takes up a small proportion of the total sales and the operational costs. According to Table 3.15, in China, the average percentage of the labour cost against the total sales ranged between 5.03% and 5.78% over the seven-year's period. On average, the percentage of the labour cost against the operational costs for the profit-making plant will be smaller than the loss-making plant in China. According to Table 3.15, in 2005, the labour costs of the profit and loss-making plants took up 4.95% and 6.18% of the operational cost respectively. Compared with the selected UK loss-making plants, the percentages of the labour cost against the operational cost of the Chinese power plants are higher.

The unit labour cost is determined by the staff number and the salary rate of the employee. Since 2001, the average number of the employees per power plant in China has decreased by 3.3%. However, the changes of the average employees working for the profit-making and loss-making plants in China are different. The average employees working for the profit-making plant increased during the period from 2002 to 2004 and then started to decline in 2005, while as to the loss-making plants, the average employees declined from 2000 and then increased slightly in the year 2005. In 1999, the ratio of the number of employees between profit-making and loss-making plants was 1.188. In 2005, such ratio became 1.43. It implies that there is a trend of the employment shift from the loss-making plants to the profit-making ones.

Table 3.15 The Comparison of the Labour Cost between the Chinese Power Plants and the selected UK Power Plants

	1999 (N=916)	2000 (N=923)	2001 (N=962)	2002 (N=984)	2003 (N=1001)	2004 (N=1193)	2005 (N=1189)	2004 Drax	2005 Drax
The Average Labour Cost per Plant (1000 RMB)									
All Plants	9,907.14	11,437.75	14,864.32	15,700.78	17,948.97	18,551.59	21,826.47		
The Profit-making Plants	11,590.22	12,045.95	16,426.89	18,135.74	20,207.61	26,328.43	29,788.81	400,537	433,842
The Loss-making Plants	8,056.56	11,299.85	12,889.35	12,193.25	12,396.22	12,722.95	13,495.27		
The Average Labour Cost per Employee (1000 RMB)									
All Plants	14.27	15.11	20.73	21.02	24.49	28.20	34.39		
The Profit-making Plants	16.08	15.13	22.56	22.50	25.64	30.40	40.15	742	738
The Loss-making Plants	13.27	16.69	20.36	18.99	20.26	24.90	26.00		
The Labour Cost Percentage against the Total Cost (%)									
All Plants	5.03%	5.18%	5.67%	5.58%	5.78%	5.51%	5.36%		
The Profit-making Plants	4.60%	4.81%	4.85%	5.13%	5.04%	4.96%	4.95%	3.92%	3.49%
The Loss-making Plants	5.18%	4.73%	6.85%	5.66%	7.90%	7.18%	6.18%		
Unit Labour Cost (Yuan/WMh)									
All Plants	8.29	10.64	12.91	12.29	11.84	12.82	13.44	17.49	18.70

Source: The data of Chinese power plants are collected from National Bureau of Statistics of China; The data of UK power plants are collected from FAME.

Note: The financial data of Drax and Uskmouth were reported as at the year end of December 31st, 2004 and October 31st, 2006 respectively.

However, the reduction in the employment in the Chinese power plants was not aimed to cut labour cost, rather is to raise it by increasing a wage rate. Under the small reduction of the average number of employees, the average labour cost per plant increased by 157.02% and 67.51% for the profit-making plants and the loss-making plants respectively, during the period from 1999 to 2005. Actually, the average labour cost per employee for both the profit-making and loss-making plants were increased by 149.74% and 95.91% respectively over the seven years. As a result, the unit labour cost for the Chinese power plant was increased by 62% during that period. This observation shows evidence in supporting our argument that the Chinese power firms are not to minimise costs, at least, labour costs.

The small proportion of labour costs in sales shown by our large sample of some 1000 power generation companies is consistent with our particular-selected sample companies. The unit labour costs of both CPID and Drax take up a small proportion of the price, i.e. only 5.05% and 3.42% respectively in 2005. Although in 2004 the average salary per person of CPID (36,118 Yuan) was only 5% of Drax. (741,736 Yuan), the higher percentage of the labour costs of CPID implies that CPID suffers from the burden of the excessive employees. Actually, in 2004, the entire group of CPID employed over 6603 employees, while Drax only employed 540 staff. Considering the total outputs of the generation, it clearly shows that the labour productivity of the UK Drax is around 10 times higher than its counterpart CPID in 2004.

Table 3.16 The Average Number of Employees per Plant in China

	1999	2000	2001	2002	2003	2004	2005
All plants	695	757	718	748	733	658	635
The profit-making plants	721	796	728	806	788	866	742
The loss-making plants	607	677	633	642	612	511	519

Source: The National Bureau of Statistics of China

For the unit labour cost of CPID, it was 12.12 Yuan/MWh and 12.50 Yuan/MWh for the year 2004 and 2005 respectively, still lower than the unit cost of Drax by -30.69% and -33.15%. However, it was higher than the price percentage difference both for the 2004 and for 2005, which means that the unit cost of CPID was relatively higher.

Although the average salary of the Chinese plant is only equal to 5% of the UK counterpart, the unit labour cost of the Chinese plant is 72% of the UK counterpart on average. The reason for this would the excessive number of staff and the low labour productivity of these Chinese power plants. In another aspect, the difference of the unit labour cost between the two was less than their price difference. Just as the fuel cost, the price control makes it difficult for the Chinese power plants to pass their labour costs to the electricity prices, when compared to the UK counterpart.

3.6.5. The finance costs

Although CPID faces the pressure from the fuel and labour costs, it gains the advantage of the interest cost. In 2005, the interest cost of CPID only took up 1.75% of the total sales revenue, while as to Drax, the percentage of the interest cost against the sales was 13.46%. For the year 2004 and 2005, the financial cost of Drax took up 17% and 19% of the total costs, respectively.

Not only does the Chinese firm enjoy a lower interest costs, but also the interest rates as well. The interest rate applied to CPID was only 4.46% in 2004 and 2.4% in 2005, while the interest rate of Drax was 8% in 2004 and 5.55% in 2005. As we know, CPID is state-controlled quoted company in Hong Kong, which can gain benefit from the stae in financing its investment. Drax is private-owned public quoted company in London, and apparently it doesn't have advantage of state support.

Table 3.17 The Comparison of the Average Financial Cost between Chinese and UK Coal-fired Power Plants

	Chinese Coal-fired Power Plants						Selected UK Power Plant	
	2000 N=923	2001 N=962	2002 N=984	2003 N=1001	2004 N=1193	2005 N=1189	2004 Drax	2005 Drax
Percentage of Financial Cost Against Total Cost (%)	7.86%	7.66%	6.87%	6.06%	4.67%	4.25%	17%	19%
Interest Rate (%)	4.41%	4.33%	4.28%	4.28%	3.25%	3.04%	8%	5.5%
Unit Financial Cost (Yuan/MWh)	16.2	17.4	15.1	12.4	10.9	10.7	67.05	58.42

Source: Numbers are calculated from the data collected from National Bureau of Statistics of China, Chinese Electric Power Yearbook 2006, FAME and Annual Report of Drax (2004, 2005)

From the historical point of view, both the average financial costs and interests rates of the Chinese power plants have declined over the years. As shown in Table 3.17, from 2000 to 2005, the unit financial costs of the Chinese power plants fell by 34%. The average interest rates for all plants decreased by 38%, i.e. 1.89 percentage points. Due to the fact that at present most large banks in China are SOEs (state-owned enterprises), it's justified to believe that those coal-fired power plants in China enjoy the indirect subsidies through the favourable interest rates granted by the state-owned banks.

3.6.6. The overheads

In the electricity industry, the overhead costs could be defined as the expenses and costs except the fuel costs and the labour costs. Classified by function, the overhead costs will be attributed to different cost pools (Landeros, Reck and Griggs, 1994), such as the distribution costs, the administrative expenses, the financial costs and the generating expenses. By definition, the overhead means all costs on the income statement except for the direct labour, the direct materials and the direct expenses. But in this study, the overhead refers to the administration only, excluding the direct labour and direct materials.

The administrative expenses of CPID were 0.5 Yuan/MWh in 2004 and then increased up to 1.54 in 2005. The administrative expenses of Drax were 11.44 Yuan/MWh in the year 2004 and 15.87 Yuan/MWh in the second year respectively. As to CPID, the unit administrative expenses as percentage of the price were 0.21% in 2004 and 0.62% in 2005 respectively, which were much smaller than Drax (3.14% in 2004 and 2.91% in 2005). In 2004 and 2005, the unit administrative expenses of CPID were smaller than Drax by 95.64% and 90.27% respectively. However, such result might be due to the different ways of the classification of the overheads and administration expenses. For example, in the UK, the overheads may include the indirect labour and materials. But in China, the indirect labour and material will be included in the cost of sales.

To address the concern above, we define the unit overheads as the unit total costs minus the unit fuel cost (direct material) and unit labour cost (direct labour). As shown in Table 4.6, the percentage difference of the overheads between CPID and Drax was -66.35% and -68.68% in the year 2004 and 2005 respectively. Again, after eliminating the element of the interests, the unit overheads of CPID (25.69% in 2004, 22.92% in 2005) took up larger percentage of the total costs, compared to Drax (23.86% in 2004, 18.18% in 2005). This provides us with evidence that the Chinese state-owned firms have higher agency costs than its English counterpart.

The institutional and managerial costs are those expenditures and charges to administrate and sustain the operation of the business, which are composed of the business taxation, administration expenses and depreciation. In 2004 and 2005, the unit institutional and managerial costs of CPID were 25.65 Yuan/MWh and 21.99 Yuan/MWh, lower than Drax by 22.98% and 38.56% respectively, but higher than the prices percentage difference between the two. It means that the institutional and managerial costs of CPID were relatively higher, compared to its own price level.

Table 3.18 The Overheads of CPID and Drax in 2004 and 2005

	2004			2005		
	CPID	Drax	Percentage Difference	CPID	Drax	Percentage Difference
Unit Overhead (Yuan/MWh)	58.35	173.38	-66.35%	53.59	171.06	-68.68%
Overheads as Percentage of the Total Cost (%)	28.00%	39.00%	NA	25.00%	32.00%	NA
Unit Overhead excluding Interest (Yuan/MWh)	53.02	106.34	-50.14%	49.27	97.55	-49.50%
Overheads excluding Interest as Percentage of the Total Cost (%)	25.69%	23.86%	NA	22.92%	18.18%	NA

Source: Annual reports of CPID 2004 and 2005, Annual report of Drax 2005

As a whole, it implies that despite of the low administrative expenses level, the overall operational efficiency of Drax would be higher than CPID because proportionally Drax has a lower overhead cost than CPID in its total costs. The low level of administrative expense may be changed if the state regulatory constraint on cost or cost-pass-through is lifted.

3.6.7. The depreciation

The depreciation is the amount written down to attribute the historical cost of the asset across its life in use. Unlike many other expenses and costs transactions, the depreciation never includes any item of cash outflow, but stands for the value of the assets that will not be recovered through the disposal process only. It means that the depreciation and amortisation expenses actually are the "hidden profit" for the companies.

Table 3.19 The Depreciation of the Chinese Power Plants

	1999	2000	2001	2002	2003	2004	2005
Average depreciation per plant (1000 Yuan)							
Profit-making plant	38746.85	41718.39	55620.26	60209.61	73927.15	76355.15	87256.75
Loss-making plants	33841.63	36808.27	32568.25	30537.37	24289.39	22176.15	27014.75
Changes of average depreciation per plant (%)							
Profit-making plant	NA	7.67%	33.32%	8.25%	22.78%	3.28%	14.28%
Loss-making plants	NA	8.77%	-11.52%	-6.24%	-20.46%	-8.70%	21.82%
Average depreciation as percentage of the total cost (%)							
Profit-making plants	15.39%	16.68%	16.42%	17.04%	18.45%	14.38%	14.49%
Loss-making plants	21.78%	15.41%	17.30%	14.19%	15.48%	12.51%	12.38%

Source: The National Statistics Bureau of China

From Table 3.19, it shows that as to the profit-making plants in China, the depreciation took up 15.39% of the total costs in 1999, increased up to 18.45% in 2003 and then dropped again to 14.49% in 2005. The proportion of the depreciation of the loss-making plants decreased from 21.75% in 1999 to 12.38% in 2005. Over those seven years, the average depreciation of the profit-making plant in China increased by 125%.

On the contrary to the costs and expenses described above, the unit depreciation and amortisation expenses of CPID (25.06 Yuan/MWh in 2004, 20.27 Yuan/MWh in 2005) were higher than Drax (21.86 Yuan/MWh in 2004, 19.92 Yuan/MWh in 2005) by 14.36% in 2004 and 1.75% in 2005 respectively. The percentage of the depreciation against the price of Drax was only 6.01% in 2004 and 1.75% in 2005 respectively, while as to CPID, it's 10.39% in 2004 and 9.98% in 2005.

In 2005, the profit margin before taxation of CPID and Drax were 12.89% and 31.01% respectively. By considering the effect of the depreciation charges, the modified profit margin of CPID and Drax would be 22.87% and 32.76%. This implies that the profit margin before taxation of CPID would be lower than Drax by 30.2 percentage points, rather than 58.4 percentage points at present. Even though, the profit margin of the Chinese power plants under the price control set by the government is smaller than the UK power plant operated in a liberalised market. The observation of depreciation and its difference between Chinese firm and the UK firm shows that the Chinese firm set a higher cost for depreciation at expenses of their profit, in which this is not a case in the UK firms that lower down the depreciation cost in order to increase profits. The reason is that the Chinese firms set up a higher cost that has no cash implication to business but helps bargain with the state for a higher plan price, or China has an industrial policy to encourage the technology upgrading by allowing higher depreciation rate before tax.

3.6.8. Subsidies

Both the profit and the loss-making power plants in China might receive the subsidies income directly granted by the government. As shown in Table 3.20, over 8% of all plants in 1999 reported that they received the subsidies and in the year 2005, such percentage increased to 23%. During the period from 1999 to 2005, the percentage of the loss-making plants with the subsidies was normally larger than the profit-making ones. However, the percentage of the profit plants with the subsidies increased dramatically. In the year 2005, the percentages of the profit and loss-making plants with the subsidies were 22% and 23% respectively.

Table 3.20 Percentage of the Power Plants receiving the Subsidies

	1999 N=916	2000 N=923	2001 N=962	2002 N=984	2003 N=1001	2004 N=1193	2005 N=1189
All Plants	8%	8%	9%	11%	15%	17%	23%
Profit-making Plants	5%	5%	7%	9%	12%	19%	22%
Loss-making Plants	13%	15%	11%	15%	19%	14%	23%

Source: The National Bureau of Statistics of China

Over the seven years, not only the percentage of the direct subsidised plants increased, but also the average amount of the subsidies grew up. Table 3.21 shows that the average subsidies income for the coal-fired power plants in China increased by 3.2 times over the seven years, up to 1.96 million Yuan in the year 2005. On average, as expected, the loss-making plants receive much greater subsidies than the profit-making plants. In the year 2005, 128 loss-making plants received over 320,565,118 Yuan from the government in China.

Table 3.21 The Average Subsidy per Power Plant in China

1000 Yuan	1999	2000	2001	2002	2003	2004	2005
ALL Plants	466.52	476.69	1031.77	1116.98	1186.28	972.76	1963.27
Profit-making Plants	255.95	121.96	543.80	1001.58	807.91	595.04	1502.19
Loss-making Plants	858.73	1231.83	1912.40	1316.14	1998.96	1343.58	2504.41

Source: The National Bureau of Statistics of China

However, from Figure 3.10, it clearly shows that both the profit-making and loss-making plants received the subsidies. Only 108 plants over the 7 years have the subsidies above 500 thousands RMB. 88.93% of the plants, which include both the profit-making and loss-making ones only received a limited subsidies below 500 thousands RMB. It means that the subsidiaries are not granted for the loss-making plants to cover part of their heavy operational expenses and costs. Actually, the plants receiving the subsidies over the 7 years are almost subject to a kind of normal distribution, which indicates that there is no linear relationship between the amount of the subsidies and the profit of the plant. The wide-reported explanation for such phenomenon is that the government granted the subsidies to the power plants for the main purpose of technology upgrading via new equipment investment to improve productive and environment efficiency[19]. For example, in Jiangsu province, the subsidies for the use of the energy efficient equipment are equal to 30% of the book value of the machine.

Figure 3.10 The Chinese Power Plants with Subsidies

Source: National Bureau of Statistics of China

Notes: The unit is one thousand RMB.

3.6.9. Discussion

Without a doubt, the overall low cost level is the precondition for the Chinese power plants to keep their prices low. However, in 2005, the total unit cost of the CPID was only lower than Drax by 42.82%, while its price was lower by 54.71% (Table 3.22). This suggests that the total unit costs of the sample plants in China were not lower "enough" to generate a profit margin in their price as similar as their English counterpart. This explains why Chinese power sector has a lower profitability,

[19] The website of NDRC, at http://www.ndrc.gov.cn/jjyx/dzxqcgl/t20070802_151927.htm, visited on June 29, 2008.

which is a result partly of state plan control, partly of the cost behaviour of the state-owned power firms and partly of institutional impact.

Our discussion shows that, under the price control set by the government, the Chinese power plants couldn't transfer their variable costs into the electricity prices as much as their UK peers do. When both the Chinese and the UK power plants are facing the increasing fuel costs, China is more effective in restricting cost-pass-through to the electricity price and so lowering profit margin of the power producers. In contrast, the UK plants can relatively straight pass through 100% of the cost to the price, because the UK firm has no regulatory control on the cost behaviour. The cost control may explain why China firms have higher incentive to invest on new technology because the firm can seek higher profit margin by cutting cost of production through investment on new technology.

Table 3.22 Breakdown of the Electricity Prices of CPID and Drax

	Percentage of Price (%)		Breakdown of Electricity Prices (¥/MWh)		Percentage of Price (%)		Breakdown of Electricity Prices (¥/MWh)	
	CPID 2004	Drax 2004	CPID 2004	Drax 2004	CPID 2005	Drax 2005	CPID 2005	Drax 2005
Unit Fuel Cost	56.98	56.42	137.45	205.33	60.83	54.09	150.46	295.42
Unit Labour Cost	4.4	4.81	10.61	17.51	4.41	3.42	10.91	18.68
Unit Financial Cost	2.21	18.42	5.33	67.04	1.75	13.46	4.33	73.51
Unit Depreciation	10.39	6.01	25.06	21.87	8.19	3.65	20.26	19.94
Unit Overhead excluding Financial Cost and Depreciation	10.2	21.91	24.61	79.74	11.93	25.35	29.51	138.45
Unit Other Exceptional Items	0	0	0	0	0	30.98	0	169.2
Unit Profit before Taxation	15.82	-7.57	38.16	-27.55	12.89	31.01	31.88	169.37
Unit Taxation	(1.08)	6.39	(2.61)	23.26	(1.00)	2.21	(2.47)	12.07
Electricity Price	100	100	241.23	363.93	100	100	247.34	546.17

Source: 1) Annual reports 2004 and 2005 of Drax, and 2) Annual reports 2004 and 2005 of CPID.

Notes: 1) In 2005, Drax received £310.9m administration income from TXU, and also recognised £19m income by the revaluation of the tangible fixed assets; 2) Excluding the exceptional income, Drax would have made losses of £66.3m through the generation activities, i.e.¥988m, in 2005; 3) the positive tax means the tax refund.

As can be seen from Table 4.9, the Chinese firms could enjoy the low interest rates granted by the state-owned banks as an indirect subsidy. It would encourage the Chinese power companies to invest more on larger plants and upgrading technology. In the UK, the higher bank interests discourage the UK power plants to invest, which could lead to the insufficient capital expenditures, and slow down technology upgrading that decides energy efficiency. However, the high profit margin would offset such effects of the high finance costs to some extent on the UK power investments.

Besides the magnified generation costs and the low interest rates, the Chinese plants could also earn extra returns, rather than their reported figures, through the depreciation charges. In the year 2004, the unit cost of the depreciation of CPID is higher than Drax both by 14.7%, while the price of CPID is lower than Drax by 33.72%. On taking into the “hidden profit”, the earnings of CPID would increase by around 10%. Such estimation would also be applicable to other power plants in China.

The impact of the liberalisation of Chinese electricity market would be ambiguous. The market competition may not be powerful enough to discipline the firm’s cost-pass-through behaviour, which has been evident by the UK firms. In addition, the collusion among the major generators may combine with the abuse of the market power and then reduce the benefits of the end-users at last. In 2006, the electricity price bidding experiment in northern China provinces failed and suspended, which confirmed such expectation.

In order to retain the sustainability of the state plan price in selling electricity, China extends its regulatory power to the coal market. All of coal supplied to the power sector has been subject to the control of the state plan. This regulatory extension to the up-stream energy market is aimed to ensure the power firm to get a low-cost supply of fuel for sustaining the low plan price that can benefit the whole down-stream industry and so the economy. But a challenge for this system is that once the price regulation to coal market is lifted, which is currently happening to China, how the current plan-based price control system in electricity sales can be sustainable will become an immediate problem for the Chinese policy maker.

3.7. Conclusions

Through this comparative analysis of power supply in China and in the UK, we identify some merits for the Chinese reforms plan-based regulatory system in managing the power industry. In contrast to the UK where it is the most liberalised market in the world, China's plan system promotes growth of power supply, capacity expansion, and technology upgrading. The reform plan system also promotes benefits for the whole society and the economy rather than a sectorial interest via imposing low plan prices in purchasing and selling electricity. The electricity price for the small users is well restricted to the same level with the large industrial users in China. The power prices for industrial users remain at a relatively lower level than many OECD economies that have liberalised power market. As to the UK electricity market, it clearly shows that the Pareto improvement was not achieved after the introduction of the decentralised wholesale arrangement, as the situation of the small users became even worse, compared to the industrial users. Furthermore, the reformed plan system is more effective than the fully-liberalised market in disciplining cost-pass-through behaviour of the firms. To stimulate technology upgrading, the state ownership provides the power firms with advantages in accessing low cost finance.

As a result of this promotion of investment, the energy efficiency of Chinese power plants improved continuously and significantly over the years, which has caught up the leading plants in the West. Especially, the actually gap of the thermal efficiency between the UK and Chinese coal-fired plants diminished very significantly in recent years. The reason for such improvement of the Chinese power plants should be due to the favourable industrial policies and the low interest rates granted by the state-owned banks, which both encouraged the investments with the implement of the new technology in the electricity sector. In contrast to China, the market-based private-owned UK electricity corporations experienced relatively slow investment on technology upgrading. The two paces of investment explain the technology gap closing between the regions.

Unlike the failure of the California electricity market that damaged the security of electricity supply, the reformed plan system has not brought any concern on the security issue of power supply in China. This is because the government sets the price and the volume of the electricity generation for each individual plant. There is no evidence to show that the reformed plan system is unable to promote energy supply to meet the growing demand of the economy.

On one hand, the plan-based regulatory system should be more suitable for the naturally monopoly industry, such as the electricity sector, because the market is unlikely to be able to function in protecting the industry from the price collusion. In future, China should be more carefully thinking about its reform in the power sector. A fault in the design of the reform may offset the benefits gained from reform. China's reformed plan system is certainly not perfect, and needs to change for the better. The behaviour of the power firm in setting higher costs needs to be changed when the price of coal supply is liberalised, how to ensure the power firms to be sustainable in business becomes a priority challenge for the Chinese policy maker — can the firm survive the impact of the fuel cost rise due to the liberalisation of the coal market? To address this question, good understanding of electricity pricing becomes priority of demand for further research.

Chapter 4. Pricing Behaviour of Chinese Power Firms

4.1. Introduction

The electricity sector plays a more and more important role in the state's economy, especially in the developing countries. Since 1990, the real GDP in China has increased by 5.8 times, up to 11,337 billion Yuan by 2008 (from the UN Data). During the same period, the total electricity produced in China increased from 0.62 billion MWh in 1990 to 3.4 billion MWh in 2008. Since 2000, the average ratio of the power consumption growth to the GDP growth was around 1.17, which indicates that the power becomes more and more important in stimulating the economic growth in China (National Bureau of Statistics of China, 2009).

By 2007, China has been the second largest electricity producer to the US in the world. In 2008, the Chinese power firms produced the electricity of 3.4 billion MWh all together, around 8.8 times as much as the electricity supplied in the UK, and equals to the 1994's level of the US (Electric Power Annual 2005, and DUKES 2006). In 2008, total power installed capacity in China increased up to 804 thousand MW, almost 10 times of the total net capacity of the power generation in the UK. As a result, China's electricity sector has been growing bigger and bigger to attract attention from both policy makers and academic research.

For existing studies, researchers have taken different approaches to study the pricing behaviour of a manufacturing firm. McFetridge (1973) showed the positive relationship between the industry concentration and the price-cost margin with the evidence obtained from the studies on the Canadian manufacturing sector. Odagiri

(1986) also found a similar view about the industry concentration and the mark-ups of the firm with the sample of the Japanese manufacturers. Shinkai (1974) studied the business pricing policies in Japanese manufacturing industries and found the input price could explain almost half of the output price of those firms. Before the liberalisation of the electricity market in the UK, the studies of electricity prices were mainly focused on the cost behaviour of the plant, which attempted to explain how various cost and external environment can affect total cost and so prices. Stewart (1979) developed the cost function of the UK power plants and found "the plant size has relatively little effect on the average cost, while the plant utilisation factor is the major element leading to reductions in average cost as cumulative output expands". However, with the construction of the cost function of the US power plants, Betancourt and Edwards (1987) argued that "the plant size has a statistically significant role in the determination of the costs when the load factor is included in the analysis". Moreover, Green and McDaniel (1989) in their study of UK power market, found that "there are likely to be large transfers of input cost rises, from electricity companies (and the coal industry) to consumers", which indicating the importance of the fuel cost in affecting electricity prices.

As the UK electricity industry has been liberalised after privatisation and vertical unbundling in the middle of the 1990s, some recent studies have attempted to explain the pricing behaviour of the generators from the point of view of market competition and market power. Green and Newbery (1992) applied the Cournot model to simulate competition on prices among the UK generators and concluded that National Power and PowerGen could exercise considerable market power "without collusion by offering a supply schedule that is considerably above marginal operating cost". Wolak and Patrick (1996) argued that the major generator in the UK could unilaterally restrict the amount of generation capacity it makes available to the market so as to increase their profit. Such argument is also supported by the study on the California electricity market (Borenstein and Bushnell, 1999). Furthermore, the market power abuse by the generators is proved by Woo, Lloyd and Tishler (2003) on their studies of the electricity market in the UK, Norway, Alberta and California. Sweeting (2007) in the study on the UK electricity sector found that "generators exercised considerable market power in the late 1990s despite falling market concentration".

In contrast to the UK power market, after December 2002, the reform of the electricity sector in China entered the stage of the vertical unbundling. However, the oligopoly model may not be suitable to explain the situation in China, because the electricity sector in China has not been fully liberalised in one hand, and it has more than thousands of power firms on another. Unlike many other industries in China, the capacity expansion rather than the price competition is encouraged in the Chinese electricity sector at present. As mentioned in the previous section, the National Development and Reform Commission (known as NDRC) set the production volume and the prices for each individual power plant in China. And, the process of the vertical unbundling of the electricity industry has not been completed yet. Although the independent power producers have been separated from the grids, the grid companies in China still undertake the integrated function, including the transmission, the distribution and the supply. The numerous papers focused on the description of the history, the status and the future of the Chinese electricity market, but a few studies investigated the determinants of electricity prices. Wang (2007) compared the electricity and the coal industries in China together and found that the low coal price protected the electricity industry, which implies that the coal prices should have positive relationship with the electricity prices. Liu, Wang and Song (2007) also stated that "at the wholesale level, power plants are paid not according to short-run marginal costs but according to the dates of production, guaranteed rates of return and total costs of the plant." Lam's study (2004) is a unique study that provides the empirical estimates of the pricing behaviour of the Chinese power firms. With the cross-sectional data for the year 1998, he argued that the "electricity prices in China are highly subsidised and below the average total costs."

This chapter attempts to test and explain the on-grid pricing behaviour of the power firm in China electricity sector, with the description of the recent pricing policies and the evidence of both the external and internal factors from Chinese coal-fired power plants. Compared with previous studies, our research will focused on investigating how electricity is priced in China. This chapter is structured as follows. Section 2 outlines the previous studies of the pricing behaviour of both the UK and Chinese power plants. Section 3 is the theory of plan price and specifies the empirical models. Section 4 and 5 describe the variables and the data to be tested in the estimation. Section 6 shows the results of the empirical estimates and discussion. Then Section 7 draws the conclusion.

4.2. Towards understanding of the electricity pricing in China

As the reform of the UK electricity industry has been carried out with the liberalisation and privatisation, the recent researches and literature investigated the electricity pricing mechanism in the UK from the point of view of the market competition. It's a common view that the UK electricity industry reform result in oligopoly behaviour rather than the expected result of perfect market competition. However, the specific pricing behaviour of market participants is still in controversy. Some studies provided evidence that the market leaders maximise their profit margin by declaring the unavailability of the electricity supply in certain periods (Ofgem's report, 1998; Wolak and Patrick, 1996). But others argued that the market leaders increased output at a relatively higher price to achieve a high profit margin (Stewart, 1979; Lopez, 2004; Sweeting, 2007).

A recent study about the Pool pricing behaviour was carried out by Sweeting (2007), which looks at the pricing behaviour in every half-hour period under the UK Electricity Pool over the period from 1995 to 2000. First, the marginal cost function was constructed with the information of unit capacity, thermal efficiencies, input fuel prices and variable non-fuel costs, and then adjusted according to the outage of the generators. After that, the highest cost unit across 25 simulations of unit availability was calculated and identified as the estimated benchmark marginal cost. He compared the estimated benchmark prices with the real prices and found "lower competitive benchmark prices, reflecting falling fuel prices and the replacement of old coal and oil capacity with more efficient CCGT capacity, as well as higher average electricity prices", which stands for the market power exercised by the dominant generators. He also found the difference between the real and the estimated prices became even greater after 1997, though the market concentration was declining. In other word, the declining market concentration and the fuel cost didn't result in the expected decline in the wholesale prices. The evidence from his study seems to suggest that the UK market-oriented reform has not achieved its aim that promotes the full competition to bring the power prices down to the perfect competition level.

However, a further study on the NETA and BETTA still needs. Besides, Sweeting's study focused on the evaluation of the UK electricity reform only, and didn't extend the implication of his finding from the UK market to other markets or economies, such as China.

Regarding the Chinese electricity sector, a number of previous studies have been made in attempt to introduce its history, status and prospect (Li and Dorian 1995, Andrews-Speed and Dow 2000, Hafsi and Tian 2005, Xu and Chen 2006, Hang and Tu 2007 and Yang 2008). A common view of these studies is that the electricity industry in China is still under a plan economy. Unfortunately, most of them didn't take any further investigation into how the firm would behave in the plan system, such as in setting costs and pricing. Lam's paper (2004) is the only one to describe the pricing behaviour of Chinese power plants with the cross-sectional data of State Power Corporation for the year 1998. In the paper, the 2SLS model was employed to construct the price function as well as the cost function.

With the cost function, it indicates that the internal cost factors, i.e. the fuel costs and the investment expenditure, were more important in the role of the price determination, rather than the capital costs, wages and the production of the quantities. With the pricing function, the catalogue prices didn't cover the full average unit cost of the electricity, because "the capital costs of the generation and transmission assets owned by the State Power Corporation of China were ignored in the process." Lam (2004) also argued that the catalogue electricity price in China might be subsidised because of the positive relationship between the electricity price and the regional income level. In other words, it's observed that the electricity price is relatively higher in the area with higher regional income and lower in the poor areas.

However, the average electricity prices of the power producers employed by that paper exclude the taxation, but include the transmission and distribution costs, other operation and maintenance costs, depreciation charges and the profit margins of the State Power Corporation. It means that the electricity prices are not "on-grid prices", but the average "catalogue prices" between the grid networks and the end-users. It also ignored the impact of external factors upon the prices, such as the average unit cost from the rival plants and the market share of the individual plant. The most recent situation of the electricity pricing after 2002 was not examined in that paper. Besides, Lam didn't derive the quantitative model from the theory of the plan economy, although it's agreed that the Chinese electricity sector was under the plan economy.

Unlike many other liberalised industries in China, electricity prices have still been under state plan control, which is set by NDRC. The price regulation has been changed several times since 1998 (Chinese Electric Power Yearbook 2005 and 2006). Generally speaking, the "on-grid price" before 2003 was based on the unit cost, the interest rate, the taxation rate and the estimated return on capital employed. In 2003, the "ex post pricing" method was introduced to set an on-grid prices. In order to be sustainable, a certain mark-up will be added up on the top of the internal rate of return or the operational costs of the power plants at the end of year (Wang 2006). Under such arrangement, it encourages the power firms to boost their capital expenditures on capacity investment.

During the period from 2001 to 2003, the coal price in China increased by around 13.7%, and thus the on-grid prices grew by 9.8% (Figure 4.1).

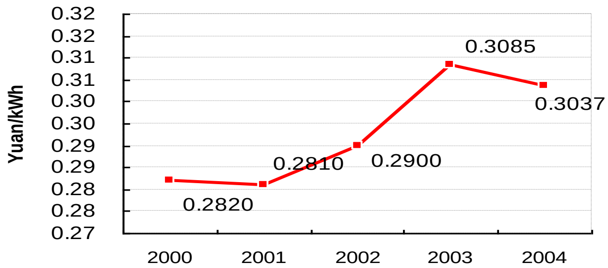

Figure 4.1 Chinese Average On-grid Electricity Price (including Tax)

Source: CPNN, Electricity Market and Electricity Price Supervision Report 2005.

In December 2004 NDRC issued the Decree 2909 (China Electricity Year Book 2005, page 464-465) to adjust the electricity price with the change in the coal price. The adjustment of the on-grid price was stipulated as the formula below.

$$PE_{it} = PE_{it-1} + \Delta PE_{it}$$

$$\Delta PE_{it} = \Delta PC_{it} \cdot \beta_{it}; \quad \beta_{it} = \frac{7000(1-r_{it})\eta_s}{H(1+17\%)(1+13\%)},$$

where PE_{it} is the ex-factory price of the individual power plant i at time t; ΔPE_{it} is the adjustment of the on-grid electricity price of the individual plant i at time t; ΔPC_{it} is the changes of the coal price; β_{it} is the conversion of the coefficient, which is related to the coal equivalent consumption rate of the electricity supply, the heating value of the fuel and the offsetting ratio; r_{it} is the offsetting ratio, i.e. the percentage of the coal price inflation that the power plant will be undertaken; η_s is the coal equivalent consumption rate of the electricity supply and H is the heating value of the natural coal.

Once the power firm's sales price is set up, the state adds the further margin on the top of the price, for the catalogue price to final users, in which the margin is set up below:

$$PS_t = PS_{t-1} + \sum_{i=1}^{n} \Delta PR_{it}$$

$$\Delta PR_{it} = \frac{\Delta PE_{it}}{1 - L_{it}},$$

Where PS_t stands for the end price of the grid company at time t; ΔPR_{it} is the adjustment of the catalogue price of the individual plant at time t; and L_{it} is the transmission loss ratio of the individual plant at time t. The end price of between the grid company and the users at time t were acquired by adding up the sum of the allocated on-grid price adjustments on the last period of end price.

Such arrangement relieved the pressure of the power producers by transferring the coal price growth to the grid companies, and then saved the grid companies by passing such inflation to the end-users again. In another aspect, the "ex post pricing" also was changed into the "ex ante pricing", in order to encourage the improvement of thermal efficiency (Chinese Electric Power Yearbook 2005, page 464-465).

In 2005, in order to mitigate the impact of a huge rise in fuel costs, the "on-grid price" was re-defined. It was split into "capacity tariff" and "volume tariff" (Chinese Electric Power Yearbook 2006, page 553), which can be expressed as the following function:

$$PE_{it} = CP_{it} + VP_{it}$$

Where PE_{it} is the on-grid price of an individual plant i at time t; CP_{it} is the capacity tariff of a plant i at time t; VP_{it} is the volume tariff of a plant i at time t.

The capacity tariff can be calculated as follows.

$$CP_{it} = \frac{K_t(DEP_{it} + FE_{it})}{CIU_{it}}$$

where K_t is the parameter determined by the demand and supply in the market at time t; DEP_{it} is the depreciation; FE_{it} is the financial expenses; and CIU_{it} is the capacity in use.

The "capacity tariff" guarantees some excessive revenues to be received by the firms to cover the fixed costs occurred by the investment and finance activities of the power plant, which encourages further expansion on capacity. The "volume tariff" includes both the variable costs incurred in the operation and also a state planned profit margin. To some extent, such arrangement lowers the operation risks for those power stations, because the fixed costs of the power stations are secured, and then the fuel cost growth are transferred to the grid companies. However, such arrangement got suspended later on, because the power stations soon colluded together and then bid a high a price that the grids companies cannot afford (Wang 2006).

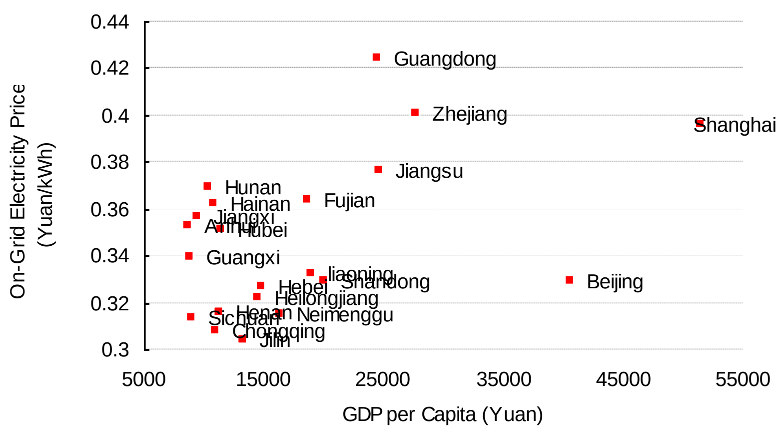

Figure 4.2 The Provincial On-grid Electricity Price of Coal-fired Power Plants and Regional GDP per Capita across China (2005)

Source: the regional GDP from National Bureau of Statistics of China; the price data from "Risk Analysis of the Coal-fired Power Generation in China 2006".

In China, the government issues a general guidance price first and then the on-grid price for each individual plant according to its cost and the average regional society cost, and the adjustment would be made according to development conditions in each region (Wang 2006). Figure 4.2 shows the average on-grid electricity prices of the coal-fired power plants in 27 regions across China in the year 2005. In the 4 regions, where the electricity price is above 0.37 Yuan/kWh, the GDP per capita exceeds 25,000 Yuan. And in the 5 regions, where the price is below 0.32 Yuan/kWh, the GDP per capita is below 11000 Yuan. It implies that the on-grid electricity prices are relatively higher in the regions with the high GDP per capita, although most of the regional prices fall within the range between 0.32 Yuan/kWh and 0.37 Yuan/kWh. It also implies that the on-grid price of each power plant is actually affected by regional incomes to some extent in China.

Table 4.1 The Provincial On-grid Electricity Price of Coal-fired Power Plants and Regional GDP per Capita in China (2005)

Region	GDP per Capita (Yuan)	On-Grid Electricity Price (Yuan/kWh)
Guangdong	24,435	0.424
Zhejiang	27,703	0.401
Shanghai	51,474	0.396
Jiangsu	24,560	0.376
Hunan	10,426	0.369
Fujian	18,646	0.364
Hainan	10,871	0.362
Jiangxi	9,440	0.357
Anhui	8,675	0.353
Hubei	11,431	0.351
Guangxi	8,788	0.339
Liaoning	18,983	0.332
Beijing	40,613	0.329
Shandong	20,096	0.329
Hebei	14,782	0.327
Heilongjiang	14,434	0.322
Inner Mongolia	16,331	0.315
Henan	11,346	0.316
Sichuan	9,060	0.313
Chongqing	10,982	0.308
Jilin	13,348	0.304
Shaanxi	9,899	0.271
Yunnan	7,835	0.256
Guizhou	5,052	0.252
Qinghai	10,045	0.24
Gansu	7,477	0.235
Ningxia	10,239	0.233
Minimum	5,052	0.233
Mean	15,814	0.325
Maximum	51,474	0.424

Source: the regional GDP from National Bureau of Statistics of China; the price data from “Risk Analysis of the Coal-fired Power Generation in China 2006”.

4.3. Theory of the plan price and its testable model for empirical estimation

According to the previous studies that identified the plan supply of electricity in China, we propose that a state planner plans a price in order to maximise the total output of the whole industry ( )[20] for given resources available at time t. In response to the planned aggregate output , the planner also sets an aggregate plan price as $\bar{p}_t$( ). The aggregate plan price is set not only for production to meet demand by both household consumers and the productions in powering other industries. Due to the mixed system of the economy, with state planning in the electricity sector on one hand, and free market in other industrial sectors on another, it is expected that a lower plan price of electricity will be responded by more market demand from other industries in using more electricity as its essential input for their production. In this sense, it is expected that $\bar{p}_t$(Q) should have a property of an inverse relationship of the social plan price with social output, which is $\frac{\partial Q_t}{\partial \bar{p}_t} < 0$.

In a symmetric scenario, every power plant or firm should have an identical cost. If this is a case, then the planner can set a plan price of each individual firm to equal the aggregate social plan price at $\bar{p}_{it} = \bar{p}_t$.

In fact, firms are different and so are costs. Thus the aggregate plan price will be adjusted by the planner to account individual firm's production condition and cost, making one firm with one plan price to reflect different cost conditions of firms. This means that there will be some adjustment in setting an individual plan price for

[20] The working assumption is "plan electricity" is same to actual level for theory development. We are aware of the difference between the actual and planned one in empirical estimation. In empirical estimation, we expect that the plan is made on the basis of the actual electricity output in the past period t-1. As a result, we use the actual output of electricity as the expectation of the plan output at period t.

firm's cost at c_{it}, in which this cost adjustment can be described as follows:

$$\frac{\bar{p}_{it}}{c_{it}} = \left[\frac{\bar{p}_t(Q)}{c_{it}}\right]^{\lambda}$$

Or

$$\bar{p}_{it} = [\bar{p}_t(Q)]^{\lambda} C_{it}^{1-\lambda} \qquad \text{………………… (1)}$$

Where, λ is the cost adjustment coefficient for a plan price of an individual firm at a range between 0 and 1. If λ=0, it means that the social plan price is fully adjusted to equal the cost of an individual firm. If λ=1, it means that the social plan price is not adjusted at all and it remains the same as the aggregate level. So λ indicates how far the social plan price is adjusted to account the cost of the firm. In other words, the more adjustment the higher price of the firm will be since the more cost impacts are taken into account in setting up a plan price for the firm.

Furthermore, in equation (1), the aggregate plan price $\bar{p}_t(Q)$ can be transformed to be more specific by specifying the total output of the industry as a sum of planned electricity output, q, and other industrial output, , produced by other industry in the free market, which is

………………………………… (2)

Since the state will attempt to set the aggregate plan supply of electricity ( ) as much as possible to meet the output growth of other industry that demands for electricity as one essential input for its production, it links with as = that has the property of . Apart from the aggregate demand that affects plan supply for given power generation capacity in the short run, a planned price can also serve as an incentive to influence power firms' decision in choosing their capacity of supply in the long run. Due to the freedom of the firm in setting its investment in capacity of electricity generation, the higher planned price can stimulate the firm to invest more capacity that will enable the state to have more capacity to plan more output q in the long run, so that it gives with the property of $\partial q_t \,/\, \partial \bar{p}_t > 0$. states that the other industry is operated in free market and so its output is a function of market price p. On this basis, we write (2) as

$$Q_t = q_t\left[Q_{jt}(p_t),\ \bar{p}_t\right] + Q_{jt}(p_t) \qquad \text{…………………(3)}$$

If we consider an argument that the aggregate plan supply of electricity can also serve as 'a strategic constraint' on the output of the other industries, in which this has been a particular case where the shortage of power is common in an economy, then the (3) can have its augment form:

$$Q_t = q_t\left[Q_{jt}(p_t),\ \bar{p}_t\right] + Q_{jt}\left[p_t,\ q_t(\bar{p}_t)\right] \qquad \text{……………………….. (4)}$$

To maximize the total output of both electricity and other industries, Q, which is the objective of the state planner in choosing a plan price for q, gives the following:

$$\frac{dQ_t}{d\bar{p}_t} = \frac{\partial q_t}{\partial Q_{jt}}\frac{dQ_{jt}}{d\bar{p}_t} + \frac{\partial q_t}{\partial \bar{p}_t} + \frac{\partial Q_{jt}}{\partial p_t}\frac{dp_t}{d\bar{p}_t} + \frac{\partial Q_{jt}}{\partial q_t}\frac{dq_t}{d\bar{p}_t} = 0$$

Manipulating above gets $\left[\frac{\partial q_t}{\partial \bar{p}_t}\frac{\bar{p}_t}{q_t}\right]\frac{q_t}{\bar{p}_t} = -\frac{\partial q_t}{\partial Q_{jt}}\frac{dQ_{jt}}{dp_t} - \frac{\partial Q_{jt}}{\partial p_t}\frac{dp_t}{d\bar{p}_t} - \frac{\partial Q_{jt}}{\partial q_t}\frac{dq_t}{d\bar{p}_t}$

Then the aggregate plan price becomes:

$$\bar{p}_t = \frac{\varepsilon}{\sigma} q_t \qquad \text{………..(5.1)}$$

Where

$$\varepsilon = \frac{\partial q_t}{\partial \bar{p}_t}\frac{\bar{p}_t}{q_t} > 0 \quad and \quad \sigma = \rho - \frac{\partial Q_t}{\partial q_t}\frac{dq_t}{d\bar{p}_t} \quad and \quad \rho = -\left[\frac{\partial Q_t}{\partial p_t}\frac{dp_t}{d\bar{p}_t} + \frac{\partial q_t}{\partial Q_t}\frac{dQ_t}{d\bar{p}_t}\right] \geq 0 \quad \text{.....(5.2)}$$

Where ε is the price-incentive elasticity of output to reflect how the firm will respond to plan prices in choosing its capacity. The state plans output for a firm according to its capacity, so that the elasticity is expected to be positive since the higher plan price will induce more capacity expansion and so output. This suggests ε>0 due to

.

For σ, it is expected to be negative. This is, first, $\rho \leq 0$, or at least, in the short run. A change in electricity prices ($\bar{p}_t$) will not be immediately responded by a change in the product price of other industries (   ) due to (1) product competition that can enforce the firm to internally absorb a cost rise as much as possible and (2) the price adjustment made by the firm in response to costs will be lagged. This shows in (5.2). If a change in electricity prices ($\bar{p}_t$) will not be responded by the product price (   ), then , since a rise in the electricity price will be expected to stimulate more supply of electricity due to a price incentive to the power producer. In a growing market with holding , then the more supply of electricity can power other industries either to produce more, , or to have output unchanged. The latter implies . As a result, in equation (5.2), we expect $\rho \leq 0$.

Secondly, the marginal output of other industries with respect to supply of electricity is positive, . This ensures $\frac{\partial Q_t}{\partial q_t}\frac{dq_t}{d\bar{p}_t} > 0$, so that with $\rho \le 0$ it shows σ<0 in (5.2).

The discussion above shows the negative relationship between the electricity price and the aggregate power quantity supplied. The negative relationship of the supply in relation to the plan price implies that economic growth will be very much affected or constrained by power supply. This creates a strategic incentive for the state to plan not only more quantity needed to be supplied but also at a lower cost to stimulate demand for power in order to produce more. This explains that the electricity price and quantity supplied is regulated for promoting growth.

To substitute (5.2) for $\bar{p}_t(Q)$ in (1) gets

$$\bar{p}_{it} = \left[\frac{\varepsilon}{\sigma}q_t\right]^{\lambda} C_{it}^{1-\lambda} \qquad \text{…………….. (6.1)}$$

Or in a non-linear form the above can be presented as

$$\bar{p}_{it} = q_t^{\lambda\gamma(\varepsilon,\sigma)}\ C_{it}^{1-\lambda} \qquad \text{……………… (6.2)}$$

Where, γ is a coefficient affected by ε and σ, and its sign indicates a technology impact of the other industry in using electricity on the state planner to set up its plan price in relation to supply: γ<0 means the technology of high electricity intensity as dominant, and γ>0 means the low electricity-intensity technology dominated over the other industry.

To turn to the cost impact on the plan price in (6.2), it is expected that the effect of individual firm's costs on setting a plan price will lead to one firm with one plan price. In response to this institutional arrangement, the firm will be motivated to play a high cost strategy. The high-cost strategy will allow the firm to gain a cost advantage in bargaining with the state planner to set up a higher price for offsetting its higher costs of the firm. Therefore, costs will be expected to be a central factor to affect the plan price of a firm in the Chinese power sector.

To test this expectation, we can further break down the cost factor, C, in (6.2) into different cost elements that the firm could use to bargain with or affect the state planner for a higher price.

$$\bar{p}_{it} = q_t^{\lambda\gamma(\varepsilon,\sigma)}\, c_{jt}^{\eta(1-\lambda)}\, r_{it}^{\beta(1-\lambda)}\, m_{it}^{\phi(1-\lambda)}\, c_{it-1}^{\theta(1-\lambda)}\, D_t^{\omega} \;\ldots\ldots\ldots\; (7)$$

Where, first, r is the cost of capital for an argument that the firm can strategically raise the cost of finance or capital, such as take more bank loans to finance its projects, set up a higher depreciation rate, etc in bargain for a higher price to offset part of the finance cost. The second is a fuel price or raw material price denoted by m in (7), which shows that the firm could ask the planner to past their costs through due to a higher input costs. The third is the overall average unit costs in the previous period, denoted by c_{it-1} in (7), in which the past cost could be used as a starting point for the price bargain between the state and the firm. We also consider the profitability state of the firm that can affect its bargain with the state. It is also possible that the firm could use the cost of rival firms (c_j) as an indication of the cost environment for bargaining for a higher price. If the price serves partly as an income distribution among power firms, then a soft-budget constraint will be expected to help the loss-making firm to get a higher plan price than the profit-making firm. In (7), it uses D to denote the profitability state of 1 for profit and 0 for losses.

We take logarithm for (7) with further inclusion of market share variable (s), the average rival cost (c_j) and other two dummy variables of location (D^L) and affiliation (D^A)   in our econometric model of the plan price bargaining theory:

$$\ln \bar{p}_{it} = \alpha + \hat{\gamma} \ln q_{it} + \tau \ln s_{it} + \hat{\eta} \ln c_{jt} + \hat{\beta} \ln r_{it} + \hat{\phi} \ln m_{it} + \hat{\theta} \ln c_{it-1} + \omega d_t + \xi d_t^L + \kappa d_t^A + \mu_{it}$$

…………………….. (8)

Where, μ is a disturbance term with a normal distribution. $\hat{\gamma} = \lambda\gamma, \hat{\beta} = \beta(1-\lambda)$, and $\hat{\eta} = \eta(1-\lambda), \hat{\phi} = \phi(1-\lambda), \hat{\theta} = \theta(1-\lambda)$.

To pursue the robustness test, we break the cost of capital (r) according to interest rate (i_r) and depreciation rate (d_r):

$$\ln \bar{p}_{it} = \alpha + \hat{\gamma} \ln q_{it} + \tau \ln s_{it} + \hat{\eta} \ln c_{jt} + \hat{\beta}_1 \ln i\_r_{it} + \hat{\beta}_2 \ln d\_r_{it} + \hat{\phi} \ln m_{it} + \hat{\theta} \ln c_{it-1} + \omega d_t + \xi d_t^L + \kappa d_t^A + \mu$$

…………………… (9)

Moreover, we also test the price-cost margin (p^M) impact of the bargaining factors:

$$\ln \bar{p}_{it}^M = \alpha + \hat{\gamma} \ln q_{it} + \tau \ln s_{it} + \hat{\eta} \ln c_{jt} + \hat{\beta} \ln r_{it} + \hat{\phi} \ln m_{it} + \tau \ln LF_{it} + \omega d_t + \xi d_t^L + \kappa d_t^A + \rho_{it}$$

……………………. (10)

$$\ln \bar{p}_{it}^M = \alpha + \hat{\gamma} \ln q_{it} + \tau \ln s_{it} + \hat{\eta} \ln c_{jt} + \hat{\beta}_1 \ln i\_r_{it} + \hat{\beta}_2 \ln d\_r_{it} + \hat{\phi} \ln m_{it} + \tau \ln LF_{it} + \omega d_t + \xi d_t^L + \kappa d_t^A + \rho_{it}$$

……………………. (11)

Where, we add the load factor (LF) in (10) and (11), which is actual output over the expected maximal output in the full capacity, to further test if there is a soft-budget constraint effect on the profit margin in the plan price, since the state planner could set up a high profit-margin price for a firm with a lower load factor in order to provide the firm with favourable price-setting support to subsidies or compensate the firm that has a lower capacity utilisation .

4.4. Data and variables

The data employed to test the model of (8), (9), (10) and (11) are collected from two sources. One is the financial reports of individual power firms on their balance sheet and income statement during the period from 1999 to 2005, prepared by the National Bureau of Statistics of China. Another set of data includes the basic production information about the power firms in five provinces in the southern China during the period from 2003 to 2005, such as a plant type, installed capacity and the generated volume. Those data are published in the Chinese Electric Power Yearbook 2005 and 2006. The combination of the two sources provides a set of 3-year's panel data of some 100 coal-fired power firms in the five southern provinces in the southern China. Based on this panel data, the construction of variables employed in our estimation is described as follows.

As shown in Table 4.3, there are 64, 100 and 98 observations in 2003, 2004 and 2005 respectively, i.e. 262 observations in total by 108 individual plants. The number of the profitable plants is 53 in 2003, 66 in 2004 and 55 in 2005 respectively, which means that the percentage of the profitable plants in the sample drops during the three years, i.e. from the 82.8% to 66% in 2004, and then to 56% in 2005. In the sample, there are 20 plants are owned by the state. The number of the profitable state-owned plants is 9 in 2003, 10 in 2004 and 12 in 2005 respectively, which take up 75% of the state-owned plants in 2003, 55% in 2004 and 70% in 2005.

The price

As the component of the dependent variable in model (8) and (9), the prices of the electricity in China per kWh are the average tariffs including the taxation, which are settled between the individual power plants and the grid companies. It's calculated by the annual sales revenue divided by the volume of electricity generated. Those prices are known as the "on-grid prices" for independent power producers, which are determined by the office of the National Development and Reform Commission (NDRC) and also be different with individual power plants. Such prices exclude both the observed transmission and distribution costs and profit margin of the grid companies.

In this paper, the "on-grid price" of an individual power plant from 2003 to 2005 will be employed in estimation, instead of the average "catalogue prices" in 1998, used by Lam (2004). Furthermore, we test the profit margin in the price and see how it will be affected. The price-cost margin is calculated by sales revenue divided by the total cost of an individual firm. We define our profit margin as sales revenue divided by the total cost of an individual firm.

Since, the dependent variables are the electricity price and the price-cost margin. The average on-grid price is 0.34 Yuan/kWh in 2003, 0.39 Yuan/kWh in 2004 and then increases to 0.44 Yuan/kWh in 2005 respectively, with a growth rate of 10% per year. However, the sample shows a steady decreasing trend of the price-cost margin during the three years. The price-cost margin of the sample drops from 1.165 in 2003 to 1.081 in 2004, and then 1.024 in 2005, which is consistent with decreasing profits shown by the panel. In order to eliminate the disturbance caused by the abnormal observations, the extreme value of the price above 1 Yuan/kWh has been dropped from the panel for estimation.

The total electricity output in the region

The total electricity output is the total production of all power plants in a province where an individual plant is located. The total output of electricity in five provinces respectively was 401 billion kWh in 2005 and 459 billion kWh in 2006 shown in Table 4.2.

Table 4.2 The Provincial Production of the Electricity in Five Provinces (2003-2009)

	Guangdong (Billion kWh)	Guangxi (Billion kWh)	Hainan (Billion kWh)	Guizhou (Billion kWh)	Yunnan (Billion kWh)	Sum (Billion kWh)	% in the total power supply of China
2003	178	34	6	62	45	325	17.66%
2004	157	27	5	58	42	289	17.62%
2005	216	41	8	78	58	401	16.74%
2006	237	47	9	97	68	459	16.70%
2007	252	62	11	116	84	525	16.50%
2008	261	81	12	119	92	565	16.66%
2009	233	83	20	126	102	565	16.95%

Source: The Development Research Centre of the State Council.

The average unit cost of the rival plants and the cost of the rivals over the plant

The average unit cost of the rival plants of the individual plant i in the region can be calculated as follows:

$$c_{jt} = \frac{\sum_{k=1}^{n} c_{kt} - c_{it}}{n-1}$$

, where n is the total number of the observation in time t, c_{it} is the unit cost of the individual plant i in time t. The rival plants are those located as the same province as the individual i.

The similarity of the costs in the industry could be one of the reasons affecting the price of an individual firm (Grant 1982). In Allen and Hellwig's study (1986), it's argued that "a small firm cannot afford to charge a high price unless all of the other firms charge prices very near competitive price". In Neufeld's paper (1987), it's argued that the demand-charge rate structure in US electricity sector "based prices not on the factors determining the utility's production costs but on the factors which would determine the cost of alternative supply".

As mentioned above, the average cost of the other plants could form the cost environment for the individual plant to bargain with the government in China. It's assumed that the higher cost of other plants could make the individual one easier to ask the government for higher price. In another word, it can be expected that the average unit cost of the rival plants could be positively correlated with the price.

In order to test the dependent variable of the price-cost margin, in the model (10), the unit cost of the rivals over the individual plant is used instead of the average unit cost of the rival plants. Such independent variable is calculated by c_{jt} divided by c_{it-1}. It measures how much is the average unit cost of the rival plants relative to the cost of the individual firm i. If such figure is larger than 1, it means that the unit cost of the individual plant is below the average unit cost of the rival plants, and vice versa. We expect that the higher average cost of rivals over the plant could lead to the higher profit margin of that particular plant, because of this will be in favour of the bargaining with the state. In another word, such variable is expected to be positively related with the price-cost margin.

The overall mean value of the total unit cost of the plant is 0.38 Yuan/kWh, and its mean value of each cross-section is 0.297 Yuan/kWh for 2003, 0.37 Yuan/kWh for 2004, and 0.445 Yuan/kWh for 2005 respectively.

The average cost of the rival plant has an overall mean value of 0.39 Yuan/kWh, of which the mean value for each year increases from 0.28 Yuan/kWh for 2003 to 0.388 Yuan/kWh for 2004, and 0.47 Yuan/kWh for 2005.

The regional market share

The regional market share of each power plant is calculated by dividing the output of each plant by the total aggregate output in the five provinces in southern China.

As a kind of homogenous product, the market share of the electricity supply is expected to be positively related with its price in the market economy. In the market economy, the individual firms will adjust their prices in response to the perceived changes in their market shares. According to the theory of Nash-Cournot, the non-collusive firms in a concentrated market will be more profitable than the un-concentrated market. And in the oligopolistic industries, it's more likely for the firms to generate the collusion and then achieve higher profits. In both cases, "the increased concentration is likely to lead to higher profitability" (Hay and Morris, 1991).

Some previous empirical studies also find evidence to support such claim. McFetridge (1973) studied the cross-sectional data of 43 Canadian manufacturing industries during the period from 1965 to 1969. In that study, the evidence shows that, "given the rate of growth of demand and the level of capital intensity", the price-cost margin is positively correlated with the Herfindahl index, i.e. the proxy of the industrial market concentration. With the study of 79 US industries, Qualls (1979) found "a statistically significant positive relationship between the cyclical variability of price-cost margins and concentration." Moreover, Domberger studies 71 industries in the UK and then found the value of partial price adjustment coefficients were positively correlated with concentration (Domberger, 1979). In the paper of Dixon (1983), with the study of 43 manufacturing sectors over the period 1948/49-1973/74 in Australia, it's concluded that "the extent of price cutting is positively related to the number of firms in an industry."

However, the theory of the market economy may not be applicable to explain the situation in China. If a firm gains a large market share, it could either raise its sale price by exercising its market power or lobby more intensively the state planner to set a plan price in the firm's favour, if the firm is under a plan control. In order to test the effect of the market concentration in the price and price-cost function, the variable of the regional market share is incorporated into the regression models. The alternative hypothesis is that the changes in the regional market share are expected to be positively correlated with the changes in the price and the price-cost margin.

The total unit cost

The total unit cost is the total costs divided by total output produced by the firm over a year, and the costs include the cost of sales, overheads and financial costs. Lam (2004) found that the catalogue price of electricity in China didn't fully track the average total cost. As described above, under the plan economy, the price of the electricity of the Chinese power plant is set to cover the total costs and also the profit margin to ensure a certain return on capital employed. The government sets a price according to cost information in the past, so that a lagged unit cost is employed in estimation, in order to capture the cost-driven expectation. As a result, the relationship between changes of the lagged cost and the on-grid price is expected to be positive, indicating the price effect of the costs.

The cost of capital

The cost of capital is the sum of the imputed interest rate and the depreciation rate. The imputed interest rate is calculated by the interest costs divided by the interest bearing debt, where the interest bearing debt is the result of the total debt minus trade payables. The depreciation rate is calculated by the depreciation charges divided by the historical cost of the fixed assets.

The cost of capital could be one important impact on price setting, since the firm can set the cost higher to strengthen its bargaining with the state in obtaining a favourable price. The price impact of the financial cost is also evident by Yochi Shinkai (1974) that 19 manufacturing industries over the period from 1967 to 1971.

Lam (2004) tested the capital cost of the power companies in China, which consists of "equity cost, debt cost and depreciation charge", and then found that it insignificantly affected the catalogue prices. However, such result contravenes the evidence found in previous chapter, where the depreciation charge is recognised as an important tool to manipulate the profit margin of the plant in China. Because of its role in bargaining with the state and then reduce taxation, it's high likely for those Chinese power plants to boost their depreciation charges. In another word, it's expected to find out the positive relationship between the price and the depreciation rate.

The fuel price

By the accounting definition, the cost of sales consists mainly of three elements, i.e. material input, capital consumption, and labour. Since coal is used as "material input" for generating power, we could calculate a fuel cost from the costs of sales minus wage costs and depreciation charges. As a result, fuel inflation can be identified as change in the unit cost of fuel in the current time against the previous time. The overall average fuel price inflation in the panel is above 1, i.e. 1.255, which indicates that the coal price keeps growing over the three years. And for 2004 and 2005, the average inflation of the fuel price in the sample is 1.341 and 1.291 respectively, which shows a slowdown of the price growth of the coal for electricity generation.

The cost of the capital

The cost of the capital of the plant consists of the interest rate and the depreciation rate. Its mean value is 0.087 for the overall panel, 0.077 for 2003, 0.081 for 2004 and 0.102, which increases by 32.5% over the three years in the sample. The average interest rate of the plant is 0.028 for the overall panel, 0.023 for 2003, 0.024 for 2004 and 0.037 for 2005. The number of the interest rate above 0.5 and below -0.05 has been regarded as "extremes" and then dropped. The average depreciation rate of the plant is 0.059 for the overall sample, 0.0547 for 2003, 0.0575 for 2004 and 0.064 for 2005. The abnormal number of the depreciation rate above 1 has been dropped.

The load factor

The load factor, measuring the utilisation of the capacity, is the ratio of the actual output of the power generated by a power plant over the output that the plant would have produced at its full installed capacity during a year. It indicates the capacity utilisation of the power plant[21]. Since the higher load factor can bring the better financial performance of a firm, it's expected that for the firms with a given lower load factor the state could compensate their low finance through allowing the firms to charge a high profit margin in its planned price. As a result, the plan price is expected to play a role of "the soft-budget constraint" in helping the firm with a poor or lower income-generating capability. If this expectation is established, then we can observe a negative relationship between the load factor as indication of income making ability and the profit margin in the planned price of a firm.

The average load factor of the sample plants decreases from 64.13% in 2003 to 62.9% in 2004, and then to 59.1% in 2005. The overall load factor of the panel is 61.78%.

[21] An average load factor can be calculated by the formula as follows:

$$\text{Average Load Factor} = \frac{\text{Total Annual Output}}{\text{Installed Capacity} \times 24 \text{ hours per day} \times 365 \text{ days}} \times 100\%$$

Table 4.3 Data Description

	Variable	Observation	Mean	Std. Dev.	Min	Max
Electricity price	Overall	262	0.3946037	0.1798012	0.102647	0.972294
(Yuan/kWh)	2003	64	0.3354982	0.1512081	0.102647	0.685363
	2004	100	0.391491	0.1720102	0.120246	0.729399
	2005	98	0.4363794	0.1945802	0.117872	0.972294
Price-cost	Overall	262	1.08028	0.1917842	0.5587857	1.686237
margin	2003	64	1.165098	0.2122232	0.7560277	1.686237
	2004	100	1.081005	0.1854567	0.5587857	1.641228
	2005	98	1.024148	0.1633468	0.66444	1.509125
Total regional	Overall	262	2123.641	188.3312	1802.9	2280.32
output	2003	64	1802.9	0	1802.9	1802.9
(10^5 MWh)	2004	100	2175.37	0	2175.37	2175.37
	2005	98	2280.32	0	2280.32	2280.32
Total unit cost	Overall	262	0.3801886	0.196389	0.100136	0.998197
of the plant	2003	64	0.2969346	0.1514268	0.115294	0.690444
(Yuan/kWh)	2004	100	0.3704158	0.1694601	0.100136	0.68515
	2005	98	0.4445307	0.2252147	0.102551	0.998197
Average cost	Overall	262	0.3920749	0.070343	0.278376	0.470011
of the rival	2003	64	0.2842493	0.0022601	0.278376	0.28696
plant	2004	100	0.3880239	0.0016614	0.384938	0.390674
(Yuan/kWh)	2005	98	0.4666252	0.0022299	0.461143	0.470011
Cost of capital	Overall	262	0.0874434	0.0749743	-0.036843	0.761336
	2003	63	0.0766327	0.0476915	-0.014872	0.205381
	2004	94	0.0806707	0.0842336	-0.036843	0.761336
	2005	90	0.1020846	0.0786797	-0.014856	0.520234
Interest rate	Overall	262	0.0279858	0.0424845	-0.047072	0.409509
	2003	63	0.0224563	0.0295012	-0.046147	0.116973
	2004	94	0.0235798	0.028321	-0.047072	0.091768
	2005	90	0.0364582	0.0585642	-0.038649	0.409509
Depreciation	Overall	262	0.0592745	0.0559033	0	0.711871
rate	2003	64	0.054737	0.0383316	0	0.2
	2004	100	0.0575429	0.0744113	0	0.711871
	2005	98	0.0640047	0.0420025	0.000243	0.230403
Inflation of the	Overall	196	1.3164	0.8754626	0.124965	7.925491
fuel price	2003					
	2004	99	1.341224	0.9355543	0.124965	5.390256
	2005	97	1.291065	0.8136584	0.367261	7.925491
Load factor	Overall	262	0.6177588	0.2149172	0.059551	0.994292
	2003	64	0.6412697	0.2147314	0.059551	0.994102
	2004	100	0.6291852	0.2010357	0.108793	0.946537
	2005	98	0.5907452	0.2277062	0.060122	0.994292

N = 262 (Number of observations)

n = 108 (Number of plants)

All of the dependent and independent variables above will be incorporated into the estimation model in the form of logarithm. To ensure the exdogeneity in our estimation, we have lagged variables that are likely to generate potential endogenous impact. These variables are the total regional output, the market share, the total unit cost of the firm, and the load factor. The average cost of the rival plants, the interest rate, the depreciation rate and the inflation rate of the fuel price remain at time t in estimation.

Moreover, three dummy variables are employed in the model, i.e. the state of the profit, the location of the plants and the affiliation of the plant. The state of the profit will be 1 if a plant makes profit, and it will be 0 if a plant makes losses. If a plant is located in Guangdong province, the dummy variable of the location will be 1, otherwise it will be 0. If a plant is owned by the state, the dummy variable of affiliation will be 1, otherwise it will be 0. As shown in Table 4.3, there are 89 profitable plants, 79 Guangdong plants, and 20 state-owned plants in the panel. And there are also 174 observations of the profit-making plants, 191 observations of the Guangdong plants and 47 observations of the state-owned plants.

Table 4.4 Dummy Variables

	2003	2004	2005	N (Observations)	n (Plants)
Profitability of plants (Profitable plant = 1)	53	66	55	174	89
Location of the plant (Guangdong =1)	44	74	73	191	79
Affiliation of the plant (State-owned plant = 1)	12	18	17	47	20

4.5. Empirical results and discussion

The STATA is employed to run the regression for the model estimation. The estimated results of the price and price-cost margin model of the Chinese power plants are shown in Table 2.4 below, respectively.

Table 4.5 Estimation of the Price and Price-cost Margin Function of the Chinese Power Plants

	Model 8		Model 9		Model 10		Model 11	
	Log price		Log price		Log price-cost margin		Log price-cost margin	
Independent variable	Coef.	t	Coef.	t	Coef.	t	Coef.	t
Constant	2.427	1.8	1.989	1.4	**2.820*** **	**3.7**	**2.837** **	**3.2**
Total regional output (Log Q_{t-1})	-0.321	-1.9	-0.059	-1.3	**-0.335*** **	**-3.4**	**-0.335** **	**-3.0**
Average cost of the rival plants (Log c_{jt})	**0.628*** **	**4.4**	**0.415* **	**2.4**				
Average cost of the rivals over the plant [Log (c_{jt}/c_{it-1})]					**0.100**	**1.9**	0.106	1.6
Regional market share of the plant (Log s_{it-1})	0.026	0.8	-0.007	-0.3	**0.032**	**1.9**	**0.038**	**1.9**
Lagged cost of the plant (Log c_{it-1})	**0.222*** **	**3.6**	**0.155* **	**2.1**				
Cost of capital (Log r_{it})	**0.049** **	**3.0**			-0.016	-1.3		
Interest rate (Log i_r_{it})			**0.033** **	**2.7**			-0.002	-0.2
Depreciation rate (Log d_r_{it})			0.024	1.1			-0.010	-0.5
Inflation of the fuel price (Log m_{it})	**0.277*** **	**6.7**	**0.192*** **	**4.0**	**-0.100** **	**-2.7**	**-0.110** **	**-2.4**
Load factor (Log Lf_{it-1})					**-0.124** **	**-3.2**	**-0.133** **	**-2.9**
State of profit of the plant (1 for profit, 0 for loss)	**-0.127*** **	**-4.0**	**-0.073* **	**-2.1**	**-0.065* **	**-2.2**	**-0.059**	**-1.8**
Location of the plant (1 in Guangdong, 0 in others)			**0.229* **	**2.5**	**-0.152**	**-1.9**	**-0.147**	**-1.7**
Affiliation of the plant (1 with central, 0 with local)	**-0.309** **	**-2.6**	-0.178	-1.5	**-0.190**	**-1.9**	-0.181	-1.6
R^2 (adjusted)	0.98	.	0.95	.	0.662	.	0.612	.
Standard error of estimation	0.118		0.110		0.098		0.105	
Number of observations	191		180		191		180	
Number of plants	99		96		99		96	
Hausman test[1] Chi-square	12.59		32.59		34.42		33.73	

Dependent variable: Log price in Model 8 and Model 9; log price-cost margin in Model 10 and Model 11

t statistics in parentheses

* p<0.05, ** p<0.01, *** p<0.001

Note: 1) H0: difference in coefficients not systematic.

In order to determine the use of the fixed or random effect estimation model, the Hausman test is carried out. It test whether the estimates of the random effect model is consistent with the fixed effect model. If the null hypothesis is rejected, it means that the random effect model is biased, and the fixed effect model is preferable. It also means that the efficient regression model, i.e. the random model, cannot be used instead of the fixed effect model. The results of our estimation for the four models are discussed as follows.

In Model 8 and 9, the chi-square of the Hausman test is 12.59 and 32.59 respectively, which are both more than the critical value 5.99. In the Model 10 and Model 11, the Hausman test gives the chi-square statistics of 34.42 and 33.72, both of which are larger than the critical value of 5.99. It means that the fixed effect model is legitimate for estimation.

The Table 4.5 shows that the average cost of rival plants, the lagged cost, the cost of capital and the fuel price inflation have a significant impact on electricity prices changes. According to the results of Model 10 and Model 11, around 66% and 61% of the variation of the price-cost margin can be explained by the explanatory variables respectively. These results show that total regional output, the average cost of rival plants, the regional market share, the inflation of the fuel price and the load factor have a significant impact on the price-cost margin.

The total regional output

As expected, the total regional output has a negative relationship with the price of electricity, with a significance of t-statistic at 1.9 in Model 8 and 1.3 in Model 9. Despite of the less significance, it's an indication that the state intends to lower prices in order to supply more & cheaper electricity that will help increase the total output and protect the total industrial outputs. In both Model 10 and Model 11, this indicator is more obvious. The total regional output is negatively correlated with the price-cost margin at a significance level, where 1% of the increase in demand for the total regional output will result in 0.335% fall in the profit margin in the price. This means that not only the prices but also the profit margin of the electricity has been limited to a certain level to favour other industries to benefit from low cost electricity in the long run. In other words, it conforms to our argument that the state intends to supply sufficient electricity at a lower cost to meet the demand of other industries that relies on power intensively for their production. With this pricing policy, the state promotes the growth of the whole industry and so the economy but at expenses of the power sector profitability.

The average cost of the rival plants

According to the results of the estimation in Table 4.5, the average cost of the rival plants is positively correlated with the electricity prices, and the average cost of rivals relative to the cost of the firm itself is also positively correlated with the profit margin of the plant. As shown by the Model 10, 1% increase in the average cost of rivals will induce 0.1% increase in the profit margin of the individual plant. If the argument of Grant (1982), Hellwig (1986), and Neufeld (1987) that the price of the production may also depend on the cost of the alternative supply can be applied to the Chinese context, then it seems to suggest that the state has taken account a market-influence element in pricing electricity. This is possible since the cost environment element could be transmitted to the planner through the bargaining process in price setting between the state and the firm that uses the cost environment to increase its influence for a high price.

The regional market share of the plant

According to the result of Model 8 and Model 9, the relationship between the regional market share and the price changes is insignificant and ambiguous. The absolute value of the t-statistics of the regional market share of the plant is 0.8 and 0.3 in Model 8 and Model 9, both smaller than 1.96, so the null hypothesis cannot be rejected. This suggests that the changes in the regional market share of the plant have no impact on the price. However, according to the results of Model 10 and Model 11, the increase in the regional market share of the plant will lead to some increase in the profits of the plant, which is consistent with the theory of the industrial organisation, and empirical findings reported by McFetridge (1973), Qualls (1979), Domberger (1979) and Dixon (1983).

In the plan supply, the positive link between market share and the profit margin of price can be interpreted as "a lobby power" to influence the planner to set a price in its favour on one hand, and also as "efficient gain" of the large firm that benefit from cost efficiency and so profitability on the other hand. Due to the fact that the energy efficiency of the large-sized power plant is higher than the small-sized one, the NDRC will allocate production to the large-sized plants with a high priority. Figure 4.3 presents the relationship among the load factor, market shares of the installed capacity of the coal-fired power plants in the 5 provinces in southern China. The size of the circle in Figure 4.3 is calculated on the basis of the size of the installed capacity. It clearly shows that the large plant normally takes up a large percentage of the market share, and also has a high load factor. But some small plants have low load factors.

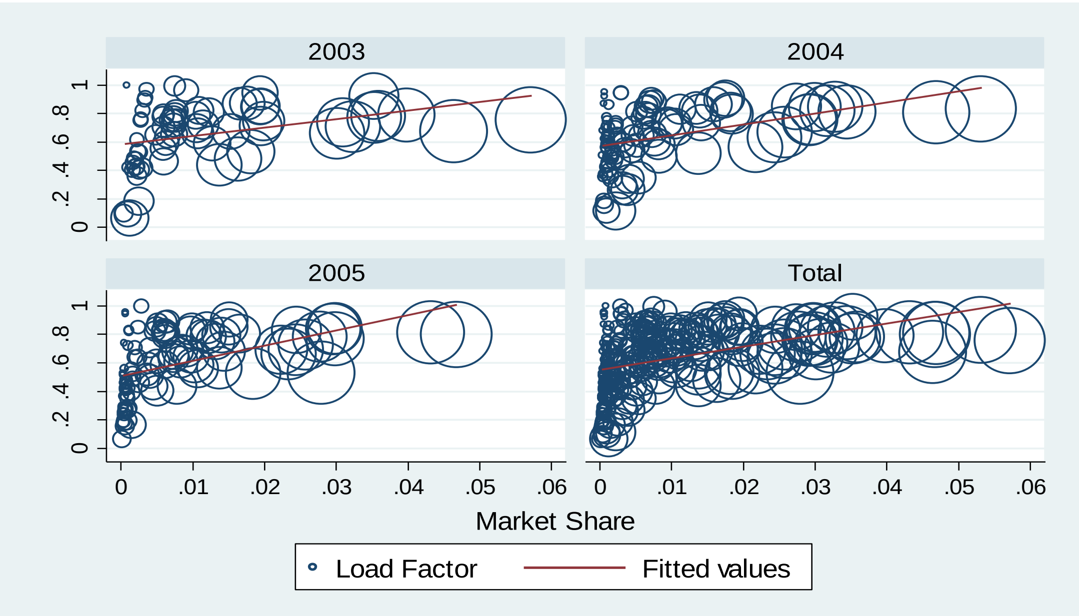

Figure 4.3 Capacity, Load Factor and Market Share of Chinese Power Plants (2003-2005)
Source: National Bureau of Statistics of China, Chinese Electric Power Yearbook 2005 and 2006.
Note: The areas of the circle indicates the size of the installed capacity of the power plant

The lagged total unit cost of the plant

The changes in the lagged cost of a plant have a strong positive relationship with the price changes of the electricity. The t-statistic of the lagged cost in Model 8 is 3.6 and 2.1 in Model 9 respectively, which means that it's significant above the 5% level.

The significant of the lagged cost impact on price supports our argument that plan prices are adjusted by the costs in the past. Such results are consistent with the pricing regulations issued by the NDRC in 2004 to reflect changes in costs such as fixed cost and the variable cost of the power plant. The estimated result in particular shows the impact of long-run costs on the price. This finding extends the argument made by Lam (2004) that electricity prices are mainly determined by "short-run costs". The close link between the price and the cost found by this study is also evident by other studies. Wang (2006) found that the prices of the Chinese power plants are set by adding a certain mark-up on the top of the internal rate of return or the annual operational costs. Besides, Liu, Wang and Song (2007) also made the expectation that "at the wholesale level, power plants are paid not according to short-run marginal costs but according to the dates of production, guaranteed rates of return and total costs of the plant." This similar relationship was also found in the centralised wholesale arrangement, i.e. Electricity Pool at UK, where Green (1999) claimed that the spot price of the UK electricity wholesale market has the positive relationship with the linear marginal cost.

The cost adjustment effect on price is not very large, only between 0.22% and 0.15%. As the coefficient of the lagged cost is below 1, it implies that a part of the change in the past costs is transferred into the present electricity price. This is perhaps that there are other present cost adjustment effects as well, i.e. short-run cost input, such as fuel inflation, which offset the long-run adjustment effect on the price.

The cost of the capital

As the combination of the interest and the depreciation, the changes in the cost of capital also have the positive relationship with the price changes at the significant level. According to Model 8, the 1% increase in the cost of capital will lead to 0.049% of the price increase. In Model 9, the cost of capital is replaced by the interest rate and the depreciation rate. 1% increase in the interest rate will result in 0.033% increase in electricity price.

The positive relationship between the cost of capital and the price indicates that the state takes into account the costs of finance in the price setting. This finding implies that, at least, a part of the cost of capital is covered in the plan price. With the link of the price and financial costs, it's expected that the firm is indeed to invest more since the part of financial costs can be covered by a rise in the price, through bargaining with the state for a higher price. Furthermore, the interest and depreciation are those items before taxation. It's believed that the cost of capital could be also employed as the tax shield to reduce the taxation.

According to the robust test, the positive relationship between the interest rate and the price is significant. It means that the borrowings for the capacity expansion would be also the important items to bargain for the higher prices. The plant borrows more loans to enlarge the capacity, and then in return it will be able to get a higher price and also spare more cash flow. In other words, the plan price set by the government covers the debt expense, so that the investment in the electricity sector will be encouraged by a reward of a higher price.

According to Model 10 and the robust test, the negative relationship between the cost of capital and the price-cost margin is insignificant, and so is the interest rate as well as the depreciation rate. This implies that a rise in financing cost will help increase a price but not lower the profit margin of a price. So this explains why a high-cost strategy is accountable for the firm to pursue in the plan supply. Although the depreciation rate is irrelevant to the reported price-cost margin according to Model 11, it doesn't mean that the depreciation has no impact on the profitability of the Chinese power plant. With the comparison between Drax in the UK and CPID in China, it clearly shows that the percentage of the depreciation against the price of Drax was only 6.01% in 2004 and 1.75% in 2005 respectively, while as to CPID, it's 10.39% in 2004 and 9.98% in 2005. In the context of the much higher operational cost of the UK plant, it means that the Chinese power plant would hide part of the profit, through the high depreciation charges.

The inflation of the fuel price

There is the strong positive correlation between the changes in the fuel price inflation and the price. In both Model 8 and Model 9, the t-statistics of the inflation of the fuel price is above 1.96. And in Model 8, 1% increase in the fuel price will result in 0.277% of the increase in the electricity price. In Model 9, the coefficient of the fuel price inflation is 0.192. However, the inflation of the fuel price shows the negative relationship with the price-cost margin of the plant. The increase in the fuel price by 1% will result in the fall in the price-cost margin by 0.1%. It means that the fuel price is a killer to firm's profitability.

As described above, under the pressure of the growth of the coal price, the regulator in China modified the rules in order to relief the heavy burden on those power generators by allowing the power firm to transfer part of the fuel cost rise to the grid companies and then the end-users. It's quite reasonable to expect the positive relationship between the changes in the price and the changes in the fuel price. The previous studies provided evidence to show the significant relationship between the input and the output prices. Hall and Hitch (1939) investigated 33 manufacturers, 3 retailers and 2 builders, and then conclude that the prices "will be changed if there is a significant change in wage or raw material costs". Ripley and Segal (1973) studied the annual data of 412 industries from 1954 to 1969 and then argued that "approximately 60 per cent of the variation of price changes can be explained by changes in three primary variables-unit labour costs, materials costs, and real output". With the evidence of Japanese manufacturing, Yochi Shinkai (1974) also found that "in the case of output prices, the single most important element of costs is the input price whose variations explain nearly half of the variations in the output price." However, in the case of electricity generators, the salary only takes up around 5% of the electricity price, so its impact on the overall tariffs is limited and can be ignored. As the fuel cost takes up around 90% of the variable cost, 70% of the generation cost and over 50% of the ex-factory price in China, it's reasonable to expect the fuel price has the significant impact on the electricity prices.

Lam (2004) studied the cross-sectional data of 26 regional and provincial power companies for the year 1998 and found that the fuel price is a significant variable in estimating the electricity prices, while the wage is insignificant. According to the results of the estimation above, the inflation of the fuel price has a strong positive relationship with the price and also a strong negative relationship with the price-cost margin. It means that the increasing fuel cost will be passed to the electricity price, but it will deteriorate the profit margin of the plant nevertheless. Such evidence supports the findings by Lam (2004) that around 40% of the fuel prices can be passed into the electricity prices in China. This is also consistent with the regulations about the adjustments of the ex-factory electricity price issued by the NDRC in recent years.

The load factor

According to the results of Model 10, 1% increase in the lagged load factor of the Chinese power plants will lead to around 0.124% drop in the price-cost margin in current period. It's not surprising that the load factor is negative related to the price. As mentioned above, the high load factor can bring the better financial performance of a power firm, the plan price plays a role of "soft budget constraint" in helping the firm with a poor or lower income-generating capability by allowing it to charge a high profit margin in its plan price.

As the costs will be spread over the products, high load factor will lead to low unit cost and then low price. The low load factor implies that the more costs will be allocated to the limited products, which will lead to high unit cost and also high price.

The similar phenomenon also happens in the UK energy sector. Some evidence from the previous study links the costs with the capacity utilisation of the power plants. , Lopez (February 2006) studied the UK power plants and found that "the greater the plant capacity the higher that is the load factor" from "a sample of half-hour data on load factor for coal-fired power plants in England and Wales", which is the evidence "in favour of increasing returns to scale in power plants". In Table 4.5, the operational indicators of two coal-fired power stations at UK provide the supplemental evidence to support the view of the observed return to scale in Lopez's study. Drax power station is the biggest coal-fired power stations in the UK, of which the capacity is 9.8 times as much as the capacity of Uskmouth. The load factor of Drax and Uskmouth is 69.1% in 2004 and 5.28% in 2006 respectively. Not surprisingly, the cost per unit of Drax in 2004 is only 16.7% of the unit cost of Uskmouth in 2006.

Table 4.6 The Return to Scale of the selected UK Power Plants

	Drax as at Dec 31, 2004	Uskmouth as at Oct 31 2006
Capacity (10 MW)	387.00	39.30
Output (10^5 MWh)	234.26	1.69
Age (Year)	30	45
Load Factor (%)	69.10%	5.28%
Price (Yuan/KWh)	0.364	1.129
Unit Cost (Yuan/KWh)	0.453	2.631
Operational Profit (Yuan/KWh)	(0.089)	(1.502)
Total Assets (1000 Yuan)	19,483,982.03	4,611,102.01

Source: FAME and the annual reports of Uskmouth and Drax power station

Moreover, in the recent study of the UK power exchange system, i.e. NETA, Sweeting (2007) performed the algorithm of the static oligopoly model and found that the dominant generators could have increased their profits "by lowering their bids and significantly increasing their output." In other word, the price-cost margin of the dominant UK power plants would be positively related to their output and the load factors. However, Sweeting's conclusion contradicted with the findings in Ofgem's report (1999) that National Power and PowerGen exercised the market power by significantly increasing the price "at which they offered their coal-fired station into the Pool over the period May to July 1999", which was consistent with Wolak and

Patrick's argument (1996) that the dominant generators would raise the electricity pool price by declaring the unavailable supply in certain periods, in order to maximise their profit.

However, because of a plan institution in China, such negative relationship in Model 10 can be interpreted as the soft-budget constraint effect on the profit margin in the plan price rather than the consequences of the oligopoly behaviour in the UK. Clearly speaking, in order to encourage the electricity supply, the Chinese government would provide the subsidies in the form of the so-called "soft price constraint on cost". As the notorious "constructive destruction", the soft price constraint is believed to lead to the low efficient production, to impede the progress of the technology change and to encourage the excessive production expansion. However, it doesn't mean that the Chinese government is going to protect the small inefficient plants with the favourite plan prices or to support them with the subsidies for the high generation cost. As shown in the previous section, the 10 smallest power plants in China with lower capacity utilisation made losses in recent years, but the 10 largest power plants with higher load factor also made the profit in the same period. Besides, the Chinese government has the plan and also takes the action to shut down the small plants gradually.

Comparing the 10 smallest coal-fired power plants and 10 largest ones in the five Southern provinces in China, it shows that the average unit total cost of the largest plants is substantially lower than the average unit total cost of the smallest ones. The former one is 54% and 49% of the latter on in 2004 and 2005 respectively (Table 4.6). The average load factor of the 10 largest plants is higher than the 10 smallest plants both in 2004 and 2005. Although the large plants may have higher fixed costs, the average unit fixed costs (including the depreciation, overhead costs and finance costs) of the 10 largest firms are still lower than the 10 smallest firms, due to the higher output quotation of allocated to the large firms by the state. Under the same level of the variable costs, it will lead to the fixed cost, and hence the total cost, to be spread over the larger amount of the electricity generated.

Table 4.7 The Return-to-scale of the Chinese Power Firms

	2004		2005	
	10 Smallest Firms	10 Largest Firms	10 Smallest Firms	10 Largest Firms
Average Capacity (10 MW)	6.09	120.45	4.63	132.49
Average Output (10^5 MWh)	2.56	77.05	2.09	80.08
Average Load Factor (%)	56.9%	72.3%	56.9%	68.0%
Average Price (Yuan/KWh)	0.459	0.331	0.539	0.340
Average Unit Cost (Yuan/KWh)	0.471	0.256	0.563	0.274
Average Unit Depreciation (Yuan/KWh)	0.056	0.027	0.091	0.052
Average Unit Overhead Cost (Yuan/KWh)	0.041	0.021	0.048	0.020
Average Unit Operational Profit (Yuan/KWh)	(0.012)	0.075	(0.024)	0.066

Source: Chinese Electric Power Yearbook 2006 and 2005

Notes: 1) the average overhead cost including the finance costs, 2) the large firms refer to those with the capacity ≥ 120 MW, 3) the small plants refer to those with the capacity ≤ 5 MW.

Stewart (1979) studied the cross-sectional data of 58 newly constructed fossil-fuel plants in 1970 and 1971 and then concluded that “the cause of declining average cost is primarily a result of the ability of plants with higher utilisation rates to spread capital expenses over a greater volume of output”. Bateson and Swan (1989) examined “the average costs of electricity generated” in New South Wales during the period from 1970 to 1984, and also argued that “costs…are highly sensitive to the degree of capacity utilisation but less so to unit size (scale)”. However, both at UK and in China, it’s likely for the larger plants to achieve the higher production, through the higher capital utilisation. The evidence above also shows that the government would set the higher price for the small plants, of which the load factors are also low. However, due to the high fixed cost, the 10 smallest plants still make the losses.

The reasonable explanation for such negative relationship between the two variables is that the Chinese government encourages the medium and large power plants to fully utilise their installed capacity to meet the growing demand for the electricity. As the larger plant will have the higher thermal efficiency, such arrangement also reduces the wastes of the society, promotes the industrial technology advance, improves the energy efficiency, and hence maximise the total outputs of the whole industry in China. So, it's reasonable to believe that the state uses the load factor as an instrument of "soft budget constraint" to control the unit cost of the electricity, and hence the electricity price.

The dummy variables

Not surprisingly, the dummy variable of the state of the profit in both Model 8 and Model 9 shows a negative relationship with the price changes. Such negative relationship shows that soft-budget constraints provide the upward adjustment of the ex-factory prices and the profit margin for the loss-making plants than the profit-making plants. It confirms expectation in the previous section that the profitability of the plant would affect the bargain power of the firm with the government. It implies that the power plant is encouraged to report higher cost and lower profit to the government, and then will receive higher price and profit margin in next period, although the transfer of the cost inflation has been suppressed and controlled by the government to some extent. In Model 10 and Model 11, the state of the profit is also negatively correlated with the dependent variable, i.e. the price-cost margin, which is consistent with prices estimation. It implies that the state uses "the price" as an instrument to help a weak or low efficient firm to get higher financial support through selling at a high price with the high margin of profit in price. The state sets the plan price on the basis of the cost. The high cost of a firm will lead to a high plan price to be given. However, the state also needs to restrict the financial budget of the power firms and to provide the cheap electricity for other industries. So, not all of the increase in the generation cost of the power firms can be passed to the grids. The power firms need to internalize some of the generation cost to make the profit. It means that the increase in the cost can erode the profitability of the power firms. Thus, there is a risk that cost-inefficient power firms may suffer the losses, if the plan price is insufficient to cover its increasing cost.

The positive coefficient of the plant's location in Model 9 shows that it's more likely for the plant in Guangdong province to enjoy the higher price. It's consistent with the conclusion drawn by Lam (2004) that electricity price in China would be higher in the region with higher per capita income. However, it's more likely for the plant out of Guangdong to receive higher profit margin, according to the negative relationship between the price-cost margin and the dummy variable of the location.

The negative coefficient of the affiliation implies that it's more difficult for centrally state-owned plants to ask for higher prices and the profit margin. The reason for such results could be that centrally state-owned plants have larger installed capacity so that they have higher energy efficiency and will report lower generation costs to the price maker. As shown in Table 4.8, according to the sample, the overall average price and price-cost margin of the centrally state-owned plants are lower than the locally state-owned plants by 103.9%.

Table 4.8 Average Total Unit Cost of the Local and State-owned Plants in China

	2003	2004	2005	Overall
Average total unit cost of locally state-owned plants	0.322	0.409	0.49	0.418
(Yuan/kWh)	(52)	(82)	(81)	(215)
Average total unit cost of centrally state-owned plants	0.19	0.194	0.227	0.205
(Yuan/kWh)	(12)	(18)	(17)	(47)
Percentage difference of the average total unit cost	69.47%	110.82%	115.86%	103.9%

Source: National Bureau of Statistics of China, Chinese Electric Power Yearbook 2005 and 2006

Note: the figure in the brackets is the number of the observations.

4.6. Conclusions

The empirical result of this chapter shows that the power firms in China are institutionally motivated to bargain with the government for a high price by means of raising their costs. The electricity price in China is determined on the basis of mixed consideration of the production cost of the power firm and the total outputs of other industries. And the competition in price doesn't exist in the Chinese power generation industry.

As the power firms bargain with the state to set the price, it's unlikely for the dominant power plant to manipulate the market, which can be seen in the liberalized market in the Western countries. However, it doesn't mean that there is no intention of the collusion among those Chinese power plants under the plan economy. According to the test, a kind of collusion among those firms may also exist, where the higher average cost of the rival firms will help a particular firm to bargain with the state for a higher price and then a higher profit margin.

The Chinese government also faces the dilemma of the plan pricing. On one hand, instead of price competition, the plan price is employed by the government to cover both the operational cost and the investment expenditures of those power plants, with the purpose of securing the sustainability of the electricity supply against the inflation of the coal price in the short run, and also attracting more investment to increase capacity in the long run. On another hand, in order to maximise the total output of the whole society, the state has to offer cheap power for the households and other industries with a low electricity price.

In order to balance the two requirements, the Chinese government implements the soft price constraint on those high-cost power plants. The inflation of the fuel price will be partly covered by a rise in the price, but it will inevitably deteriorate the profitability of the power plants since a rise in fuel costs is partially compensated by the plan price. The appetite of plants, which charge a higher price in the high income area, is also suppressed, as no evidence shows that those firms can obtain a higher profit margin than the firms in other areas.

Unlike the European market, where the price is set by market directly via market competition, the electricity price setting in China is in the hand of the government mainly on the basis of the cost of the production. At present, the fundamental aim of the electricity pricing in China is to maximise the total social output rather than maximising the profits of the power industry. However, in order to promote the efficiency and the productivity of the Chinese power plants, the state has introduced market competition in capacity investment and free entry to the business. The UK experience shows that market liberalisation leads to developing imperfect competition. The dominant market players can abuse their market power to exploit an extra return from the consumers, in particular, in the long run. In contrast, China takes a reformed plan system to supply power. Although the plan supply results in the high cost behaviour of power firms, it has a merit in removal of market power and improvement of household benefits as well as stimulation of capacity expansion. How has capacity been expanded and what determines capacity investment is a question that we will further study next chapter.

Chapter 5. The Determinants of the Chinese Power Supply Capacity

5.1. Introduction

The aim of this chapter is to look at what determines capacity expansion of power supply in China. China has experienced a tremendous increase in electricity supply over last three decades. In 2008, China's total installed capacity is 803 MW, which is around 10 times of the UK and around 70% of the US (online database of the International Energy Agency). When compared with 30 years ago, it had only around 72,350 MW, which was about today's capacity in the UK. As can be seen, China's installed capacity has increased by more than 12 times over the past 30 years.

This huge capacity growth has enabled China to serve its growing demand for power without a serious problem of supply shortage of supply. Interestingly, the institutional environment of the Chinese power sector has still been in the plan system as discussed in the previous chapters. One common phenomenon of a plan system is "shortage", but the Chinese plan economy in the power sector doesn't suffer this problem. The contrast of the conventional wisdom to the Chinese experience motivates us to understand the issue about what drives the growth of supply of power with respect to capacity in a situation where the sector has been under the reformed plan control. Normally, supply always responds to demand at least in the long-run regardless of a plan or market economy. In a market economy, the pace of supply response to demand is much quick and fast. In contrast, in a plan economy, the pace of supply response to demand is slow. But over that three decades, in particular, since 1992, we have been able to observe a fast pace of response of supply to demand in China's power sector. The growth of GDP as an indication of demand for power has been always responded by the growth of electricity available for end users. This response can be illustrated by the link between the growth index of the GDP and the growth index of the power consumption shown in Figure 5.1. In contrast, the link is not shown strongly in the UK (see Figure 5.1). This comparison provides us with an idea that power supply has a stronger relationship with GDP growth in China than in the UK.

If capacity investment is a long-run commitment for power supply, and power supply is more responsive to GDP, then we expect that GDP can play a role of demand in driving up power supply in the long-run. This view provide us with expectation that GDP drives power supply for both the long run and the short run given other factors, such as prices and an economic structure. The close link between GDP and power in China can alternatively be interpreted as “power drives GDP” since without electricity, China will lose its power to grow the economy. This may be particular true when the structure of the Chinese economy is dominated by manufacturing industry. Against these two opposite arguments, the chapter will start with testing the causality between GDP and power supply for given the electricity price and an economic structure. The latter two elements in relation to power supply will also be investigated with reference to OECD power sectors.

Most previous studies attempt to estimate the power shortage and surplus of a particular country through identifying the relationship between the power consumption and the development of the economy. Some academics tried to explain the intensity of the energy uses with various factors, such as the structure of the economy (Zhang & Nie, 2005; Crompton & Wu, 2005; Zhang & Sun, 2008), the industry production (Yang & Zhang, 2007), the GDP growth (Shiu & Lam, 2004; Liao, Fan & Wei, 2007), and even the technical change (Garbaccio, Ho & Jorgenson, 1999). In some studies, evidence shows that the high energy demand of a particular country could be resulted from its high GDP growth (Li & Dorian, 1995; Wu & Li, 1995; Crompton & Wu, 2005; Rosen and Houser, 2007). In order to quantify the energy supply risks, Asia Pacific Energy Research Centre (known as APERC) in their research report (2007) listed four factors which would influence the energy security of an economy, i.e. "availability, accessibility, acceptability and affordability".

Because of the special technique property of electricity, the availability of the power supply will largely depend on the capacity adequacy of the power generation. As power generation is believed to be the bottleneck that affects down-stream production[22], an economic growth can be constrained by the capacity of power generation. At the end of 2008, the total installed capacity in China reached up to 802.6 GW, i.e. 5.23 times of the 1991's level. However, the capacity is still inadequate for China's fast growing economy. In 2005, China experienced the most serious blackouts since the 1990s[23] which hit 26 provinces. A number of previous studies tried to identify the relationship of the net capacity with a group of factors, such as demand, prices and even the return of the investment. Ma, Oxley and Gibson (2009) in their paper compared the growth of the capacity with the aggregate demand in the Chinese energy sector, and argued that the energy demand in China can be affected by "the rapid income growth", "the expanding transportation", "the lagged electricity price reform" and etc., while the energy supply can be affected by "the increasing investment", "the improved energy efficiency", "the energy reforms" and etc.. Wen, Wu and Ni (2004) argued that "the prices of electricity to reflect short-term supply and demand status will create market signal for a proper capacity expansion". Tishler, Milstein, Woo (2008) in their study investigated "the interdependence among equilibrium capacity, market price level, market price volatility, and supply shortage due to the price capping" with the Israel data, and argued that price capping would lead to power shortages, "because the tightening of the price cap induces an increase in the quantity demanded which is higher than the increase in the optimal capacity". Some other studies even employed the real option

[22] Wu Yin, 2004, "Electricity Sector Development Strategy in China", http://www.iea.org/textbase/work/2004/coal/WuYinText.pdf, visited on 8th November, 2006.
[23] Liu Wei, 27th August, 2006, "How to get rid of the strange cycle of the excess and the shortage of the electricity supply?", http://finance.people.com.cn/GB/4745157.html, visited on 1st June 10, 2009.

theory to explain the optimal investment strategy of different types of power plants (Shinichiro Takizawa, Atsuyuki Suzuki, 2004; Gollier, Proult, Thais, Walgenwitz, 2005; Botterud & Korpas, 2007; Fleten, Maribu, and Wangensteen, 2007).

However, those studies have a limit on identifying which effects are general internationally and which effects are country-specific. In contrast to the studies above, our approach to examine the determinants of power supply will be on the basis of using a comparative analysis of China with OECD experience to look at elements discussed by previous studies in terms of international general effects or China specific phenomenon respectively. Furthermore, we also intend to identify the elements in terms of direct and indirect impacts respectively on supply. The impact on power supply will be assessed first by looking at the explanatory power of our proposed elements to electricity consumption, and then the elements directly related to consumption will be further investigated for their possible impact on power supply in the long run — capacity. If the elements have a significant impact on both demand and the supply, we then call it a direct effect on supply. Otherwise, if the impact is not identified on supply but on demand, then we call it an indirect effect on supply because the impact is made via effect on demand. In this sense, our strategy to investigate determinants of power supply is a two-stage approach, which estimates the determinants of power consumption in stage one, and then verifies these demand-related determinants for their possible impact on capacity in stage two. Any elements that explain directly power consumption but may have no direct impact on power supply are called "indirect determinants" of power supply since these indirect determinants affect power supply through their impact on power consumption. With this two stage investigation strategy, we will illustrate the link between power supply and the determinants, respectively, with reference to OECD countries in the next section. Then in the third section, these respective links will be modelled more rigorously by using econometrics in terms of time series data estimation. Having statistically verified relationship between power supply and our proposed determinants, we will conclude our analysis and discussion in the last section.

Table 5.1 The Growth of the Installed Capacity

Unit:%	China	France	Germany	Italy	Japan	UK	US
1981	4.85%	11.27%	2.52%	1.93%	4.41%	-6.25%	2.39%
1991	9.85%	0.91%	20.91%	2.34%	2.69%	-3.97%	1.08%
1992	9.94%	0.87%	-2.22%	6.50%	2.77%	-3.99%	1.39%
1993	9.84%	2.28%	-0.80%	3.04%	3.80%	1.53%	1.18%
1994	9.29%	-0.39%	0.16%	1.03%	3.77%	0.65%	1.37%
1995	8.66%	0.36%	1.22%	2.73%	2.78%	1.66%	0.68%
1996	8.89%	1.94%	-1.10%	3.59%	3.04%	4.79%	0.87%
1997	7.48%	4.05%	-0.80%	3.13%	3.79%	-0.73%	0.35%
1998	9.07%	-1.36%	-0.30%	2.98%	3.24%	0.60%	-0.16%
1999	7.75%	1.92%	0.95%	1.84%	1.36%	2.81%	1.98%
2000	6.88%	-0.06%	3.15%	2.23%	2.31%	3.91%	1.56%
2001	6.32%	1.07%	1.47%	0.77%	1.21%	1.79%	12.49%
2002	5.03%	0.82%	5.11%	0.54%	1.70%	-3.72%	6.68%
2003	9.77%	-0.08%	-0.95%	2.36%	0.92%	1.98%	6.01%
2004	12.60%	0.18%	-0.39%	3.86%	1.73%	2.38%	1.63%
2005	15.36%	-0.65%	0.37%	5.12%	0.75%	1.60%	1.71%
2006	22.34%	-0.04%	5.24%	4.66%	0.52%	2.02%	0.85%
2007	14.68%	0.32%	0.77%	4.60%	0.13%	1.62%	1.10%
2008	12.69%						
Average	10.36%	0.71%	1.93%	3.02%	2.15%	0.88%	2.40%

Source: National Bureau of Statistics of China and Electricity Information 2009 (IEA)

5.2. Major elements in relation to power consumption and supply: an illustration of China with reference to OECD countries

5.2.1. Economic development and power consumption

China's economy is characterised by its high GDP growth. For the past 30 years, China's real GDP increased by around 15 times, with an average growth rate of 10%. In contrast, other six OECD countries only achieved relatively moderate economic growth over the past two decades, where the average annual growth of the real GDP of France, Germany, Italy, Japan, the UK and the US is 1.88%, 1.73%, 1.34%, 1.39%, 2.51% and 2.93% respectively. So far in 2007, the real GDP in China reached up to 11 trillion Yuan (online database of UNData), ranked as the third largest in the world.

As an emerging economic giant, China becomes a huge power consumer in the world quickly. Today, China is the second largest power consumer next to the US. In 2007, the total observed net power consumption in China is up to 2,814,663 GWh, i.e. almost equal to the aggregated usage in France, Germany, Italy, Japan and the UK, or 72% of the power consumption in the US. Even back to 1990, China was the third largest power consumer in the world, next to the US and Japan, where its annual net consumption was only 534,890 GWh, i.e. around 70% of Japan and 20% of the US. Obviously, the power demand in China has increased dramatically for the last two decades.

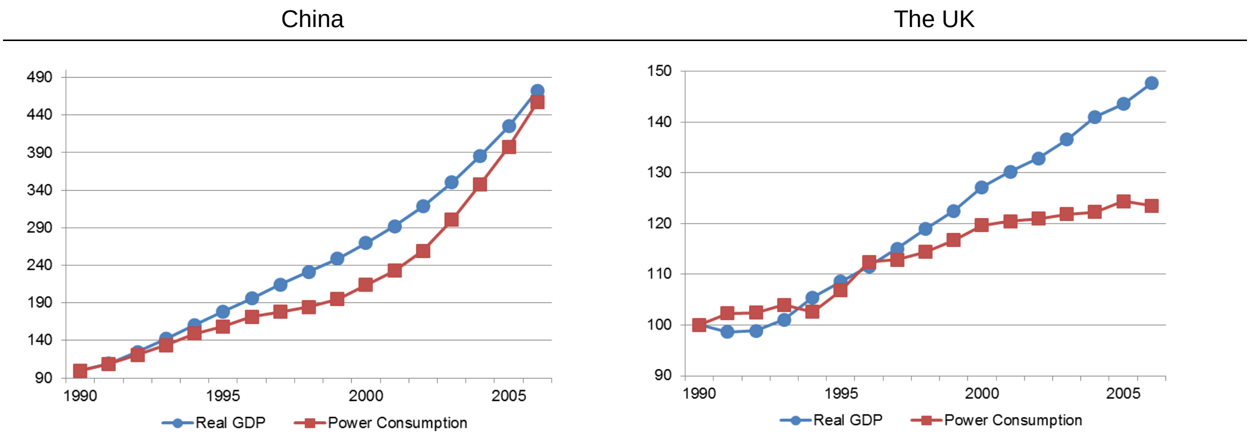

Figure 5.1 The Real GDP Index and the Power Consumption Index of China and the UK (1990 – 2006)

Source: UNdata, International Energy Agency, and the National Bureau of Statistics of China

From 1990 to 2007, the average annual growth rate of the net power consumption in China was around at 10%. In recent years, the average annual growth even reached up to 14.55% from 2002 to 2007. By contrast, the power consumption of the six OECD countries only increased by no more than 10% during the same period, with an average annual growth of less than 1.9 %.

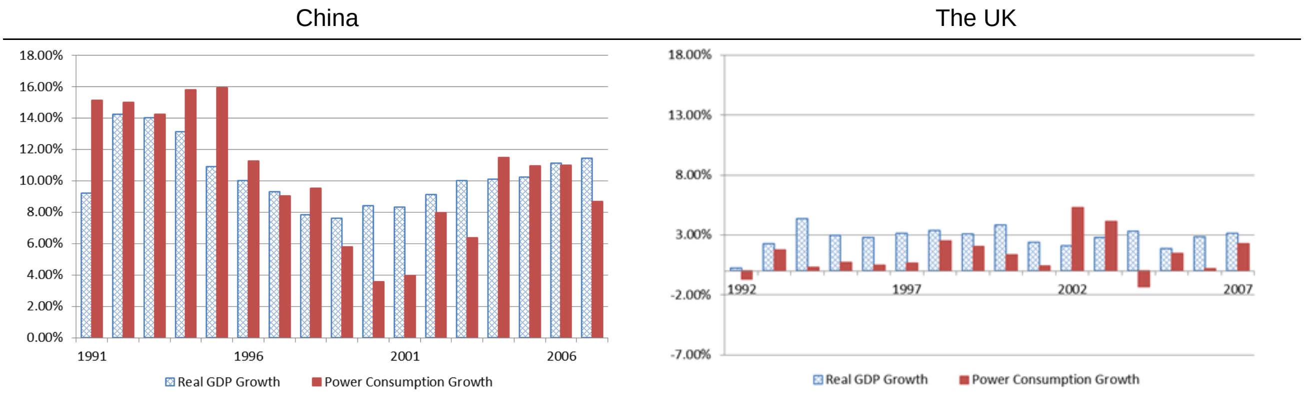

Figure 5.2 The Growth of the Real GDP and Power Consumption in China and the UK(1991 – 2007)
Source: UNdata, International Energy Agency, and the National Bureau of Statistics of China

As shown in the Figure 5.1 above, we can easily find that both the power consumption and the real GDP have increased dramatically during the past two decades. From 1991 to 2007, the growth rates of both the power consumption and the real GDP are at some 10% in China. In contrast, the relationship between power consumption and GDP in the UK has become weaker and weaker since 1997, where the increase in the power consumption growth tends to be less linking with GDP growth.

According to Figure 5.2, it clearly shows that the power consumption fluctuated with the real GDP in the similar pattern. During in the early 1990s, the growth of the real GDP is around 12% and the power consumption growth is around 15% in China. From 1996 to 2001, the average growth of the real GDP and the power consumption in China dropped to around 8.6% and 7.2%, respectively. After that, the China recovered its economic growth and the power consumption growth again. However, according to Figure 5.2, it shows a different situation in the UK, where the power consumption growth is unlinked with economic growth.

Thus, it’s expected that the real GDP has a positive relationship with the power consumption in both the long run and the short run in China, while this relationship appear weak or insignificant in some OECD countries. This suggests that this relationship is China-specific, and it cannot be generalised without analysis to other economies in the world.

Table 5.2 Power Intensity of Electricity Consumption per GDP (kWh/USD): China vs. OECD Countries

	China	France	Germany	Italy	Japan	UK	US
1990	1.3224	0.2598	0.2806	0.1930	0.2514	0.2856	0.4712
1991	1.3158	0.2759	0.2670	0.1944	0.2508	0.2961	0.4967
1992	1.2786	0.2793	0.2583	0.1967	0.2504	0.2961	0.4826
1993	1.2444	0.2821	0.2556	0.1992	0.2519	0.2938	0.4860
1994	1.2267	0.2815	0.2479	0.2015	0.2657	0.2778	0.4803
1995	1.1763	0.2791	0.2472	0.2016	0.2673	0.2810	0.4820
1996	1.1547	0.2883	0.2485	0.2023	0.2664	0.2878	0.4772
1997	1.0985	0.2801	0.2457	0.2047	0.2681	0.2802	0.4635
1998	1.0552	0.2789	0.2431	0.2075	0.2754	0.2748	0.4587
1999	1.0375	0.2753	0.2399	0.2087	0.2817	0.2721	0.4502
2000	1.0481	0.2710	0.2375	0.2105	0.2798	0.2687	0.4505
2001	1.0554	0.2733	0.2399	0.2114	0.2744	0.2642	0.4427
2002	1.0761	0.2694	0.2459	0.2147	0.2782	0.2601	0.4451
2003	1.1342	0.2775	0.2484	0.2211	0.2723	0.2549	0.4378
2004	1.1927	0.2781	0.2490	0.2219	0.2725	0.2476	0.4286
2005	1.2365	0.2748	0.2477	0.2256	0.2716	0.2474	0.4265
2006	1.2800	0.2666	0.2427	0.2270	0.2662	0.2389	0.4152
2007	1.3226	0.2629	0.2372	0.2247	0.2685	0.2312	0.4174
Changes1990-2001	-20.19%	5.21%	-14.51%	9.50%	9.14%	-7.50%	-6.05%
Changes2002-2007	22.91%	-2.43%	-3.52%	4.67%	-3.49%	-11.10%	-6.23%
Changes1990-2007	0.02%	1.19%	-15.44%	16.42%	6.78%	-19.05%	-11.41%

Source: Based on the information from the Electricity Information 2009 (IEA) and the UN data.

In 2007, China consumed 35.73% of the global electricity generated, but it only contributes 5.9% of the total GDP in the world. This implies that China's ability in using the power to generate the economic wealth is very low. This may reflect a problem in Chinese economic structure or institution in promoting the efficiency of power usage for production. In Table 5.2, the electricity intensity is calculated by dividing the electricity consumption by the real GDP. The lower electricity intensity indicates a low power consumption required to produce one dollar of GDP.

Not surprisingly, China's electricity intensity is the highest among the seven countries. In 2007, China's electricity intensity equals to 3.17 times of the US, 4.93 times of Japan, 5.72 times of the UK and 5.89 times of Italy. It obviously shows that China has a lot to improve its usage of electricity to generate national output, compared with developed countries. It also implies that China has massive energy-intensive industries to produce little but consume more of power. Moreover, such problem became even worsen in recent years. From 1990 to 2001, the electricity intensity in China was decreased by 20.19%, which was the sign of improvement of the energy efficiency. But, from 2002 to 2007, China's electricity intensity increased by 22.91%. It made the overall electric power intensity of China almost unchanged over the past 20 years.

In contrast, the overall electricity intensity of France, Italy and Japan also increased by 1.19%, 16.42%, and 6.78% respectively in the period from 1990 to 2007, although France and Japan dropped the intensity by 2.43% and 3.49% respectively after 2002. The best performing economies in lowering the intensity have been Germany, the UK and the US, which have experienced continuous improvement of the electricity intensity since 1990, where the intensity of the three countries dropped by 15.44%, 19.05% and 11.41% respectively. This implies that most OECD countries have reached a stage of development with a low-energy-intensity structure of the economy in the recent years.

Table 5.3 The Growth of the GDP and the Power Consumption of the OECD Countries and China

	China		France		Germany		Italy		Japan		UK		US	
Year	Δ GDP	Δ C	Δ GDP	Δ C	Δ GDP	Δ C	Δ GDP	Δ C	Δ GDP	Δ C	Δ GDP	Δ C	Δ GDP	Δ C
1991	9.20%	15.11%	1.02%	0.47%	5.11%	0.16%	1.53%	0.44%	3.35%	2.98%	-1.37%	-0.22%	-0.19%	2.73%
1992	14.20%	15.01%	1.37%	-1.06%	2.23%	0.80%	0.77%	2.49%	0.97%	0.36%	0.21%	-0.69%	3.34%	0.15%
1993	14.00%	14.25%	-0.91%	0.53%	-0.80%	0.28%	-0.89%	1.76%	0.25%	1.62%	2.27%	1.76%	2.69%	2.56%
1994	13.10%	15.78%	2.22%	2.68%	2.66%	1.28%	2.15%	1.57%	1.10%	2.82%	4.32%	0.32%	4.06%	1.47%
1995	10.90%	15.94%	2.12%	4.11%	1.89%	0.82%	2.83%	3.03%	1.96%	-0.74%	2.94%	0.73%	2.54%	0.84%
1996	10.00%	11.24%	1.11%	-0.41%	0.99%	2.51%	0.72%	1.92%	2.75%	1.64%	2.78%	0.47%	3.75%	2.18%
1997	9.30%	9.05%	2.24%	2.72%	1.80%	2.24%	1.89%	2.21%	1.57%	-1.75%	3.10%	0.65%	4.55%	-0.99%
1998	7.80%	9.51%	3.50%	2.28%	2.03%	2.19%	1.44%	4.50%	-2.05%	2.15%	3.35%	2.48%	4.22%	3.76%
1999	7.60%	5.79%	3.30%	1.97%	2.01%	0.65%	1.93%	2.48%	-0.14%	2.15%	3.04%	2.06%	4.49%	2.54%
2000	8.40%	3.55%	3.91%	3.06%	3.21%	0.95%	3.58%	2.81%	2.86%	0.63%	3.80%	1.33%	3.69%	3.16%
2001	8.30%	3.98%	1.85%	-0.67%	1.24%	0.67%	1.80%	3.14%	0.18%	2.21%	2.37%	0.40%	0.76%	1.53%
2002	9.10%	7.98%	1.03%	4.43%	0.00%	1.50%	0.34%	1.02%	0.26%	2.40%	2.05%	5.26%	1.61%	2.73%
2003	10.00%	6.35%	1.09%	1.28%	-0.22%	1.61%	0.04%	2.92%	1.41%	2.57%	2.77%	4.12%	2.52%	2.90%
2004	10.10%	11.48%	2.47%	1.98%	1.06%	-0.45%	1.20%	3.32%	2.74%	6.66%	3.26%	-1.34%	3.65%	2.84%
2005	10.20%	10.95%	1.71%	0.09%	0.78%	-1.83%	0.09%	0.39%	1.93%	0.82%	1.84%	1.47%	3.08%	3.41%
2006	11.10%	10.97%	1.99%	2.62%	2.87%	-1.08%	1.87%	1.96%	2.40%	0.80%	2.85%	0.21%	2.87%	0.40%
2007	11.40%	8.66%	1.90%	7.28%	2.48%	0.01%	1.46%	2.24%	2.12%	3.11%	3.12%	2.26%	2.19%	5.22%
1991-2001	167.34%	114.43%	22.64%	21.49%	18.60%	6.57%	17.37%	27.63%	9.75%	20.06%	31.99%	17.76%	39.73%	24.52%
2002-2007	65.18%	103.0%	9.50%	6.84%	7.14%	3.38%	4.73%	9.62%	11.07%	7.19%	14.61%	1.89%	15.14%	7.97%

Source: Electricity Information 2009 (IEA) and UN data.

Notes: Δ GDP: the changes of the GDP; Δ C: the changes of the power consumption.

5.2.2. Industry structure and power consumption

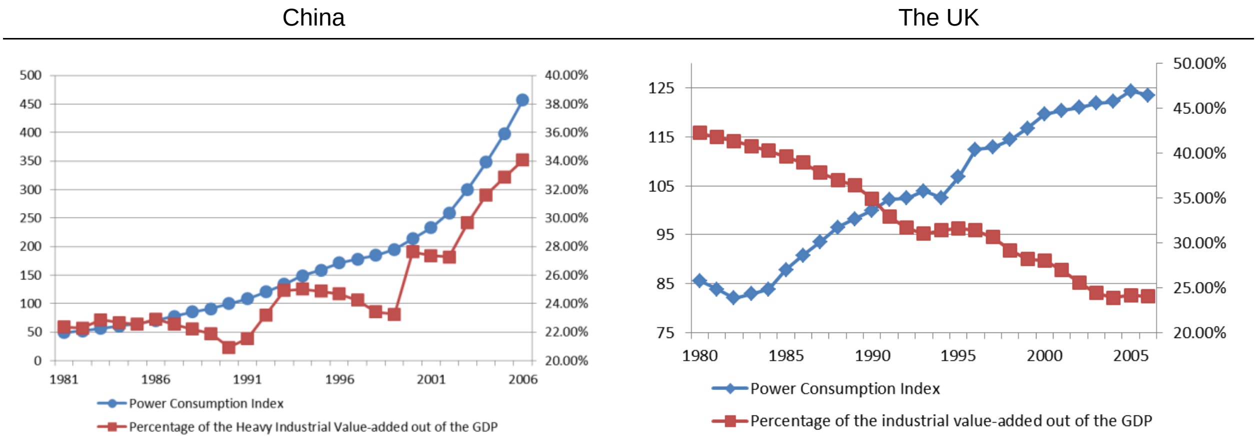

Figure 5.3 The Power Consumption Index and the Percentage of the Industrial Value-added out of the GDP of China and the UK (1981-2006)

Source: UNdata, International Energy Agency, and the National Bureau of Statistics of China

An economic structure in relation to power consumption is illustrated in Figure 5.3 for China and the UK, respectively. China shows a close link but the UK does not. From 1971 to 2006, the output of China's industrial sector increased by around 23 times, making its percentage in the GDP enlarged from 42.15% in 1971 to 48.50% in 2007. Therefore, in Figure 5.2 of this increase of industrial output in the GDP, it has been mainly driven by a rapid growth of China's heavy industry, for instance, on heavy industry increased its output in total industry sector form 58% in 1999 to 70% in 2007(Table 5.6). We plot the heavy industry against power consumption in China, which shows the percentage of the heavy industrial value-added and the power consumption has increased in the same pace over the past three decades.

In contrast, the six OECD countries have experienced the process of "de-industrialisation" of the manufacturing sector over the past three decades, where the industrial outputs increased slowly, and the industrial sector lost its share in the economy. For example, the UK's industrial sector only increased by 1.26 times from

1971 to 2006, and it lost almost by 20% share in the GDP from 1971 to 2007. By the end of 2007, the industrial sector of all the six OECD countries falls to the level below 31% of the total GDP. For example, in the UK, the industrial sector contributes only 23.08% of the value-added output to its total GDP in 2007. According to Figure 5.3, it clearly shows that the percentage of the industrial output relative to the GDP decreased despite of the increase in the power consumption over the past three decades. This suggests that, unlike China, power consumption is no longer related to the manufacturing industry but related to consumption of households and the service sector in the UK (Table 5.4). The impact of the service sector growth on electricity consumption is also seen for China, Italy, Japan, the US and France (Table 5.4). From the comparative observation presented in Table 5.4, we argue that the economic structure of the service sector matters for power consumption, but not the structure of the manufacturing industry except China where the heavy industry plays a more and more importance in the manufacturing and the economy.

Table 5.4 Composition of the GDP and the Power Consumption by Type of Users

Industry	% of the Industrial Sector out of the GDP			% of Industrial Usage out of the Total Power Consumption		
	1990	2000	2007	1990	2000	2007
China (Overall Industry)	41%	46%	49%	78%	72%	75%
China (Heavy Industry)	*21%*	*28%*	*35%*	*50%*	*45%*	*45%*
France	27%	23%	21%	35%	33%	30%
Germany	37%	30%	30%	45%	42%	45%
Italy	32%	28%	27%	51%	51%	46%
Japan	40%	32%	30%	44%	38%	33%
UK	35%	28%	24%	35%	34%	34%
US	28%	24%	22%	32%	32%	24%

Service & Commerce	% of the Service Sector out of the GDP			% of Service Usage out of the Total Power Consumption		
	1990	2000	2007	1990	2000	2007
China	32%	39%	40%	4%	8%	9%
France	70%	74%	77%	25%	25%	29%
Germany	61%	68%	69%	17%	24%	22%
Italy	64%	69%	71%	18%	20%	25%
Japan	58%	66%	68%	28%	32%	35%
UK	63%	71%	75%	25%	27%	28%
US	70%	75%	77%	31%	32%	34%
Household	% of the Household Consumption out of the GDP			% of the Household Usage out of Total Power Consumption		
	1990	2000	2007	1990	2000	2007
China	49%	42%	37%	8%	12%	11%
France	57%	56%	58%	30%	31%	33%
Germany	58%	58%	55%	28%	26%	26%
Italy	57%	58%	57%	24%	22%	21%
Japan	53%	54%	52%	24%	27%	28%
UK	62%	64%	65%	33%	33%	34%
US	67%	68%	71%	34%	33%	36%
Agriculture	% of the Agriculture out of the GDP			% of the Agricultural Usage out of Total Power Consumption		
	1990	2000	2007	1990	2000	2007
China	27.00%	15.00%	11.00%	6.85%	5.00%	3.00%
France	3.77%	2.84%	2.20%	0.65%	0.66%	0.71%
Germany	1.49%	1.26%	0.92%	1.50%	1.50%	1.55%
Italy	3.49%	2.80%	2.04%	1.93%	1.76%	1.77%
Japan	2.59%	1.77%	1.47%	0.22%	0.17%	0.09%
UK	1.89%	1.04%	0.94%	1.35%	1.28%	1.09%
US	2.06%	1.23%	1.08%	N/A	N/A	N/A

Source: The National Bureau of Statistics of China, Electricity Information 2009 (IEA) and UN data.

In 2007, China’s industrial usage accounts for over 75% of the overall power supplied, much higher than any other six OECD countries. By contrast, industrial users in the US only consumed 24% of the total electricity generated in 2007. Before 2000, China has a decreasing percentage of the industrial usage in the total power consumption. From 1990 to 2000, China’s industrial power consumption dropped from 78% to 72%. But after 2000, this trend reversed. This phenomenon was also noticed by existing studies. Kahrl and Roland-Holst (2009) argued that "the growth in energy use was paralleled by an abrupt upswing in the energy intensity of China's GDP beginning in 2002, which, although peaking in 2004 and falling slowly since, reversed a two decades trend of steady declines in energy intensity".

Table 5.5 The Changes in the Power Intensity by Sector: China vs. OECD Countries

		1971-1980	1981-1990	1991-2000	2001-2006	1971-2006
China	Overall	18.18%	-12.13%	-20.34%	21.29%	-1.95%
	Industry	11.22%	-15.32%	-33.63%	27.01%	-21.13%
	Agriculture	43.60%	-35.83%	-7.67%	-4.33%	-4.90%
	Service	NA	NA	5.78%	8.10%	NA
France	Overall	23.82%	6.85%	-1.77%	-2.45%	39.86%
	Industry	1.78%	17.65%	11.54%	3.20%	37.59%
	Agriculture	96.80%	30.10%	18.86%	50.82%	487.14%
	Service	36.50%	28.13%	-5.17%	5.72%	88.21%
Germany	Overall	11.72%	-8.69%	-11.03%	1.21%	-11.89%
	Industry	16.24%	-5.99%	1.93%	1.12%	13.84%
	Agriculture	47.08%	28.26%	-24.62%	64.14%	195.96%
	Service	-0.29%	-0.92%	-3.06%	4.49%	10.22%
Italy	Overall	4.37%	6.83%	8.30%	7.39%	29.35%
	Industry	-1.03%	12.37%	21.36%	4.09%	40.57%
	Agriculture	118.08%	93.93%	28.61%	30.24%	741.21%
	Service	10.17%	29.54%	9.64%	23.92%	110.50%
Japan	Overall	1.79%	1.53%	11.54%	-2.98%	6.80%
	Industry	0.51%	-23.49%	17.23%	-11.91%	-25.97%
	Agriculture	40.11%	22.33%	35.35%	-43.47%	43.27%
	Service	43.73%	145.51%	11.60%	6.35%	331.42%
UK	Overall	-6.10%	-9.51%	-9.25%	-9.56%	-29.26%
	Industry	-9.83%	8.87%	4.30%	3.49%	10.30%
	Agriculture	21.14%	-13.45%	47.73%	-6.31%	57.80%
	Service	12.89%	-12.58%	-12.87%	-11.52%	-21.28%
US	Overall	5.94%	-5.85%	-9.31%	-6.21%	-12.34%
	Industry	0.77%	4.83%	-5.19%	-21.76%	-15.69%
	Agriculture	NA	NA	NA	NA	NA
	Service	16.18%	-6.06%	-6.34%	-6.12%	2.23%

Source: Electricity Information 2009 (IEA) and UN data.

China's industrial output increased from 42% in 1990 to 49% in 2007 relative to the

GDP, but the power consumption of the industry in the total remains almost unchanged over the same time period (see Table 5.4). This dis-link between output growth and power intensity of the industry: a decline of the power intensity by some 6% (i.e. 33% between 1991 and 2000, and 27% between 2001 and 2006, see Table 5.5). The power intensity improvement is evident by the Chinese steel sector and cement & glass manufacturing sector. The production of one tonne of steel fell from using 847 kWh of electricity in 2000 to 719 kWh in 2006. The same was true for cement & glass that experienced a fall in power usage by some 20% between 2000 and 2006, see Figure 5.4. Those observations show that the positive relationship between China's industrial output and power consumption cannot be explained by production technology employed but arise in output volume. The rapid growth of the volume drives up power consumption and also offsets or marginalises the effect of industrial technology progress on power consumption. In particular, the volume is accountable for increasing power consumption in the heavy industry when it experienced a rapid increase from 58% in the total industrial output to 70% over the period of 7 years for 1999 to 2007 (see table 5.6). This indicates the industry structure that has switched from low-energy-intensity to high-energy-intensity as a result of the world heavy industry restructuring of shifting production from the West to the East. The discussion above suggests that the positive impact of China's industrial structure on power consumption can be explained by the volume change and the industrial restructuring to a more heavy-industry dominant character.

The rapid development of the heavy industry in China also impacts the power intensity of the total industry. From 1981 to 2000, the overall electricity intensity in China improved by around 32%, at the same time, the electricity intensity of its industrial sector also lowered down by 49%. However, after 2000, such trend of the electricity intensity reversed in China. By 2006, the overall and the industrial electricity intensity increased again by about 21% and 27% respectively. The reason for this kind of changes would be attributable to the development of the heavy industries in recent years. The heavy industry takes up over 70% of the total gross industrial output in 2007, while it's only 58% in 1999.

Table 5.6 Percentage of the Gross Industrial Output by Light and Heavy Industries in China

	1999	2000	2001	2002	2003	2004	2005	2006	2007
Light Industry	41.97%	39.80%	39.43%	39.14%	35.49%	33.47%	32.44%	29.96%	29.53%
Heavy Industry	58.03%	60.20%	60.57%	60.86%	64.51%	66.53%	67.56%	70.04%	70.47%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: National Statistics Bureau of China

Because of the concentration of the development on heavy industry, the heavy industrial output of China increased dramatically along with its power consumed. For example, in 2006, China produced over one third of iron & steel in this world, by consuming around 31% of the global power supplied for the iron & steel production. In the same year, China also produced 48% of the cement & glass in this world, by using 41% of the global power used for the cement & glass production.

Compared to China, those six OECD countries takes up limited and declined shares in the global heavy industrial outputs. For example, the UK produced 1.79% of the global iron & steel output in 2000, and its global share dropped to 1.11% in 2006. During the meantime, the power consumed for the iron & steel production dropped by around 7.9%, and its global share dropped to 0.59%.

However, the dramatic increase in power consumption for the heavy industry doesn't necessarily mean that the power intensity in China has worsened during the period. Take the iron & steel sector as example. Although the Chinese power efficiency of iron & steel production is not the highest among the seven countries, it still improved by 15% during the period from 2000 to 2006, and became even higher than the US by around 11% in 2006.

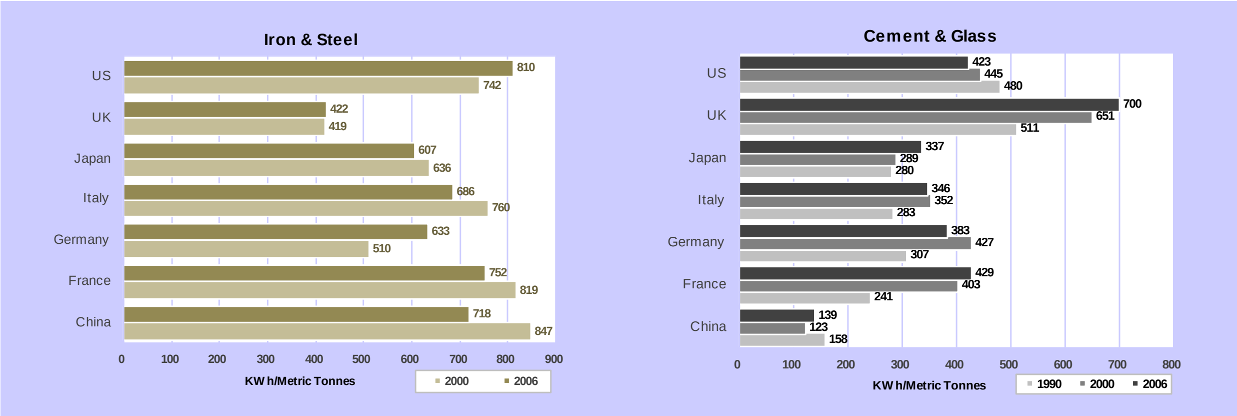

Figure 5.4 Power Consumption per Unit of Industrial Outputs (kWh/Metric Tonne)

Source: The World Steel Association, the US Geological Survey Minerals Information Team, the National Statistics Bureau of China and the Electricity Information 2009 (IEA)

Generally speaking, the power efficiency of the heavy industrial production in China has been improved to some extent over the years. The reason why the electricity intensity rebounded in recent years is that the Chinese economy became reliant upon the heavy industry more and more since 2000. As the industrial sector is so critical to China's economy, China needs much more power than any other developed countries to support its industry restructuring to the heavy-industry-dominant manufacturing. Again, the high concentration in the energy-intensive sector raised overall electricity intensity in China.

In contrast, the service and commercial usages and the residential usages of electricity only take up very limited percentage in the total power consumption in China. In 2007, the commercial and the household consumption only took up around 9% and 11% of the total power consumption in China. In terms of the OECD countries, the commercial and the household users consumed much more power than China. For example, in 2007, the commercial users and the household users consumed 28% and 34% of the total power supply in the UK. Besides, the percentage of the industrial power consumption keeps on decreasing while the percentage of the commercial and household consumption increase in the OECD countries. For example, in Japan, the percentage of the industrial usage dropped from 44.45% in 1990 to 32.26% in 2006, while the commercial and the household power consumption increased by 8.67% and

3.86%, respectively.

From the discussion and analysis above, we argue that the economy structure in China has a positive relationship with the power consumption, which is unique to some extent, since this relationship is not observed in some "de-industrialised" OECD countries.

5.2.3. Electricity prices, power consumption and capacity

Having discussed economic growth and industrial structure in the relation to power consumption, this section will look at how price can impact on the power. In China, as previous chapters have identified, there are two prices that can be expected to influence power supply and consumption. One is called the on-grid price, which is the price taken by Chinese power firms to sell their output to grids. Another is the catalogue price that is used by end-users to pay distributors for their electricity bills.

Table 5.7 The Catalogue Price (End Price) and On-grid Price in China

	End Price (Yuan/MWh)	On-grid Price (Yuan/MWh)	% of On-grid Price out of End Price	Growth of End Price (%)	Growth of On-grid Price (%)
2000	405.0	282.0	69.63%		
2001	407.5	281.0	68.96%	0.62%	-0.35%
2002	410.0	290.0	70.73%	0.61%	3.20%
2003	434.7	308.5	70.96%	6.02%	6.37%
2004	458.2	303.7	66.27%	5.41%	-1.55%
2005	485.0	317.9	65.56%	5.84%	4.70%
2006	499.0	331.0	66.33%	2.90%	4.12%
2007	514.1	336.8	65.51%	3.01%	1.74%
2008	523.5	347.3	66.35%	1.83%	3.14%
2009	534.3	367.6	68.80%	2.07%	5.84%
Average	467.1	316.6	67.77%	31.11%	30.82%

Source: the annual report of the power industry monitoring 2006, 2007, 2008, 2009, and the electricity market and electricity price monitoring report 2005.

From Table 5.7, we could find that although both the catalogue price and the end price increased by around 30% from 2000 to 2009, the two prices could fluctuate in different way in each year. For example, in 2004, the catalogue price increased by around 5.41%, while the on-grid prices dropped by -1.55%. As both the two prices are planned by the government, there is no direct link between the changes in two prices annually.

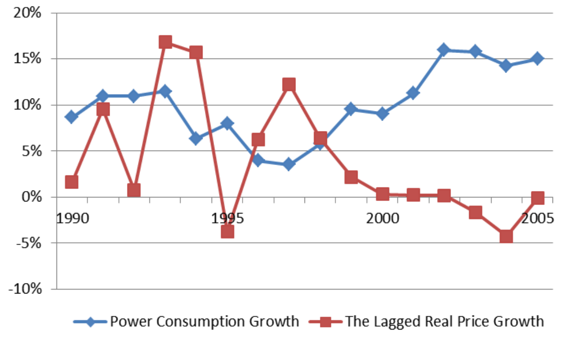

Figure 5.5 The Lagged Real End Price of the Electricity and the Power Consumption in China (1990-2006)

Source: International Energy Agency and the National Bureau of Statistics of China.

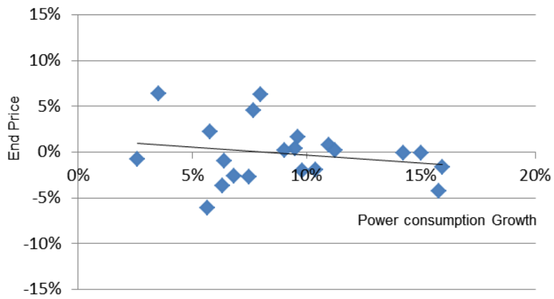

Figure 5.6 The Plot of the Growth of the Catalogue Price (End Price) and Power Consumption of China (1980 to 2006)

Source: the National Bureau of Statistics of China.

In Figure 5.5, it clearly shows that the changes in catalogue electricity price against changes in power consumption in China. It indicates that the end users have been in general responsive negatively to the fluctuation of the electricity price. This observation that the interaction between plan on price setting and market for free choice is working since at an aggregate level, power consumption can be influence by changes in the catalogue price.

Table 5.8 The Changes in the End Electricity Price: China vs. the OECD Countries

	China	France	Germany	Italy	Japan	UK	US
From 2000 to 2004	-5.42%	-0.90%	35.44%	26.14%	-5.30%	-3.01%	6.98%
From 1986 to 2006	55.37%	-28.39%	-19.27%	74.09%	-27.67%	9.69%	-21.14%

Source: National Statistics Bureau of China and Electricity Information 2009 (IEA)

Notes: The real electricity price index in 1990 is 100.

Since the reform in the 1980s, the electricity price in China has increased significantly, although its growth became flat in recent years. According to Table 5.7, from 1986 to 2006, the electricity price in China increased by around 55%. During the period from 1986 to 2006, the electricity price in France, Germany, Japan and the US decreased by -28.39%, -19.27%, -27.67% and -21.14% respectively. In Italy and the UK, the electricity prices increased by 74% and 9.69%, respectively. This is an increasing comparison. Over the two decades from 1986 to 2006, as significant rise in the price in China is not alone since Italy has experienced even more price rise. But China's power price is under the plan control and Italy price is left to market to decide. This suggests that plan and market can be indifferent in terms of discipline of prices in moving up, in particular, when market fails in promoting competition. The UK is another example to show this point.

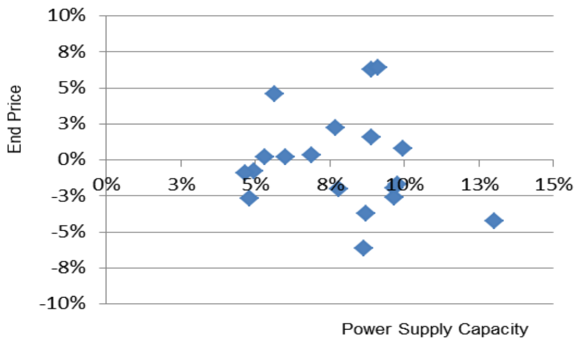

Figure 5.7 The Plot of the Growth of the Catalogue Price (End Price) and Power Supply Capacity in China (1980 to 2006)
Source: National Bureau of Statistics of China

The impact of the electricity price on the capacity would be complex in China. Definitely, the increase in the electricity price would be welcomed by the power firms. Kroeber (2008) argued that "the simply raising end-user electricity prices … would merely spur the construction of more unneeded generating capacity." However, the decrease in the electricity price has not been evidenced by the decrease in the growth of the power capacity. From 2000 to 2006, the net capacity of the power supply increased by around 95%, although the real price dropped slightly by around 6% in China. It implies that the electricity price may not be the reason for the power firms to expand their capacity.

In contrast, in the West, Wolak and Patrick (1996) found that the major generator at UK could increase their profits by unilaterally restricting the amount of generation capacity available for the market. Such argument is also supported by the study on the California electricity market by Borenstein and Bushnell (1999). Their observation shows that the monopolist firm can manipulate the prices through the capacity of the power supply. If this can be established, then what we can observe is a negative relationship between capacity and the price. However, the counter force to offset this negative relationship is free entry to the market since the higher price can affect new entrants and more investment on capacity. Therefore, the price can be positively related to capacity if market is competitive.

5.2.4. The power consumption and the power supply capacity

In the past two decades, China achieved a dramatic and steady expansion of the power generation capacity, compared with other six OECD countries. From 1991 to 2008, the average annual growth of the power capacity in China is as high as 10.36%. In 1990, the total capacity in China was only equal to 18.8% of the US. After fast expansion for over two decades, the generation capacity in China increased by 5.8 times during the period from 1990 to 2008. In 2007, China's installed capacity is equal to 65.5% of the US, and almost equal to the sum of the total capacity of France, Germany, Italy, Japan and the UK.

In contrast, the six OECD countries have only achieved a relatively flat growth of the net capacity. The average annual growth in Italy, the US, Japan, Germany, the UK and France is 3.02%, 2.40%, 2.15%, 1.93%, 0.88% and 0.71% respectively.

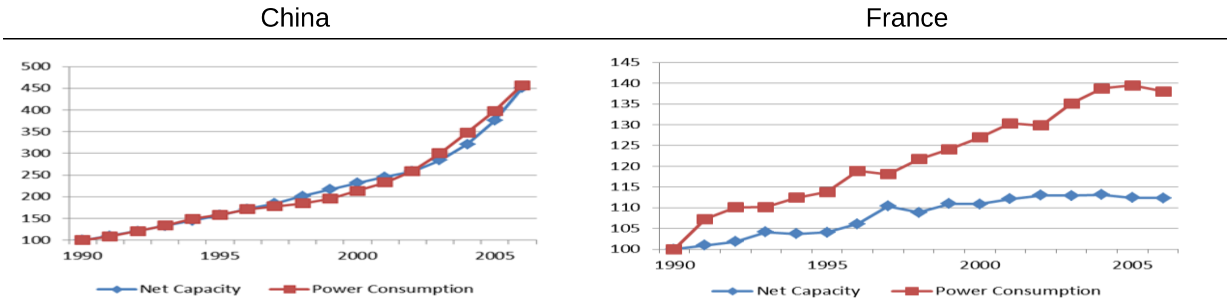

Figure 5.8 The Net Capacity Index and the Power Consumption Index of China and France (1990 -2006)
Source: International Energy Agency and the National Bureau of Statistics of China

According to Figure 5.9, both the net capacity and power consumption in China have increased around 4.5 times over the past two decades. In France, the net capacity have increased by around 12%, but the domestic power consumption increased by around 38%.

According to Appendix 5.4, in 2007, the average load factor in China is around 52%, which is higher than Italy (38%), Japan (47.2%) and the US (45%), but lower than France (55.8%), Germany (54.8%) and the UK (53.7%). It shows that the load factor in Italy, where more than 16% of the total power supply is imported from other countries, is the lowest among those OECD countries. Besides, its load factor has declined significantly, i.e. from 43% to 38%, over the past two decades. It implies that the Italian power firm couldn't compete with the international power producers with competitive electricity price, and Italy relies on the power imports to replace its expensive domestic power generation[24]. In another aspect, France exports around 16% of its total power output to other countries, and this encourages higher utilisation of its existing power supply capacity.

In contrast, the load factor in China has been almost unchanged over the past two decades. It suggests that China chooses to build up more power supply capacity to satisfy its domestic power demand, rather than increase the utilisation of the existing

[24] The end prices for household and industrial users of OECD countries are compared and discussed in Chapter 3.

capacity or the power imports. One of the reasons why the overall load factor of the Chinese power supply keeps almost unchanged could be due to the poor transmission facilities. Kroeber (2008) argued that raised an example that Jiangsu was busy building more power plants, although there was adequate generation capacity in the whole province. The reason was that most of the plants were built in "the coal-rich north of the province", while most of the power demand came from "the industrial south". The insufficient grid facilities limit amount of electricity that can be transmitted from the north to the south of the province, so that excessive generation capacity "had to be built in the south". Thus, it suggests that the relationship between the power consumption and the power supply capacity would be particularly strong.

The power generation in China heavily relies on the thermal plants, which take up over 77% of the total capacity and produce over 83% of the electricity in 2007. Although the hydro and nuclear capacity in China increased by 5.09 times from 1990 to 2007, the percentage of the thermal plants out of the total capacity even increased from 73.86% in 1990 to 77.73% in 2007. As over 97% Chinese thermal plants are using coal and coal products as the fuel, it implies that China heavily relies on the coal-fired plants to provide the electricity supply, and such reliance becomes more and more serious. Besides China, the OECD countries, except France, also heavily rely on the thermal plants to produce electricity. In 2007, the thermal plants in Germany, Italy, Japan, the UK and the US take up 58.63%, 73.74%, 22.56%, 63.91%, and 79.00% of the total capacity respectively, and produce 62.06%, 81.83%, 67.52%, 77.37% and 72.04% of the total power supply. France is an exception, where 55% of the total capacity and over 75% of the total supply can be attributed to the nuclear plants. However, the structure of thermal capacity in those OECD countries is much more diversified than China. In Italy, Japan, the UK and the US, coal-fired plants only take up 0.08%, 19.34%, 35.83% and 39.22% of the total thermal capacity respectively, which means that other types of fuels, such as natural gas and oil, play an important role in power generating in those OECD countries.

5.3. Data and Empirical Estimation

5.3.1. Estimation Models

Having discussed how power consumption can be related to GDP, economic structure and prices from a descriptive aspect, we in this section move further to verify statistically our expectation of the relationship derived from the last section. We take a two-stage estimation approach to identify and quantify both the direct and indirect factors which could have a significant impact upon the aggregate capacity expansion of power plants in China and other six OECD countries. In the first stage, estimation is pursued for identifying the factors that can affect the power consumption in terms of both the long term and the short term, respectively. An increase in power consumption is expected to be responded by power generators in committing more investment to increase supply in the long run, which is capacity investment. To test this expectation, in the second stage, our estimation then focuses on examining the demand-driving variables for their impact on capacity expansion at an aggregate level of a nation. The variables in our estimation that explains the capacity derived from our supply capacity function that may include demand for the power consumption and the load factor. We also estimate the supply function by replacing the power consumption with its determinants identified in the stage 1 of demand estimation, in which it has real GDP, electricity prices for end users, and the power exported. This extension enables us to identify which determinants of demand can also impact on supply directly. In order to make an international comparison, our econometric models are estimated with reference to some OECD countries respectively.

Stage 1

Rosen and Houser (2007) classified the driver of the total energy demand in China into “the industry-led demand” and “the consumption-driven demand” elements.

They argued that as China is making high energy-intensive industrial products rather than importing, it would raise its energy consumption. This argument is consistent with our expectation discussed in the last section of this chapter that GDP as an aggregate output of a nation, together with the price of power and economic structure, are expected to affect demand of power, in which this can be written as:

$$C = f(GDP, p, y)$$

Where C is the aggregated level of power consumption, p is the electricity price for end users, and y represents economic structure. This is a demand function with the expectation that both GDP and the structure of the industry will plan a positive role in stimulating demand but price will be reverse. The power demand function will be estimated in stage 1 in aim of identifying the factors that affect the power consumption in both the long term and the short term, respectively. So, two separate demand functions are specified as follows.

Model 1a — Long-run relationship

Model 1a is our long-run demand function:

$$C_t = \alpha + \beta_1 GDP_{t-1} + \beta_2 p_{t-1} + \beta_3 y_t + \gamma_1 D_1 + \gamma_2 D_2 + \varepsilon_t \quad \text{……….………. (1a)}$$

, where C is the index of the power consumption; GDP is the index of the real GDP; p is the index of the real price of the electricity for end users; y is the percentage of the industrial value added out of GDP, or the share of heavy industry in the GDP, i.e. the proxy for the economic structure; D is the dummy variable of time for different periods; α is the constant and ε is the random noise with normal distribution .

According to Model 1a, power consumption in the current period is explained by the lagged real GDP, the lagged real electricity price, and the economic structure. In order to control the endogeneity in estimation, we use the lag of those variables except the economic structure, which is considered to be a predetermined variable that is relevant to policy or the context of an economy. The dummy variables are also added in the function in order to control the time heterogeneity of the estimation. As the Chinese power sector reform started in 1980s, the model (1) to capture the long-run relationship covers the periods from 1980 to 2006. In order to make a reasonable international comparison, the all of other six OECD countries are measured in the same periods with China. Thus, there are two the dummy variables of time incorporated in the model, which control the time effect of 1990s and 2000s respectively. All those explanatory variables except y and dummy variables of time are converted into the logarithm form.

Model 1b — Short-run relationship

Model 1b attempts to examine the short-run relationship between the power consumption and its explanatory variables. The regression model is specified as follows:

$$\Delta C_t = \alpha + \beta_1 \Delta GDP_{t-1} + \beta_2 \Delta p_{t-1} + \beta_3 \Delta y_t + \gamma_1 D_2 + \varepsilon_t \quad \text{.................... (1b)}$$

Model 1b uses the first differences of the variables to investigate the short-term relationship. China has liberalised its prices for most of industrial and consumer goods since 1992. As a result, we choose the periods from 1992 to 2006 to estimate the model. In order to control the change in China's market environment that was very different between the 1990s and the 2000s, we employ a dummy of time to capture the change in estimation. Again, all variables except Δy_t and D_2 are in the form of logarithm.

Stage 2

The second stage is aimed to find out what factors can directly influence the supply capacity in the long-term. According to our derived function of power supply capacity, it specifies two basic elements that can affect the supply in the long run: one is demand shocks and another is capacity utilisation indicated by the load factor. Empirically, we augment this function by replacing the demand shocks captured by the variable of power consumption with its pre-determinants or predictors identified in stage 1, such as the GDP, the price of electricity and exports.

Box 1. Derivation of the Function of Power Supply Capacity

At an aggregate level, suppose we observe an actual capacity K that equals to the equilibrium capacity K* at time t. The current K at t is grown from the previous level of K at t-1. Therefore, K can be grown from the past to the equilibrium level of K* at t, or K can be grown to a new level that diverts from the equilibrium. This growing process can be described by the adjustment function as follows:

…………… (a)

where λ is the growing-adjustment coefficient. λ=0, K is grown to a level where . λ=1, K is given as same as the past, . When 0< λ<1, then K is grown from the past to a new level that diverts from the equilibrium. At the K*, the equilibrium means that supply of power outputs Q^s equals to demand for power Q^d. When the utilisation of the capacity is taken into account, we can write Q^s as ρK*, where ρ is a load factor that measures how much production capacity has been utilized to produce Q^s. This gives:

……….(b)

Since the load factor can be defined as , where is the maximal capacity utilisation or the maximum load factor feasibly allowed by technique. is less than 100% since a power firm must retain some capacity reserves from the management perspective of the technique safety and the supply security of power. We call as the technically feasible load factor. The manipulation of and provides us with:

………….….……….(c)

Substituting (c) to (a) gets: ….………..……….(d)

This means: ………….….…..……(e)

By manipulating (e) gives: ……………...……(f)

Or gives: ………………..……(g)

Apparently, the capacity at time t is expected to be grown from the previous through the growth adjustment for a change in the technically feasible load factor and the demand shocks to the supply that is indicated by . If the demand shock is greater than what supply can server, then , which promotes capacity to grow more; if the demand shock can be served by part of , then , which discourages capacity to grow. For the same analogy, any increase in the load factor will be expected to be responded by capacity positively.

Piao and Zhong (2008) argued that the growing shortage of the electricity supply encourages investment into the power generation sector. Kroeber (2008) also admitted the fact that new power plants are built in the industrial areas where the energy demand is high. Their view suggests that the power consumption should play a direct role in affecting power generation capacity in China. Lam (2004) in his paper argued that investment in power generation in China had the positive relationship with electricity prices. With these expectations, we therefore extend our theoretical function of the capacity:

…..……….. (g)

to an empirical model with taking into account a sequence of investment and capacity formation, which usually takes two or three years to build up a new power plant after start of the investment (Lin, 2004):

………… (2a)

where ΔK is the growth of capacity formed at time t, ΔQ is the growth of power consumption that captures the demand shocks occurred on the capacity investment decision made at t-2. $_{t-2}$ is the load factor reported two years before new capacity is formed. Empirically, we employ the average load factor of the year in estimation. To replace the power consumption variable with its predictors identified in stage 1 of estimation, such as the GDP, the power price and power exports, the equation (2a) becomes:

$$\Delta K_t = \alpha + \beta_1 \Delta GDP_{t-1} + \beta_2 p_{t-2} + \beta_3 Ex_{t-2} + \theta \overline{\rho}_{t-2} + \gamma_1 D_1 + \gamma_2 D_2 + \varepsilon_t \text{ .... (2b)}$$

where the one-year lagged GDP is applied instead of the lagged two years, because this is to mitigate multi-collinearity between the GDP and other variables specified in equation 2b. Ex is the index of the power exports, and p is the index of the real electricity price for end users.

In Model 2a and 2b, it represents a long-run relationship in the model. We then employ a long time-series data to pursue our estimation from 1980 to 2006. For the same reason discussed previously, we control the time effect in the 1990s and the 2000s by defining the two time dummy variables in the model. All those variables are in natural logarithm, except the dummy variables.

5.3.2. Data

Data Source

The variables for regressions include the supply capacity of the power generation (GW), the observed power consumption (GWh), the power exports (GWh), the real electricity price index for the end users, the real GDP (billion USD), and the industrial value added (billion USD) at a national level. The aggregated annual data on China, France, Germany, Italy, Japan, the UK and the US over period from 1980 to 2007 are collected from: Statistics Yearbook of China published by the State Bureau of Statistics of China, International Energy Agency, UN Data, and World Development Indicators of the World Bank, which gives 27 observations for each country in the dataset.

Table 5.9 Data Description of Variables (1980-2006)

	China	France	Germany	Italy	Japan	UK	US
Capacity (GW)							
Mean	222.37	101.81	107.91	64.82	214.85	72.71	787.37
Minimum	65.87	63.66	82.55	46.82	143.70	66.43	625.92
Maximum	622.00	116.98	131.58	89.49	278.78	83.14	1,077.69
Power Consumption (GWh)							
Mean	864,582.85	349,444.33	480,915.04	232,994.85	784,358.52	296,304.78	2,954,104.56
Minimum	256,780.00	231,657.00	418,918.00	162,798.00	520,245.00	233,332.00	2,075,684.00
Maximum	2,445,233.00	450,946.00	542,394.00	317,566.00	993,882.00	353,816.00	3,816,845.00
Real Electricity Price Index (1980=100)							
Mean	116.09	90.56	100.32	89.69	79.86	102.22	96.11
Minimum	79.71	85.84	86.85	78.21	75.59	94.67	90.00
Maximum	152.13	100.00	108.83	102.48	100.00	126.57	103.10
Real GDP (Billion USD)							
Mean	730.84	1,296.77	1,798.53	1,157.31	2,992.34	1,067.65	6,395.41
Minimum	166.44	981.46	1,361.97	893.53	2,050.53	756.10	4,184.68
Maximum	1,910.30	1,673.53	2,234.38	1,399.07	3,733.30	1,470.65	9,192.91
Percentage of Industrial Value Added (%)							
Mean	45.17%	27.82%	36.65%	33.03%	37.77%	35.04%	28.74%
Minimum	41.34%	20.65%	28.86%	26.83%	30.13%	23.08%	22.03%
Maximum	48.68%	35.58%	46.73%	40.24%	45.70%	43.03%	34.51%
Load Factor (%)							
Mean	52.19%	49.63%	58.57%	41.61%	46.44%	52.20%	48.37%
Minimum	47.63%	43.15%	52.12%	38.12%	42.90%	44.23%	41.74%
Maximum	56.73%	56.59%	65.07%	45.98%	49.76%	58.02%	56.93%
Power Exports (GWh)							
Mean	4,107.93	53,373.00	33,721.11	1,164.00	0.00	510.11	11,026.56
Minimum	0.00	12,394.00	16,224.00	372.00	0.00	0.00	2,558.00
Maximum	12,271.00	80,739.00	65,441.00	3,018.00	0.00	2,959.00	24,271.00
No. of Observation	27	27	27	27	27	27	27

Source: National Bureau of Statistics of China, Electricity Information 2009 (IEA), UN Data, and World Bank.

The real GDP of all the seven countries are collected from the online database of the UNData. A group of previous studies tried to investigate and explain the relationship between the energy consumption and the economic growth. With the study of the Chinese data during the period from 1971 to 2000, Lam (2004) argued that "real GDP and electricity consumption for China are co-integrated and there is unidirectional Granger causality running from electricity consumption to real GDP but not vice versa". Yuan, Kang, Zhao and Hu (2008) again confirmed the co-integration between output and energy use in China. Mahadevan and Asafu-Adjaye (2007) employed the panel error correction model to investigate 20 countries from 1971 to 2002, and then proved that, "among the energy exporters, there was bidirectional causality between economic growth and energy consumption in the developed countries in both the short and long run." From the illustration in the previous section, it's expected that there is a positive relationship between the real GDP and the power consumption in those seven countries, but this relationship may be country-specific.

The percentage of industrial value added in GDP is obtained from the World Development Indicators in the World Bank online database. For China, we use the percentage of heavy industrial value-added instead. As shown by the discussion in section of 5.2, the growth of the heavy industrial outputs is highly related to power consumption. Thus, we believe that our estimation will be consistent with the expectation of the positive relationship between the two variables we discussed in section 5.2.

The real electricity price index of the OECD countries and China are obtained from Electricity Information 2009 and National Bureau of Statistics of China respectively.

The data of the power consumption of all of sample countries including China are collected from the online database of Electricity Information 2009 prepared by the International Energy Agency.

The data of the power supply capacity are collected from the online database of Electricity Information 2009 prepared by the International Energy Agency. Before the regression, all data, except the percentage of the industrial value added, are converted into the index and then the logarithm form. And the dummy variables of time are generated on the basis of the three periods, i.e. the 1980s, the 1990s, and the 2000s. In other words, the value of the time dummy variables will be 1, when the corresponding observation falls in that particular period. Otherwise, it will be 0.

The load factor is calculated by the following formula: ————————.

The total power output and the capacity are collected from the online database of the Electricity Information 2009 issued by the International Energy Agency.

Concerning and problems in the data

The ordinary least square (OLS) regression needs the time-series variables being stationary themselves or jointly stationary at least. If the series is non-stationary, the OLS would produce biased estimates, known as "spurious regression". The unit root of those time-series variables of each country must be investigated before the regression. The Augmented Dickey and Fuller test has been employed to test the unit root of those variables for each country. The null hypothesis H_0 assumes that the series is non-stationary, and it could be rejected if the unit root or non-stationarity doesn't exist. The element of the time trend would also be added in the test for the particular country as appropriate. If all of the independent variables in the same model have the same number of unit root with the dependent variable, it means that the model is qualified for the OLS regression. Otherwise, the variables with different number of unit root may not be suitable for the OLS regression in the same model. If a stationary variable has been found correlated to a non-stationary variable, it means that such relationship is just a "spurious correlation".

However, the non-stationary variables can also constitute a co-integration. We will perform the ADF test on the residual of the model to prove the validity of the long-run model.

Table 5.10 T-statistics of the Augmented Dickey-Fuller Test for Stationarity

	US		Germany		Italy		UK		France		Japan		China	
	Level	δ	Level	δ	Level	δ	Level	δ	Level	δ	Level	δ	Level	δ
Power Consumption	-1.602	-5.520***	-0.665	-3.426**	-0.040	-4.527***	-0.056	-4.076***	-3.796***	-3.334**	-1.804	-4.971***	1.607	-2.635*
Real GDP	-0.117	-3.037**	-0.472	-3.475**	-1.443	-3.485**	0.957	-2.896*	-3.544*	-4.471***	-1.976	-4.138***	0.954	-3.275**
Electricity Price	-2.106	-3.357**	-2.537	-2.845*	-3.485**	-3.818**	0.330	-5.817***	-2.843**	2.640*	-4.981***	-4.049***	-1.524	-2.801*
Percentage of Industrial Value Added out of GDP	-0.550	-2.977*	-1.049	-3.612**	-1.387	-4.711***	0.676	-2.946*	-4.273**	-3.825***	0.023	-2.813*	-0.082	-3.950***
Net Capacity	-0.012	-3.086**	-0.887	-6.148***	-0.045	-3.128**	-0.688	-4.135***	-3.830***	-2.305**	-1.877	-3.337**	1.555	-2.115**
Load Factor	-1.624*		-1.546*		-3.602**		-1.649*		-4.283**		-2.972*		-4.300***	

Notes: The δ stands for the first difference. *, **, and *** represent the rejection of the null hypothesis of non-stationarity at the 10% level, the 5% level and the 1% level. The lag in the Augmented Dickey-Fuller test is selected by the Akaike Information Criterion test.

The Augmented Dickey-Fuller test has been applied in order to test the stationarity of both the long-term and short-term time-series variables of the seven countries. As shown in the table above (5.10), for China, the levels of the power consumption, the real GDP, the electricity price and the net capacity are found to be non-stationary. Such findings are consistent with the results of the ADF tests in Lam's paper (2004), where the time series of the power consumption and the GDP for China are found to be non-stationary. As a result, the legitimate using OLS to estimate the long run mode of power consumption with the listed explanatory variables will be dependent on the stationary of the residuals. This will be tested further in estimation. The test also shows that the percentage of the industrial value added of China intends to be relative to the dependent variable, as it turns non-stationary. In terms of the first differences, the results of the ADF test reject the null hypothesis of the unit root for the power consumption, the real GDP and the electricity price of China. So, this justifies OLS as a suitable approach to estimate the short-run relationship of the changes in the power consumption with the real GDP and the electricity prices.

As to the UK and Germany, the levels of the first five variables are all non-stationary. As those variables have the same unit root, they are justified for the OLS regression in the same model. In terms of the first order of the first difference of the first five variables of the two countries, the results of the ADF test reject the null hypothesis of the non-stationarity.

In the case of the US, the levels of the power consumption, the real GDP and the percentage of the industrial value added all have the same integration of order one. It means that those variables are qualified for the OLS regression to give an unbiased estimation.

In the case of Italy, the result of the test shows that the electricity price is stationary, which is different from other four variables. The ADF statistics of the first difference of the variables are all below the critical value, so that the null hypothesis of unit root shall be rejected.

In terms of France the variables are all found to be stationary under the levels as well as the first differences. In terms of Japan, the electricity price is found to be stationary, which is different from other four variables, which implies that any significant relationship between the electricity price and the power consumption would be spurious correlation.

According to the results of ADF tests, the load factors of all those seven countries are found to be stationary, which is eligible for the OLS regression of Model 2a and 2b.

5.3.3. Empirical Results

Causality Tests

We start our estimation by performing the Granger Causality test first to check the causality relationship between GDP, power consumption and supply capacity. The null hypothesis of the Granger Causality test is that the variable *X* does not Granger cause the variable *Y*. If the null hypothesis is rejected, we can say that the changes in X could cause the changes in Y. Then it's justified to use the variable X to explain the variable Y in the model.

According to Table 5.11, it suggests that the relationship between the power consumption and the GDP in China should be bidirectional. Moreover, it also suggests that the changes in the power supply capacity are resulted by the changes in the GDP, the power consumption and the load factor respectively in the case of China.

Table 5.11 The Granger Causality Tests

China	F-Statistic	Prob>F	Null Hypothesis		F-Statistic	Prob>F	Null Hypothesis
GDP does not Granger cause Power Consumption	6.0142	0.0069	Rejected	Δ GDP does not Granger cause Δ Capacity	4.1850	0.0244	Rejected
Power Consumption does not Granger cause GDP	5.1700	0.0126	Rejected	Δ Capacity does not Granger cause Δ GDP	16.2490	0.0001	Rejected
Δ Power Consumption does not Granger cause Δ Capacity	5.4790	0.0127	Rejected	Load Factor does not Granger cause Δ Capacity	7.1430	0.0046	Rejected
Δ Capacity does not Granger cause Δ Power Consumption	0.5004	0.6137	Accepted	Δ Capacity does not Granger cause Load Factor	1.3532	0.2811	Accepted
US				**UK**			
GDP does not Granger cause Power Consumption	3.5081	0.0485	Rejected	GDP does not Granger cause Power Consumption	7.1520	0.0031	Rejected
Power Consumption does not Granger cause GDP	6.1459	0.0079	Rejected	Power Consumption does not Granger cause GDP	1.8301	0.1791	Accepted
Δ GDP does not Granger cause Δ Capacity	0.1581	0.8548	Accepted	Δ GDP does not Granger cause Δ Capacity	8.7066	0.0016	Rejected
Δ Capacity does not Granger cause Δ GDP	1.8248	0.1848	Accepted	Δ Capacity does not Granger cause Δ GDP	1.5094	0.2431	Accepted
Load Factor does not Granger cause Δ Capacity	4.3020	0.0338	Rejected	Load Factor does not Granger cause Δ Capacity	6.5882	0.0057	Rejected
Δ Capacity does not Granger cause Load Factor	0.0509	0.9978	Accepted	Δ Capacity does not Granger cause Load Factor	10.1310	0.0008	Rejected
Germany				**France**			
GDP does not Granger cause Power Consumption	4.0663	0.0282	Rejected	GDP does not Granger cause Power Consumption	0.3428	0.7126	Accepted
Power Consumption does not Granger cause GDP	2.5025	1.0000	Accepted	Power Consumption does not Granger cause GDP	0.1728	0.8422	Accepted
Δ GDP does not Granger cause Δ Capacity	2.9887	0.0711	Accepted	Δ GDP does not Granger cause Δ Capacity	1.7075	0.2045	Accepted
Δ Capacity does not Granger cause Δ GDP	3.6436	0.0430	Rejected	Δ Capacity does not Granger cause Δ GDP	0.3187	0.7304	Accepted
Load Factor does not Granger cause Δ Capacity	4.7438	0.0085	Rejected	Load Factor does not Granger cause Δ Capacity	3.5748	0.0324	Rejected
Δ Capacity does not Granger cause Load Factor	2.2834	0.0988	Accepted	Δ Capacity does not Granger cause Load Factor	3.3571	0.0393	Rejected
Italy				**Japan**			
GDP does not Granger cause Power Consumption	3.4316	0.0465	Rejected	GDP does not Granger cause Power Consumption	7.4196	0.0026	Rejected
Power Consumption does not Granger cause GDP	2.9784	0.0672	Accepted	Power Consumption does not Granger cause GDP	1.1730	0.3242	Accepted
Δ GDP does not Granger cause Δ Capacity	2.0641	0.1508	Accepted	Δ GDP does not Granger cause Δ Capacity	1.2738	0.2996	Accepted
Δ Capacity does not Granger cause Δ GDP	4.5466	0.0220	Rejected	Δ Capacity does not Granger cause Δ GDP	0.6605	0.5265	Accepted
Load Factor does not Granger cause Δ Capacity	3.6980	0.0413	Rejected	Load Factor does not Granger cause Δ Capacity	3.1720	0.0388	Rejected
Δ Capacity does not Granger cause Load Factor	8.1709	0.0022	Rejected	Δ Capacity does not Granger cause Load Factor	1.4729	0.2518	Accepted

Model 1

Table 5.12 The Estimation Results of Model 1a and 1b

A: Model 1a. The Long-run Determinants of the Power Consumption (1980 - 2006)

	Power Consumption (t)						
	US	Germany	Italy	UK	France	Japan	China
Real GDP(t-1)	0.7334***	1.300***	1.403***	0.677***	0.458	0.893***	0.777***
	(8.70)	(6.04)	(8.41)	(6.49)	(1.47)	(8.76)	(31.02)
Electricity Price(t-1)	-0.195	0.161	-0.148**	-0.209**	-0.252	-0.162	-0.199***
	(-1.50)	(1.45)	(-2.35)	(-2.64)	(-1.46)	(-1.50)	(-4.05)
Economic Structure (t)	-0.003	0.026***	0.002	0.0001	-0.036**	-0.011**	0.038***
	(-0.57)	(3.99)	(0.35)	(0.03)	(-3.49)	(-2.86)	(9.81)
Dummy for 1990s	0.049**	-0.113***	-0.001	0.031*	0.027	0.015	0.08**
	(2.87)	(-3.72)	(-0.05)	(1.72)	(0.90)	(0.56)	(3.10)
Dummy for 2000s	0.024	-0.107**	0.038	0.005	-0.012	0.009	0.035
	(0.82)	(-2.47)	(1.30)	(0.20)	(-0.21)	(0.26)	(0.80)
Constant	2.21**	-2.99**	-1.21	2.45***	4.63**	1.69*	1.103***
	(2.57)	(-2.33)	(-1.21)	(3.42)	(2.52)	(1.84)	(5.12)
Adjusted R-square	0.9917	0.8864	0.9933	0.9858	0.9854	0.9894	0.9978
Observations	27	27	27	27	27	27	27
ADF Test for the Residuals	-2.724*	-3.352**	-5.637***	-3.359**	-3.951***	-5.122***	-3.588**

B: Model 1b. The Short-run Determinants of the Power Consumption (1992 - 2006)

	△Power Consumption (t)						
	US	Germany	Italy	UK	France	Japan	China
△Real GDP (t-1)	0.282	0.244	-0.0021	0.617	0.108	-0.4117	0.934**
	(1.38)	(1.03)	(-0.01)	(1.59)	(0.24)	(-1.26)	(2.48)
△Real Price (t-1)	-0.179**	0.025	-0.022	0.085	-0.184	0.235	-0.778
	(-2.09)	(0.60)	(-0.51)	(0.54)	(-0.96)	(1.39)	(-0.61)
△Economic Structure (t)	0.006	0.0097*	0.0124	0.0002	-0.0052	0.0054	0.007
	(0.86)	(1.69)	(0.98)	(0.03)	(-0.29)	(0.58)	(1.43)
Dummy for 2000s	-0.008	0.007	0.002	-0.0145	-0.0013	-0.016	0.049**
	(-1.60)	(1.08)	(0.36)	(-1.35)	(-0.12)	(-1.65)	(2.69)
Constant	0.017	0.0054	0.026***	0.0039	0.0128	0.032**	-0.02
	(2.19)	(0.87)	(4.45)	(0.32)	(0.98)	(3.08)	(-0.50)
Adjusted R-square	0.455	0.2113	-0.2411	0.0115	-0.2457	0.1261	0.6050
Observations	15	15	15	15	15	15	15

Note: T-statistic significance: * at 10% level, ** at the 5% level, ***, at the 1% level. The lags in the ADF tests of the Model 1a are selected by the AIC tests.

According to Table 5.12, the residuals of the long-run model are stationary in terms of the seven countries according to the reported ADF test, which suggests that the model does not constitute the "spurious correlation".

The real GDP

According to results of Model 1a and Model 1b, the real GDP has the significant positive impact upon the power consumption in China, in both the long term and the short term. The existing studies (Lin, 2003; Lam, 2004; He, Zhao, Li and Huang, 2006; Yuan, Zhao, Yu and Hu, 2007) focused on the causality relationship between the real GDP and the electricity consumptions in China, and argued that there was only unidirectional relationship from the power consumption to the real GDP in China. Those studies covered the periods before the reform of the power sector, when the power supply in China was the bottleneck for the economic growth in most time. However, with the data from the reform years, we provide a different view about the relationship between the power consumption and the economic development.

As the Chinese economy relies more and more upon the investment and exports, the fluctuation of the global economy could affect the power consumption in China. During the Asia financial crisis, the decline in the power consumption growth was larger than the decline in the real GDP growth. It suggests that it might not be the right way to recover the economy from the economic downturn by supplying and consuming more energy. It also implies that the economic condition affects the power consumption in China. Some existing studies also confirmed our results. Lin (2001) studied the Chinese data from 1956 to 1994 with error correction model and found that 1% increase in the real GDP growth would lead to 0.883% increase in the power consumption. Again, Lin (2003) expanded the period from 1952 to 2001 and found that the real GDP could be the positive reason to explain the power consumption in the same period for both the long and short term. And later on, Wu (2009) also found that a 1% increase in the real GDP in China would lead to a 0.38%

increase in the power consumption in the long term. Thus, the effect of GDP on power consumption is persistently and has been clearly observed. During the first three months of 2009, the growth of the Chinese GDP decreased by 4.5 percentage points to 6.10%[25], and the power consumption in China shrank sharply by 4.02%[26]. And during the first eight months of 2009[27], the load factor of the coal-fired power plants decreased by around 9.95% on the year-on-year basis. These changes are consistent with the results of our study.

Moreover, just as China, the other six countries also show the positive impact of the real GDP on the power consumption in the long run, but not in the short run. The coefficients of the real GDP of Germany, Italy and Japan are higher than China, which suggests the higher elasticity of power consumption with respect to the GDP in those three countries in the long run. However, in terms of the short run, it's observed that the real GDP of all those six developed countries has no impact on the power consumption, in which this finding is very different from China that has the strong relationship in the short-run. This suggests that firstly, China's power consumption is very responsive to changes in the GDP, and secondly, the GDP impact on power consumption is generalised internationally across countries for the long run, but the impact is country-specific for the short run, like only observed in China.

The electricity price

According to the estimation of Model 1a and 1b, the end-user price have a negative impact on the power consumption in the long run, but not in the short run in China and in other OECD countries except the US. On average of the sample countries, a 1% of increase in the electricity price will lead to around 0.2% of decrease in the power consumption. A similar long-term relationship between the two variables for the case of China was also identified by Lin (2001), but his coefficient was -0.4645, higher than our estimated by 0.20. The difference may be of different sample data.

[25] http://news.xinhuanet.com/newscenter/2009-04/16/content_11194063.htm, visited on January 15th, 2010.
[26] http://www.chinairn.com/doc/70310/411935.html, visited on January 15th, 2010.
[27] http://www.gov.cn/gzdt/2009-09/14/content_1416848.htm, visited on January 15th, 2010.

Lin's (2001) data is from 1956 to 1994, when compared with our data from 1980 to 2006. Since 1978, the old plan system has been replaced by the market-oriented economy in many industries in China. This change may be the underlying reason for this difference. For the short run, we found that the price elasticity with respect to consumption is almost inelastic, because China has the rigidity in changing electricity price since the electricity price adjustment is a very complicated and politically sensitive issue for the nation. This makes the state to be very cautious in changing the price, in particular, in a large rise. As a result, we can expect that price adjusted will be small or insignificant to affect demand in the short-run.

Again, as same as GDP impact on power consumption, the price impact is almost a common phenomenon across the sample countries in the long run, but the impact is country-specific in the short run.

The economic structure

The variable for the economic structure is measured by the industrial outputs in GDP. According to the results of Model 1a, for China and Germany, the structure has the positive impact on the long-run power consumption. This finding suggests that China would need more power if its economy relies upon the industrial sector more and more. With the Chinese data from 1952 to 2001, Lin (2003) found the similar results that the gross output of the light industries has negative relationship with the power consumption in the long run. Wu (2009) studied the cross-sectional data from 30 Chinese provinces in 2005, and also found that the proportion of the industrial sector in GDP has a positive impact upon the regional electric power consumption, which is consistent with our finding.

In contrast to China, the long-run impact of the structure does not appear in every sample country. Furthermore, two sample countries show a negative impact of the structure on the consumption, such as France and Japan.

Table 5.13 The Production of Energy-Intensive Industries in China

Energy Consumption (mtce)	2000	2005	2006	2007	∆(2000-2007)
- Ethylene	5.29	8.11	9.53	10.11	91.27%
- Cement	108.06	178.50	199.12	215.07	99.03%
- Steel	100.74	252.21	283.34	326.84	224.43%
Annual Growth of the Production (%)	2000	2004	2005	2007	2000-2007
- Ethylene	8.05%	34.01%	19.96%	24.48%	136.28%
- Cement	4.19%	61.95%	10.55%	15.71%	137.55%
- Steel	3.41%	120.16%	24.86%	18.66%	293.76%

Source: National Bureau of Statistics of China

Compared to other six developed counties, the Chinese economic development relies upon the energy-intensive industrial sector more and more over the past 30 years. From 2000 to 2007, the production of ethylene, cement and steel, which are heavy energy-consuming products, has increased by 136.28%, 137.55% and 293.76% respectively in China. The heavy industry has taken up the major part of the industrial sector in China, of which the proportion keeps on growing over the time. Just as described previously, the heavy industries in China produced 58.03% of the total industrial outputs in 1999, and such figure increased to 70.47% in 2007. And, the percentage of the whole industrial sector out of the GDP in China is still growing in recent years, i.e. from 45.9% in 2000 to 48.5% in 2007.

Under such a pattern of economic development, China needs more and more consumption of energy. From 2000 to 2007, the energy consumed in China for producing the ethylene, the cement and the steel all increased by over 90%. In 2007, the Chinese heavy industry consumed about 91% of the energy and about 89% of the electricity supplied to all industrial sectors. Meanwhile, in the same year, the Chinese industrial sector consumed around 71% of the total energy and around 75% of the total power supplied for the whole country. Actually, over the past 10 years in China, the average industrial power consumption for each unit of the value-added is around 3.5 times and 8.8 times of the agriculture sector and the service sector respectively. He and Zhang (2005) have the similar understanding and argued that the main reason for the recent rise in the energy-intensity could be due to the growth of the proportion of the heavy-industries out of the GDP in China.

This argument is consistent with our evidence in Table 5.12 that a significant increase in the power consumption can be attributed to the Chinese industry restructuring process towards a more heavy-industry dominant structure. By having more heavy industry outputs in the economy, it produces two effects on consumption of power: (a) the power intensity effect and (b) the production volume effect. And increase in outputs from heavy industry will change the overall average of power consumption intensity in an economy, and the increase in the intensity can lead to a power consumption rise. Recent studies (Rosen and Houser, 2007; Di and Wang, 2008; Andrews-Speed, 2009; Kahrl and Roland-Holst, 2009) found that the energy intensity of China started to rise up again in recent years. From 2000 to 2004, the industrial energy intensity of China increased by around 10%. Meanwhile, the industrial power intensity in China grows even faster. From 2000 to 2007, in China, the power intensity of the production of the non-metal materials increased by around 33%, while the power intensity of the overall industrial sector increased by 23.75%.

For given the power intensity, increasing production volume will increase power consumption. Especially, this is significantly true for the heavy industry. The heavy industry needs a large scale-of-economies, which drives up production to massive quantities and so pushing up power consumption. For instance, over the last three decades, industrial outputs have grown by 22 times, and steel production has alone increased by almost 3 times from 2000 to 2007 (see Table 5.13). This explains why, with a process of heavy industrialisation, changing economic structure can result in a positive impact on power consumption. This argument is also evident by German case where it has a dominant manufacturing sector in the economy.

In contrast, if an economy is under a process of growing its service sector to be more and more dominate in the economy, then the change in the economics structure could lead to a reverse impact of the structure on the economy, such as evident by France and Japan in our estimation.

The time dummies

According to the results of the Model 1b, the time dummy for the 2000s has a positive relationship with the power consumption. It means that the growth of the power consumption in China would accelerate during the 2000s, which would be caused by the further reform of the power sector. By 2002, the Chinese power industry has been freed from the single and vertically integrated mechanism, which stimulated the vigorous capacity expansion and production (Varley, 2006).

Estimation of Model 2a and 2b

Table 5.14 Estimation Results of Model 2

A: The Estimation Results of Supply Capacity Model for China

	Model 2a	Model 2b	Model 2c	Model 2d
	0.2011**		0.1966*	
	(1.97)		(1.88)	
		0.1703*		0.1864*
		(1.66)		(1.79)
	0.5147**	0.5891***	0.5117***	0.5759***
	(6.87)	(9.60)	(6.66)	(9.09)
			-0.0084	-0.0194
			(-0.40)	(-0.90)
	0.0124**	0.0180***	0.0127*	0.0186***
	(1.96)	(2.97)	(1.95)	(3.03)
	0.0409***	0.0517***	0.0445***	0.0597***
	(5.00)	(7.48)	(3.60)	(5.29)
Constant	-2.3221***	-2.6701***	-2.2673***	-2.5178
	(-6.77)	(-9.45)	(-6.03)	(-7,62)
	0.8637	0.8573	0.8648	0.8628
	0.8378	0.8301	0.8310	0.8286
Observations	26	26	26	26

Notes: T-statistic significance: * at the 10% level, ** at the 5% level; *** at the 1% level

B: Estimation Results of Supply Capacity Model 2 for selected OECD Countries						
	US	Germany	Italy	UK	France	Japan
	-0.1483	0.2546	-0.2550	0.6339**	0.2586	0.0275
	(-0.60)	(0.50)	(-1.13)	(2.00)	(0.63)	(0.23)
	0.1969***	0.4468***	0.2120***	0.2880**	0.2342*	0.1229*
	(2.58)	(3.23)	(3.38)	(2.28)	(1.74)	(1.94)
	0.1283	0.1156	-0.0456	0.2095**	0.2729*	0.0737**
	(0.96)	(0.96)	(-1.16)	(2.06)	(1.81)	(2.35)
	0.0055	0.0457	0.0094	0.0022	-0.0121	N/A
	(0.42)	(0.66)	(1.37)	(0.65)	(-0.32)	N/A
	-0.0366***	0.0576**	-0.0014	-0.0257	-0.0632***	-0.0049
	(-2.48)	(2.33)	(-0.20)	(-1.52)	(-3.41)	(-0.76)
	-0.0022	0.0662***	-0.0010	-0.0425*	-0.0958***	-0.1414***
	(-0.15)	(2.74)	(-0.12)	(-1.82)	(-3.30)	(-2.92)
Constant	-0.8600**	-2.042***	-0.9360	-1.3271**	-2.2369***	-0.8681***
	(-2.52)	(-3.24)	(-3.26)	(-2.32)	(-2.38)	(-2.76)
	0.4721	0.4260	0.4286	0.6019	0.6168	0.6596
	0.3463	0.2893	0.2926	0.5072	0.5256	0.5822
Observations	28	28	27	27	27	28
Notes: T-statistic significance: * at the 10% level, ** at the 5% level; *** at the 1% level						
Note: Germany uses and ; Japan uses and , as of Japan is stationary; France uses .						

The power consumption

According to Table 5.14, as expected by the function of power supply capacity, the demand shocks have a significant impact on capacity in the long run, evident by the Chinese case. For instance, 1% increase in power consumption leads to some 0.20% increase in capacity two years after in China. This result is consistent when we replace the consumption variable with GDP in the estimation, in which GDP has a direct impact on the consumption.

However, in contrast, the significantly positive impact of GDP on capacity cannot be observed for OECD countries except the UK. One explanation for China to have a significant response of capacity to GDP is because of Country's poor transmission and distribution network. Kroeber (2008) pointed out that due to the poor transmission between different regions, it is difficult for power transmitted from one region to another, creating a phenomenon that power shortage and power surplus co-exists in the economy. In response to the structure shortage of power, more generating capacity has to be built near the big users, which is "in excess of actual underlying demand". Thus, it is unavoidable for the repeated and duplicated building of power plants in different regions, making capacity highly responsive to change in GDP.

China is responsive to demand shocks by promoting capacity expansion but the responsiveness is not high, where 1% growth in demand only brings up 0.2% growth in supply capacity. The inelasticity of capacity with respect to GDP can be explained by two reasons. One is of replacement investment, which replaces small power plants with big ones. Another is of capacity surplus at an aggregate level, in which the surplus can absorb excessive demand to some extent.

In terms of the replacement effect, China promotes the replacement of small power plants with the big ones via new investment. This replacement creates productive efficiency gains for given capacity, since the big is more efficient than the small. The efficiency gains means more productivity and so more outputs that can be produced in using the same amount of capacity. This enables 1% growth of new capacity to server more than 1% growth of demand. The extra capacity gained from using more efficient facilities could be significant at an aggregate level for China since more than 90% of power firms are small, see Table 5.15.

Table 5.15 The Large Power Plants with more than 1000MW capacity in the UK and China

	2005		2008	
	Number	Capacity (MW)	Number	Capacity (MW)
The UK				
Plants > 1000 MW	30	48,251	31	49,130
Total	264	77,504	320	78,293
Per cent	11.36%	62.26%	9.69%	62.75%
China				
Plants > 1000 MW	129	192,930		
Total	3,078	508,410		
Per cent	4.19%	37.95%		

Source: Digest of United Kingdom energy statistics 2006 & 2009, Department of Energy & Climate Change of the UK, Table 5.11; National Bureau of Statistics of China; China Electric Power Yearbook 2006; "Annual Report of Power Industry in China 2008", China Economic Information Network, pp. 75

In terms of the surplus effect on capacity, it is obvious. Table 5.16 shows that there is some 50% of capacity that have not been utilised, which helps absorb excess demand shocks. As a result, this weakens the responses of capacity to changes in GDP.

Table 5.16 The Spare Power Capacity in China (2008)

	% out of total capacity %	Load factor %	Thermal efficiency (gross calorific value basis) %
UK			
Combined cycle gas turbine stations	34.66	69.3	51.9
Coal fired stations	30.26	40.5	36
Nuclear stations	14.36	49.4	37.9
Overall	100	55.71	42.7
China			
Combined cycle gas turbine stations	0	0	NA
Coal fired stations	77.15	51.2	NA
Nuclear stations	2.27	56.7	NA
Overall	100	51.74	35.21

Source: The UK data are collected from the Department of Energy & Climate Change of the UK; The Chinese data are collected from the National Bureau of Statistics of China.

The load factor

As predicted by the capacity function, the load factor is surprisingly strong across all of our sample countries including China. The average load factor of an economy implies a state of demand for power since the higher load factor implies the higher consumption of electricity. Apparently, the load factor driving capacity appears in every sample country, which appears as a strong international phenomenon in every power industry. The capacity is very responsive to the change in the load factor. For instance, in China, 1% increase in the load factor can be responded by 0.59% growth of the capacity. For most of OECD countries, the capacity elasticity with respect to the factor is around 0.2.

The dominant impact of the load factor on capacity suggests that a power industry does respond to the change in demand through the consumption impact on the capacity utilisation of the industry. The industry does not respond directly to the demand shocks in adjusting its long-run supply, except China. Furthermore, the industry is likely not to respond to the change in demand at all if the change does not increase the utilisation of the capacity. That is to say, as long as demand for power affects the utilisation, then the industry responds to the demand. This finding suggests that the impact of demand on capacity is indirect. One possible explanation is that, the decision maker may feel uncertain about the future's power demand when they are making the investment decision. And the most reliable indicator for the power firms is the load factor, which provides a direct and clear record of the power surplus and shortages. It could be especially true for the OECD countries, which have experienced the "de-industrialisation".

The electricity price

In general, an increase in the price of electricity shall be responded by the firm positively to produce more by expanding its capacity in the long run. This expectation is evident by Germany, France and Japan, but not in other economies. The evidence shows that the price impact on capacity can be country-specific. This implies that using the price as a policy instrument to promote the growth of power supply in the long run is likely to be in question except an economy possesses the economic characteristics of the three OECD countries.

One possible explanation to the failure of the price in affecting the long run supply in the EU is because of the electricity cross-board trading, which is a result of the power market integration. A rise in the price in one region could shift demand for power to other regions, and therefore it is difficult to expect the supply will increase in response to the price since demand could fall as a result of the substitution effect. For instance, Italy imported 16% of total electricity consumption from other EU countries in 2007 and it is expected that the imports could further increase to substitute domestic supply if the price continues arising.

In China, the electricity price does not affect the capacity of power supply. This may be due to the price variable we employed for the estimation, which is of end-users. A change in the end-user price will not affect power firms but the grids, since Chinese power firms only sell their power to the grids at an on-grid price. The re-selling price of power by the grid does not affect the benefits of up-stream power firms since revenues from sales to end-users are all taken by the grids. As a result, the separation of power generation from the grid in the Chinese current model will limit a role of electricity price as a signal in directing supply in the long run. However, this does not mean that the price cannot affect supply at all. What we suggest is that the capacity impact of the end prices is not direct but indirect, through affecting the demand for power on supply. As the on-grid price was only formed in 2000s, the time-series data could be relatively short for regression model. The relationship between the on-grid price and the supply capacity will be tested by using the panel data in the upcoming study, but not in the scope of this study.

The power exports

In our estimation presented in Table 5.14, exports do not appear significantly in determining capacity. China has a few exports of power, so that we do not estimate it in estimation for it. For other OECD countries, it seems to suggest that exports do not play a significant role in stimulating capacity expansion directly. The non-significance of exports seems to appear as general evidence across all of sample countries.

Since opening cross-board trades in the electric power market, we understand that France is an electricity exporting nation in the EU. In 2007, France exported 16.7 GWh and 15.1 GWh power to Germany and Italy, which are equal to 49% of its total export. Actually, from 2001 to 2007, France exported around 16% of its production on average to other countries. Therefore, we expect that the export impact should have an impact on capacity in the French case, but it fails in identifying it in our estimation. The possible explanation is that any increase in the power export could be satisfied through various ways, such as increasing the utilisation of the capacity, building more capacity, and cutting down the domestic usage of the power, and even importing the power from other countries for reselling on the market. And all those factors make the results of the capacity expansion become insignificant.

The time dummies

The dummies for 1990s and 2000s have some positive significant relationship with the growth of capacity in terms of China. It means that the growth of the power supply capacity in China is booming in past two decades.

5.4. Conclusions

What determines power supply in the long run? The committable supply is of capacity. China's power supply capacity has been increased by 12 times over the last 3 decades, the capacity doubled around every 10 years on average. How can China achieve such rapid growth over a long time period? Can we learn any generic experience for other economies? A general view from existing literature is that power consumption and economic growth are related with each other. But which determines which is not addressed very clearly. Some argue it is power to drive economic growth and some reverses. However, there is a lack of a rigorous study on directly examining a relationship between supply capacity and economic growth, in particular, via quantitative examination. The chapter fills the gap.

China liberalises market any entry and investment on building power plants, but still remains state plan control over prices and outputs for each power firm. The output of a firm is allocated according to its capacity (see Chapter 4). With the price regulation and the linkage of plan output with the capacity of the firm, in response to demand, the profit-seeking power firm will complete capacity of the firm in order to gain more plan outputs and so profits. The lower plan price will further accelerate demand and so stimulate capacity. Therefore, the Chinese reformed plan management model of the power supply can be characterised by which "the state plan a lower price of power to promote economic growth and so increase demand, and the more demand stimulates the industry to expand capacity for more profits".

This is contrast to the market-based management system of the industry in response to increasing demand by raising both prices and supply, and the price rise limits further rise in demand. China increase supply but not price, so demand grows further.

This argument is evident by our study in this chapter: (1) demand is responsive to the prices, in which this is almost a generic phenomenon across countries including China; (2) the GDP growth is a driving factor to demand for power consumption , in which this factor is particular significant in China; (3) the economic structure adds further impact on demand for power consumption, although this impact is country-specific, such as China that has been experiencing heavy industrialisation over the last 10 years; (4) an increase in power consumption can change the capacity utilisation of the industry, promoting further investment in capacity.

The evidence above together with findings identified by the last chapter show us a clear pattern of China's reformed plan model of the power management: to lead the industry to compete capacity but not the price, and the low plan price promotes growth and so demand, in which the demand leads the industry to decide capacity. Clearly, both market and plan play a role in stimulating supply. This is why the reformed plan system can be successful in stimulating supply, and challenging the conventional wisdom of the plan creating shortage.

Chapter 6. Conclusions

The electric power industry is very important for the economic growth of a country, particular for China, which has been experiencing the heavy-industrialisation over the last 10 years. The existing studies, such as Wu and Li (1995), Li and Dorian (1995), Andrews-Speed and Dow (2000), Yeoh and Rajaraman (2004), Hafsi and Tian (2005), and Wang (2007), argued that the plan will result in the high generation costs and low thermal efficiency, and power shortage, and then promote a market-oriented mechanism to the Chinese policy makers without stating the potential risks of market failure and its possible impacts on the industry that this has been experienced by the US and noticed by the Western researchers. A series of studies (Thomas, 2003; Graham, 2006; Sweeting, 2007) argued that the dominant generators could obtain the extra gain from the market in the West. But those studies didn't refer to the case of China. So a question is raised. Can the market approach really work in China, in terms of stimulating the power supply and productive efficiency and as asserted? In order to address this, our study makes a comprehensive comparison of prices and costs of the power supply between China and the OECD countries. It finds that the reformed plan can provide an effective power supply with better protection of the small consumers' benefits. In order to explain this further, the investigation into the pricing behaviour is needed. Unfortunately, very few studies focused on this topic, except Lam (2004). He studied the catalogue price in China and argued that the electricity prices across China are mainly determined by short-run cost factors. But this study only depicted the situation before the form of independent power producers in China. In order to fill the research gap, we use the on-grid prices to estimate southern Chinese provinces over the period from 2003 to 2005, which provides an in-depth and extensive view on the price setting of the power supply in China. Besides, the capacity expansion is also an important issue for China's power supply. A general view from the existing literature (Lin, 2003; Shiu and Lam, 2004; Rosen, 2007; Kroeber, 2008) is that the power consumption and economic growth are related with each other. But which determines which is not addressed very clearly, where some argue it is power to drive economic growth and some reverses. Besides, there is also a lack of a rigorous study on directly examining a relationship between supply capacity and economic growth. This study fills the gap with the rigours model and the international comparison with the OECD countries. The whole study attempts to remind the fact that plan may not be always inferior while the market may not be always superior in promoting a successful electric power supply system for a nation.

6.1. Findings and contributions

Since the 1980s, China has started its long march of economic reform in all industrial sectors including the electric power sector. On one hand, the Chinese power sector has been restructured in line with market-oriented reform, such as the separation between the grids and generators, opening market entry to power generation business, decentralising decision on investment from the state to the power company, and the self-accountability of the profits of the power producers. On another, the features of the plan economy still remain. The transmission, distribution and retailing of the electric power are still integrated together under the control of the grids. The on-grid price and the catalogue price of the electricity, the electricity coal price, and the output of the power generation are still under the governmental plan control. In other words, the current Chinese power sector is different from the highly integrated mechanism under the plan economy, but still far away from the fully unbundling market system. During such transitional process, it's very important for the policy makers to design, adjust and update the reform schemes carefully, promptly and flexibly, so as to respond to the current issues effectively. In order to pursue a suitable reform, we need to learn the lessons and experiences from the past internationally.

Since the reform, the Chinese power sector supply has grown rapidly for last three decades, with both the cost and price advantages of generation when compared with the West. Besides, the household price in China was set to the same level of the industrial price, which promotes the household benefits better than the West. Generally speaking, the reform of the Chinese power industry has achieved great successes, in terms of growth, security, sustainable development and affordability of the power supply for its economic growth. As China adopts a mixed plan and market economy, the state needs to plan prices to balance the benefits of all of interest parties in the supply chain of the electric power, including the coal suppliers, the power suppliers, the grids, and the industrial and household users.

At a macro level, China relies upon the coal-fired power heavily. It generates some 80% of China's total electricity. And, at the micro level, the fuel costs account a substantial part of the generation cost of the coal-fired plant. Thus, the electricity coal price is critical to decide the electricity price. In order to lower down the electricity price, the state sets the electricity coal price below the market coal price. However, the cheaper plan coal price does not create incentives for the coal producers to sell coal in excess of the plan target to the power producers. And, the power generators have to procure the coal from the market to produce excessive output above the plan targets. Due to the rigidity of plan prices for power producer in selling their power, a rise in the coal price will erode the profitability of the power producers, which will reduce their incentives to produce more to meet excessive demand for power. Therefore, the shortage of power supply and capacity surplus can co-exist in the economy. This is just an example of the phenomena of the Chinese power sector that has still been in plan. Through our study in this thesis, more interesting phenomena are identified for the reformed plan system:

1) The high cost strategy for price bargain

Inevitably, the integration of power production with coal-mining would be a right choice to help the state eliminate the problem of conflict of interest on pricing, where the inflation of the fuel costs can be transferred to the on-grid prices. Through the estimation of the panel data of the coal-fired plants in the southern Chinese provinces, we found that the power producers would take the "high cost strategy" to bargain with the government for higher prices of the electricity. Obviously, such behaviour of the firms would induce the slack budgets and cost inefficiency of the power generation, which would offset their cost advantages. This price setting in line with costs creates a soft price constraint on costs of the firm.

2) The better protection of the benefits for the small consumers

Obviously, the electricity price is not set for the power sector only, but also for the economic development of the whole country. With the estimation of the time-series model, we found that the high electricity price would be welcomed by the power suppliers, but it would also supress the power consumption of the end users. However, if the end price is set too low to cover the increase in the on-grid price, the grids would suffer. With the international comparison, we found that China adopts a different strategy of the end user price from the West, to secure the competitiveness of the industrial production and also protect the benefits for the small consumers. China sets the household price of electricity lower than the West in an absolute term. Although China has a lot of cost advantages, this does not help China gain significant cost advantage in supply of power to the industrial production when compared with the West. For example, China has lower costs of investments, fuel, labour and environmental protection. Thus means that China limits the profits for the power industry in order to protect the benefits for both industrial and household users. In contrast, some OECD countries allow power producers or traders to charge small household users twice more than the industrial users. Apparently, price discrimination in China is used for providing subsidies to the poor, but the discrimination is adopted to make more profits in particular at expense of small-quantity users' welfare. Thus, it's reasonable to argue that the plan mechanism in the Chinese power industry better protects the benefits for the small consumers than some market-mechanism-based OECD countries. Therefore, the plan is not always evil and market is not always successful for protection of the small consumers' benefits, and promotion of outputs.

3) The competition in capacity

As mentioned above, the price and output are controlled by the government. It means that the electricity price is not determined by the equilibrium of the demand and supply. It also implies that there is no competition in the electricity price, as there is no market mechanism in the Chinese power sector. It has been exactly proved by the insignificant relationship between the electricity price and the regional market share of the plant. However, the government restriction on capacity investment into the power generation sector was removed at the very beginning of the economic reform, which stimulates capacity expansion. According to the previous studies, the power supply was thought to be the bottleneck of the economic development in China. But, in turn, economic growth could demand for more power supply, as shown by our empirical evidence in this study that the power consumption is driven by GDP in China. However, output is planned by the state for each firm according to its capacity. For given plan price, the firm's profits can be increased by asking more plan outputs, which drives the firm to increase capacity. As long as the demand is there, the capacity increase can always help gain more outputs. The positive relationship between capacity and power consumption in China exactly confirmed such demand-capacity-outputs link in China's power industrial development. For the power producers, the larger capacity will bring the larger quota of the output and the cheaper electricity coal, which could easily converted to the higher revenue and profits. Thus, competition among the power producers is not the price but the capacity expansion for making more profits.

How does the firm respond to more demand? Western firms respond to it by increasing both prices and supply capacity. But the price rise will provide a counter force for bringing down demand and so slow down supply, so that capacity will not have a rapid increase. In contrast, the Chinese counterpart will respond to demand by not changing price but purely increasing supply. Thanks for plan that retains the low price, which removes the counter force to limit demand growth and so supply, so that capacity can grow rapidly in response to demand that is fuelled up by a lower plan price. Apparently, China takes pro-economic-growth policy to manage power supply, which is very different from a market-based power management system.

6.2. Implications for future reform

Although the Chinese power sector has achieved dramatic expansion, the current plan mechanism of the Chinese power supply is not perfect. According to the analysis above, we could derive some implications for the reform of the power supply system in the future:

1) The price freedom of the power supply chain

As mentioned above, the "coal-power linkage" increases the on-grid price, which would erode the profits of the grids. Some previous studies claimed that governmental control over the electricity price should be fully removed so that the inflation in the coal price will be able to pass to the end users. We should notice the consequence of such kind of action. Obviously, the removal of the governmental control over the electricity and coal prices would be very helpful for the participants on the power supply chain to realise higher profits. According to the Western experience, the market dominators would simply exert their market power to set higher price for higher profits at the expenses of the benefits of the end users of the electric power. Due to the insufficient facilities of the transmission network in China, it's very easy for the large power producer to take the monopoly or duopoly position in a particular region. So, if the governmental control of the electricity price were completely removed, it's reasonable to expect that the similar results in the West could happen in China.

Another concern is about the efficiency of the energy utilisation. The advocators of the price liberalisation argued that the increase in the end price will push the end users to enhance the efficiency of the energy utilisation in China. And they prefer the increase in the household price rather than the industrial price, in order to promote the energy-savings technology for the household use. As most of the power is supplied to industrial users rather than the household users, the energy save in the household usage will be very limited under such arrangement. In another aspect, if the industrial price doesn't increase, the industrial users will not be pushed to improve their energy efficiency, as there is no the pressure from the increase of the electricity price.

However, no matter who undertakes the inflation of the electricity price, the immediate consequence of the full price liberalisation in the power supply chain would be either the losses in the industrial competition or the losses in the industrial competiveness or the losses in benefits for small consumers.

2) The insufficient facilities of the grids and the excessive capacity of the power generation

As discussed in the previous chapter, the grids facilities are insufficient in China to undertake the tasks of the power transmission from the energy-rich inland regions to the economy-advanced coastal regions. It would result in poor utilisation and allocation of the social resources. On one hand, the power producers have to build the excessive capacity of the power generation repeatedly in the high-power-demand regions. On another, the energy source in the energy-rich regions could not be able to get fully developed. Besides, the transport of the energy source, like coal, would again increase the fuel cost. Thus, it's not strange to find the co-existence of the capacity surplus and the power shortages in China. The best solution for this structure shortage problem would be further investment in transmission facilities, rather than more power generation capacities. So, the proper distribution of the profits on the power supply chain should be carefully designed to attract the investments into the power transmission sector.

3) The risks of the capacity idle in the economic downturn

The existing literature suggests that the economic growth would continue, as long as more electric power would be supplied. However, this study revealed another fact that the economic growth would also impact the power consumption in China. The empirical evidence shows that, more power will be supplied and consumed in the economy-expansion periods. The high power demand would deliver the positive signal to the power producers to build more generation capacity. However, as mentioned previously, the industrial sector is the largest consumer of the power supply in China, and also the largest contributor of the economy in China. The global economy downturn will heavily strike the manufacturing industry in China, which would then result in the decline in the power demand and power production. It could be especially true at the present, and the newly-built capacity would face the idleness during the current economy downturn. There is a risk that the rapid capacity expansion in recent years would induce considerable economic pressure upon the power producers in China in foreseeable future.

6.3. Further studies

As mentioned above, China heavily relies on the coal-fired power generation, which is a large polluter of environment. In order to improve its energy profile and protect environment, China must take several actions, such as changing the structure of the power supply, closing the small power plants and implementing advanced technologies to improve the efficiency of the power generation. Thus, how much will the technological change affect the productivity of the Chinese power generation sector? And how much will those actions of the environmental protection improve the overall energy profile in China? Those questions need to be addressed in the future research.

Appendices

Appendix 2.1 The Power Self-sufficiency and the Industrial Value-added at Provincial Level in China				
	2006		2007	
Province	Power Generation to Consumption	Industrial Value Added per Capita (1000 Yuan)	Power Generation to Consumption	Industrial Value Added per Capita (1000 Yuan)
Beijing	0.32	11.32	0.34	11.17
Tianjin	0.83	21.25	0.79	22.63
Hebei	1.49	5.63	0.76	6.14
Shanxi	1.43	6.16	1.28	6.69
Inner Mongolia	2.89	6.73	1.63	7.99
Liaoning	0.83	8.99	0.78	10.00
Jilin	1.10	5.15	1.06	5.83
Heilongjiang	1.11	6.64	1.09	7.10
Shanghai	0.72	24.27	0.68	24.05
Jiangsu	0.91	13.40	0.89	14.49
Zhejiang	0.97	11.55	0.90	12.18
Anhui	1.13	2.86	1.10	3.24
Fujian	1.04	7.44	1.04	8.19
Jiangxi	0.99	2.66	0.88	3.08
Shandong	1.17	11.98	1.05	13.34
Henan	1.18	4.50	1.04	5.18
Hubei	1.60	4.05	1.58	4.57
Hunan	1.08	3.12	0.92	3.55
Guangdong	1.45	11.36	0.88	12.22
Guangxi	1.49	2.24	1.11	2.55
Hainan	1.75	2.43	1.14	2.86
Chongqing	0.73	2.98	0.77	3.39
Sichuan	1.49	3.29	1.01	3.83
Guizhou	2.95	1.84	2.13	1.96
Yunnan	2.03	2.69	1.36	2.80
Tibet	1.16	0.74	1.03	0.83
Shaanxi	1.15	4.30	1.12	4.74
Gansu	1.04	2.95	0.99	3.20
Qinghai	1.22	4.36	1.04	4.79
Ningxia	1.02	4.30	1.02	4.57
Xinjiang	1.36	5.58	1.03	5.82

Source: The provincial data of the industrial value added, the power generation and power consumption from the Development Research Centre of the State Council; the population data from National Bureau of Statistics of China.

Appendix 2.2 The Electricity End Price and the Economic Power Efficiency at Provincial Level in China

	2006		2007	
Province	Industrial Value Added per Unit of Power Consumed (Yuan/kWh)	Average End Price (Yuan/kWh)	Industrial Value Added per Unit of Power Consumed (Yuan/kWh)	Average End Price (Yuan/kWh)
Beijing	2.93	0.53	2.74	0.63
Tianjin	5.27	0.53	5.10	0.54
Hebei	4.05	0.44	2.11	0.46
Shanxi	2.03	0.41	1.68	0.42
Inner Mongolia	3.41	0.35	1.73	0.34
Liaoning	3.18	0.51	3.16	0.52
Jilin	3.51	0.49	3.44	0.53
Heilongjiang	4.44	0.48	4.32	0.52
Shanghai	4.46	0.65	4.17	0.66
Jiangsu	4.22	0.59	3.74	0.59
Zhejiang	3.44	0.57	2.82	0.57
Anhui	2.72	0.50	2.57	0.51
Fujian	3.04	0.49	2.93	0.49
Jiangxi	2.88	0.51	2.63	0.52
Shandong	5.61	0.48	4.83	0.49
Henan	3.19	0.43	2.68	0.43
Hubei	2.79	0.52	2.63	0.53
Hunan	3.04	0.50	2.57	0.51
Guangdong	6.44	0.68	4.00	0.69
Guangxi	3.33	0.45	2.19	0.46
Hainan	3.76	0.62	2.55	0.61
Chongqing	2.26	0.51	2.14	0.53
Sichuan	3.40	0.47	2.64	0.49
Guizhou	2.10	0.38	1.35	0.39
Yunnan	3.61	0.39	2.05	0.39
Tibet	1.59	0.51	1.60	0.51
Shaanxi	3.19	0.42	2.78	0.43
Gansu	1.52	0.36	1.36	0.37
Qinghai	1.06	0.29	0.93	0.31
Ningxia	0.68	0.36	0.63	0.38
Xinjiang	4.83	0.42	3.10	0.45

Source: The provincial data of the industrial value-added, the electricity end price the power generation and power consumption are obtained from the Development Research Centre of the State Council.

Appendix 3.1 Unit Cost of the Power Generation for the Year 2004

	Unit	Shanxi Shentou 2004	Liaoning Qinghe 2004	Pingdingshan Yaomeng 2004	Jiangsu Changshu 2004	Anhui Pingwei 2004	CPID 2004	Drax 2004
Total Unit Cost	Yuan/MWh	118.05	204.96	179.57	230.63	197.64	203.07	391.49
Unit Cost of Sales	Yuan/MWh	115.43	204.86	179.81	231.67	188.37	200.50	378.70
Unit Variable Costs	Yuan/MWh	69.94	133.14	125.28	164.92	125.89	139.01	NA
Unit Fuel Costs	Yuan/MWh	68.95	126.84	120.40	164.92	125.69	137.44	205.32
Unit Water Costs	Yuan/MWh	0.98	6.30	4.88	0.00	0.20	1.57	NA
Unit Electricity Procurement Costs	Yuan/MWh	0.00	0.00	0.00	0.00	0.00	0.00	NA
Unit Fixed Costs	Yuan/MWh	45.49	71.72	54.53	66.75	62.47	61.50	NA
Unit Material Costs	Yuan/MWh	4.00	4.98	3.83	4.20	3.04	3.68	NA
Unit Salary	Yuan/MWh	11.24	23.93	10.67	120.03	12.07	12.12	17.49
Unit Depreciation	Yuan/MWh	8.08	16.39	18.50	31.11	24.92	25.06	21.86
Unit Maintenance Expenses	Yuan/MWh	9.73	6.09	3.93	5.99	10.49	6.94	23.12
Unit Transportation Expenses	Yuan/MWh	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other Unit Costs	Yuan/MWh	12.44	20.33	17.61	11.96	11.95	13.69	59.56
Unit Business Taxes	Yuan/MWh	1.34	0.00	0.00	0.25	0.00	0.09	0.00
Unit Other Profit	Yuan/MWh	0.64	1.04	0.30	3.95	0.26	1.84	49.56
Unit Administrative Expenses	Yuan/MWh	0.00	0.00	0.00	0.00	0.00	0.50	11.44
Unit Financial Expenses	Yuan/MWh	1.37	1.10	0.17	2.25	9.37	3.67	51.48
Unit Interest Paid	Yuan/MWh	1.42	1.16	0.09	5.66	9.55	5.33	67.05
Unit Interest Received	Yuan/MWh	0.05	0.09	0.07	3.51	0.18	1.74	15.57
Unit Subsidies	Yuan/MWh	0.00	0.16	0.00	0.00	0.00	0.00	0.00

Unit Non-operational Income	Yuan/MWh	0.10	0.24	1.34	0.01	0.01	0.41	1.66
Unit Non-Operational Expenses	Yuan/MWh	0.66	0.44	1.19	0.42	0.17	0.57	NA
Electricity Price	Yuan/MWh	134.39	203.84	195.59	275.08	248.16	241.23	363.93
Total Unit Cost	Yuan/MWh	118.05	204.96	179.57	230.63	197.64	203.07	391.49
Unit Profit before Taxation	Yuan/MWh	16.34	(1.12)	16.02	44.45	50.52	38.16	(27.56)
Dark Spread	Yuan/MWh	73.45	89.31	85.95	118.47	127.57	103.79	158.61
Unit Institutional and Managerial Costs	Yuan/MWh	9.42	16.39	18.50	31.36	24.92	25.65	33.30
Unit Income Taxation	Yuan/MWh	0.00	0.00	0.32	44.45	3.90	2.61	(23.25)
Unit Minority Interests	Yuan/MWh	0.00	0.00	0.00	0.00	0.00	26.92	0.00
Unit Gross Profit	Yuan/MWh	17.63	(1.02)	15.78	43.16	59.79	40.64	158.61
Unit Operational Profit	Yuan/MWh	16.90	(1.08)	15.90	44.86	50.68	38.31	36.44
Unit Net Profit	Yuan/MWh	16.34	(1.12)	15.70	0.00	46.62	8.62	(4.31)
Interest Rate	%	4.58%	2.08%	NA	6.67%	5.81%	4.46%	8.00%
Coal Equivalent Price	Yuan/Tonne	182.42	323.38	349.50	476.68	372.76	401.14	NA
Coal Price	Yuan/Tonne	109.95	187.68	218.11	361.87	273.01	282.45	587.85

Source: 1) Annual reports 2004 and 2005 of Drax, and 2) Annual reports 2004 and 2005 of CPID.

Appendix 3.2 Percentage of Unit Cost against Price for the Year 2004

	Unit	Shanxi Shentou 2004	Liaoning Qinghe 2004	Pingdingshan Yaomeng 2004	Jiangsu Changshu 2004	Anhui Pingwei 2004	CPID 2004	Drax 2004
Total Unit Cost	%	87.84%	100.55%	91.81%	83.84%	79.64%	84.18%	107.57%
Unit Cost of Sales	%	85.89%	100.50%	91.93%	84.22%	75.91%	83.12%	104.06%
Unit Variable Costs	%	52.04%	65.31%	64.05%	59.95%	50.73%	57.63%	NA
Unit Fuel Costs	%	51.31%	62.22%	61.56%	59.95%	50.65%	56.98%	56.42%
Unit Water Costs	%	0.73%	3.09%	2.49%	0.00%	0.08%	0.65%	NA
Unit Electricity Procurement Costs	%	NA	NA	NA	NA	NA	NA	NA
Unit Fixed Costs	%	33.85%	35.18%	27.88%	24.27%	25.17%	25.49%	NA
Unit Material Costs	%	2.98%	2.44%	1.96%	1.53%	1.23%	1.52%	NA
Unit Salary	%	8.36%	11.74%	5.46%	43.64%	4.86%	5.03%	4.81%
Unit Depreciation	%	6.02%	8.04%	9.46%	11.31%	10.04%	10.39%	6.01%
Unit Maintenance Expenses	%	7.24%	2.99%	2.01%	2.18%	4.23%	2.88%	6.35%
Unit Transportation Expenses	%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Other Unit Costs	%	9.26%	9.97%	9.00%	4.35%	4.82%	5.67%	16.37%
Unit Business Taxes	%	1.00%	0.00%	0.00%	0.09%	0.00%	0.04%	0.00%
Unit Other Profit	%	0.48%	0.51%	0.15%	1.44%	0.11%	0.76%	13.62%
Unit Administrative Expenses	%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	3.14%
Unit Financial Expenses	%	1.02%	0.54%	0.09%	0.82%	3.78%	1.52%	14.15%
Unit Interest Paid	%	1.06%	0.57%	0.04%	2.06%	3.85%	2.21%	18.42%
Unit Interest Received	%	0.04%	0.04%	0.04%	1.28%	0.07%	0.72%	0.84%
Unit Subsidies	%	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%

Unit Non-operational Income	%	0.07%	0.12%	0.68%	0.00%	0.00%	0.17%	0.46%
Unit Non-Operational Expenses	%	0.49%	0.22%	0.61%	0.15%	0.07%	0.23%	NA
Electricity Price	%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Total Unit Cost	%	87.84%	100.55%	91.81%	83.84%	79.64%	84.18%	107.57%
Unit Profit before Taxation	%	12.16%	-0.55%	8.19%	16.16%	20.36%	15.82%	-7.57%
Dark Spread	%	54.65%	43.81%	43.94%	43.07%	51.40%	43%	44%
Unit Institutional and Managerial Costs	%	7.01%	8.04%	9.46%	11.40%	10.04%	10.63%	9.15%
Unit Income Taxation	%	0.00%	0.00%	0.16%	16.16%	1.57%	1.08%	-6.39%
Unit Minority Interests	%	0.00%	0.00%	0.00%	0.00%	0.00%	11.16%	0.00%
Unit Gross Profit	%	13.12%	-0.50%	8.07%	15.69%	24.09%	16.85%	43.58%
Unit Operational Profit	%	12.58%	-0.53%	8.13%	16.31%	20.42%	15.88%	10.01%
Unit Net Profit	%	12.16%	-0.55%	8.03%	0.00%	18.79%	3.57%	-1.18%

Source: 1) Annual reports 2004 and 2005 of Drax, and 2) Annual reports 2004 and 2005 of CPID.

Appendix 3.3 Percentage Difference of Unit Costs compared to Drax for the Year 2004

		Shanxi Shentou	Liaoning Qinghe	Pingdingshan Yaomeng	Jiangsu Changshu	Anhui Pingwei	CPID
	Unit	2004	2004	2004	2004	2004	2004
Total Unit Cost	%	-69.84%	-47.65%	-54.13%	-41.09%	-49.52%	-48.13%
Unit Cost of Sales	%	-69.52%	-45.91%	-52.52%	-38.83%	-50.26%	-47.05%
Unit Variable Costs	%	NA	NA	NA	NA	NA	NA
Unit Fuel Costs	%	-66.42%	-38.22%	-41.36%	-19.68%	-38.78%	-33.06%
Unit Water Costs	%	NA	NA	NA	NA	NA	NA
Unit Electricity Procurement Costs	%	NA	NA	NA	NA	NA	NA
Unit Fixed Costs	%	NA	NA	NA	NA	NA	NA
Unit Material Costs	%	NA	NA	NA	NA	NA	NA
Unit Salary	%	-35.76%	36.80%	-38.99%	586.27%	-31.01%	-30.69%
Unit Depreciation	%	-63.02%	-25.03%	-15.41%	42.30%	14.00%	14.63%
Unit Maintenance Expenses	%	-57.94%	-73.67%	-83.02%	-74.09%	-54.64%	-69.97%
Unit Transportation Expenses	%	NA	NA	NA	NA	NA	NA
Other Unit Costs	%	-79.11%	-65.86%	-70.44%	-79.92%	-79.93%	-77.02%
Unit Business Taxes	%	NA	NA	NA	NA	NA	NA
Unit Other Profit	%	-98.70%	-97.90%	-99.40%	-92.03%	-99.47%	-96.29%
Unit Administrative Expenses	%	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%	-95.64%
Unit Financial Expenses	%	-97.34%	-97.86%	-99.67%	-95.63%	-81.80%	-92.88%
Unit Interest Paid	%	-97.88%	-98.26%	-99.87%	-91.55%	-85.75%	-92.05%
Unit Interest Received	%	-98.20%	-97.12%	-97.72%	15.07%	-94.00%	-43.01%
Unit Subsidies	%	NA	NA	NA	NA	NA	NA

Unit Non-operational Income	%	-94.13%	-85.44%	-19.34%	-99.66%	-99.62%	-75.04%
Unit Non-Operational Expenses	%	NA	NA	NA	NA	NA	NA
Electricity Price	%	-63.07%	-43.99%	-46.26%	-24.41%	-31.81%	-33.72%
Total Unit Cost	%	-69.84%	-47.65%	-54.13%	-41.09%	-49.52%	-48.13%
Unit Profit before Taxation	%	-159.28%	-95.94%	-158.12%	-261.28%	-283.30%	-238.44%
Dark Spread	%	-54%	-44%	-46%	-25%	-20%	-35%
Unit Institutional and Managerial Costs	%	-71.71%	-50.78%	-44.46%	-5.82%	-25.15%	-22.98%
Unit Income Taxation	%	-100.00%	-100.00%	-101.36%	-291.14%	-116.76%	-111.24%
Unit Minority Interests	%	NA	NA	NA	NA	NA	NA
Unit Gross Profit	%	-88.89%	-100.64%	-90.05%	-72.79%	-62.30%	-74.38%
Unit Operational Profit	%	-53.62%	-102.96%	-56.35%	23.11%	39.09%	5.13%
Unit Net Profit	%	-479.37%	-74.00%	-464.60%	-100.00%	-1182.62%	-300.20%
Interest Rate	pp	-42.78%	-74.00%	NA	-16.70%	-27.34%	-44.22%
Coal Equivalent Price	%	NA	NA	NA	NA	NA	NA
Coal Price	%	-81%	-68%	-63%	-38%	-54%	-52%

Source: 1) Annual reports 2004 and 2005 of Drax, and 2) Annual reports 2004 and 2005 of CPID.

Appendix 3.4 Unit Cost of the Power Generation for the Year 2005

		Shanxi Shentou	Liaoning Qinghe	Pingdingshan Yaomeng	Jiangsu Changshu	Anhui Pingwei	CPID	Drax
	Unit	2005	2005	2005	2005	2005	2005	2005
Total Unit Cost	Yuan/MWh	140.84	261.74	209.40	248.49	217.88	215.45	376.78
Unit Cost of Sales	Yuan/MWh	139.44	256.90	208.87	246.21	209.08	208.90	454.92
Unit Variable Costs	Yuan/MWh	92.91	179.15	153.70	177.00	156.74	152.01	NA
Unit Fuel Costs	Yuan/MWh	92.04	173.41	148.72	177.00	156.52	150.46	295.41
Unit Water Costs	Yuan/MWh	0.87	5.74	4.98	0.00	0.22	1.55	NA
Unit Electricity Procurement Costs	Yuan/MWh	0.00	0.00	0.00	0.00	0.00	0.00	51.28
Unit Fixed Costs	Yuan/MWh	46.54	77.75	55.17	69.21	52.35	56.89	NA
Unit Material Costs	Yuan/MWh	4.21	5.97	3.46	2.97	2.75	3.22	NA
Unit Salary	Yuan/MWh	7.30	21.61	12.08	15.96	12.29	12.50	18.70
Unit Depreciation	Yuan/MWh	10.02	16.20	14.94	29.31	21.89	20.27	19.92
Unit Maintenance Expenses	Yuan/MWh	12.96	11.17	5.68	6.62	6.82	7.37	20.56
Unit Transportation Expenses	Yuan/MWh	0.00	0.00	0.00	0.00	0.00	0.00	NA
Other Unit Costs	Yuan/MWh	12.04	22.79	19.01	14.36	8.59	13.53	48.92
Unit Business Taxes	Yuan/MWh	0.74	0.00	0.00	0.25	0.00	0.18	NA
Unit Other Profit	Yuan/MWh	0.67	0.10	0.12	3.21	0.26	1.66	NA
Unit Administrative Expenses	Yuan/MWh	0.00	0.00	0.00	0.00	0.00	1.54	15.87
Unit Financial Expenses	Yuan/MWh	1.43	4.59	(0.03)	5.08	8.83	2.10	58.42
Unit Interest Paid	Yuan/MWh	1.50	3.07	0.05	4.88	9.01	4.32	73.52
Unit Interest Received	Yuan/MWh	0.07	0.08	0.08	0.30	0.18	2.32	15.10
Investment Income	Yuan/MWh	0.00	0.00	0.00	0.00	0.00	(4.11)	(75.19)

Unit Subsidies	Yuan/MWh	0.00	0.00	0.00	0.00	0.00	0.00	NA
Unit Non-operational Income	Yuan/MWh	0.16	0.20	0.42	0.98	0.00	0.41	NA
Unit Non-Operational Expenses	Yuan/MWh	0.00	0.00	0.00	0.00	0.00	0.00	169.20
Unit Other Costs and Expenses	Yuan/MWh	0.05	0.56	1.10	1.14	0.23	0.69	NA
Electricity Price	Yuan/MWh	162.93	253.01	227.70	290.49	267.16	247.34	546.17
Total Unit Cost	Yuan/MWh	140.84	261.74	209.40	248.49	217.88	215.45	376.78
Profit Before Taxation	Yuan/MWh	22.10	(8.73)	18.30	42.00	49.28	31.89	169.39
Unit Gross Profit	Yuan/MWh	22.75	(3.89)	18.83	44.03	58.08	38.26	250.04
Unit Operational Profit	Yuan/MWh	21.99	(8.37)	18.97	42.16	49.50	36.28	227.81
Unit Income Taxation	Yuan/MWh	0.00	0.00	3.15	3.90	1.74	2.46	(12.08)
Unit Minority Interests	Yuan/MWh	0.00	0.00	0.00	0.00	0.00	5.23	0.00
Unit Profit	Yuan/MWh	22.10	(8.73)	15.15	38.11	47.53	24.19	181.47
Dark Spread	Yuan/MWh	82.39	99.55	92.30	122.74	117.84	96.88	250.76
Unit Institutional and Managerial Costs	Yuan/MWh	10.77	16.20	14.94	29.56	21.89	21.99	35.79
Interest Rate	%	1.16%	3.47%	0.03%	5.09%	5.94%	2.40%	5.55%
Coal Equivalent Price	Yuan/Tonne	243.89	429.92	433.59	515.18	471.90	436.34	NA
Coal Price	Yuan/Tonne	145.40	244.44	271.14	384.87	330.90	293.21	510.61

Source: 1) Annual reports 2004 and 2005 of Drax, and 2) Annual reports 2004 and 2005 of CPID.

Appendix 3.5 Percentage of Unit Cost against Price for the Year 2005

	Unit	Shanxi Shentou	Liaoning Qinghe	Pingdingshan Yaomeng	Jiangsu Changshu	Anhui Pingwei	CPID	Drax
		2005	2005	2005	2005	2005	2005	2005
Total Unit Cost	%	86.44%	103.45%	91.96%	85.54%	81.56%	87.11%	68.99%
Unit Cost of Sales	%	85.58%	101.54%	91.73%	84.76%	78.26%	84.46%	83.29%
Unit Variable Costs	%	57.02%	70.81%	67.50%	60.93%	58.67%	61.46%	NA
Unit Fuel Costs	%	56.49%	68.54%	65.32%	60.93%	58.59%	60.83%	54.09%
Unit Water Costs	%	0.53%	2.27%	2.19%	0.00%	0.08%	0.63%	0.00%
Unit Electricity Procurement Costs	%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.39%
Unit Fixed Costs	%	28.56%	30.73%	24.23%	23.83%	19.59%	23.00%	NA
Unit Material Costs	%	2.58%	2.36%	1.52%	1.02%	1.03%	1.30%	0.00%
Unit Salary	%	4.48%	8.54%	5.31%	5.49%	4.60%	5.05%	3.42%
Unit Depreciation	%	6.15%	6.40%	6.56%	10.09%	8.19%	8.19%	3.65%
Unit Maintenance Expenses	%	7.96%	4.42%	2.49%	2.28%	2.55%	2.98%	3.77%
Unit Transportation Expenses	%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	NA
Other Unit Costs	%	7.39%	9.01%	8.35%	4.94%	3.21%	5.47%	8.96%
Unit Business Taxes	%	0.46%	0.00%	0.00%	0.09%	0.00%	0.07%	0.00%
Unit Other Profit	%	0.41%	0.04%	0.05%	1.11%	0.10%	0.67%	NA
Unit Administrative Expenses	%	0.00%	0.00%	0.00%	0.00%	0.00%	0.62%	2.91%
Unit Financial Expenses	%	0.88%	1.81%	-0.01%	1.75%	3.31%	0.85%	10.7%
Unit Interest Paid	%	0.92%	1.22%	0.02%	1.68%	3.37%	1.75%	13.46%
Unit Interest Received	%	0.05%	0.03%	0.03%	0.10%	0.07%	0.94%	2.76%
Investment Income	%	0.00%	0.00%	0.00%	0.00%	0.00%	-1.66%	-13.77%

Unit Subsidies	%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Unit Non-operational Income	%	0.10%	0.08%	0.19%	0.34%	0.00%	0.16%	0.00%
Unit Non-Operational Expenses	%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	30.98%
Unit Other Costs and Expenses	%	0.03%	0.22%	0.48%	0.39%	0.09%	0.28%	0.00%
Electricity Price	%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Total Unit Cost	%	86.44%	103.45%	91.96%	85.54%	81.56%	87.11%	68.99%
Profit Before Taxation	%	13.56%	-3.45%	8.04%	14.46%	18.44%	12.89%	31.01%
Unit Gross Profit	%	13.96%	-1.54%	8.27%	15.16%	21.74%	15.47%	45.78%
Unit Operational Profit	%	13.50%	-3.31%	8.33%	14.51%	18.53%	14.67%	41.71%
Unit Income Taxation	%	0.00%	0.00%	1.38%	1.34%	0.65%	1.00%	-2.21%
Unit Minority Interests	%	0.00%	0.00%	0.00%	0.00%	0.00%	2.12%	0.00%
Unit Net Profit	%	13.56%	-3.45%	6.65%	13.12%	17.79%	9.78%	33.23%
Dark Spread	%	50.57%	39.35%	40.53%	42.25%	44.11%	39.2%	45.8%
Unit Institutional and Managerial Costs	%	6.61%	6.40%	6.56%	10.17%	8.19%	8.89%	6.55%

Source: 1) Annual reports 2004 and 2005 of Drax, and 2) Annual reports 2004 and 2005 of CPID.

Appendix 3.6 Percentage Difference of Unit Costs compared to Drax for the Year 2005

		Shanxi Shentou	Liaoning Qinghe	Pingdingshan Yaomeng	Jiangsu Changshu	Anhui Pingwei	CPID
	Unit	2005	2005	2005	2005	2005	2005
Total Unit Cost	%	-62.62%	-30.53%	-44.42%	-34.05%	-42.17%	-42.82%
Unit Cost of Sales	%	-69.35%	-43.53%	-54.09%	-45.88%	-54.04%	-54.08%
Unit Variable Costs	%	NA	NA	NA	NA	NA	NA
Unit Fuel Costs	%	-68.84%	-41.30%	-49.66%	-40.08%	-47.02%	-49.07%
Unit Water Costs	%	NA	NA	NA	NA	NA	NA
Unit Electricity Procurement Costs	%	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%
Unit Fixed Costs	%	NA	NA	NA	NA	NA	NA
Unit Material Costs	%	NA	NA	NA	NA	NA	NA
Unit Salary	%	-60.96%	15.57%	-35.38%	-14.68%	-34.27%	-33.15%
Unit Depreciation	%	-49.69%	-18.66%	-25.03%	47.12%	9.89%	1.75%
Unit Maintenance Expenses	%	-36.96%	-45.67%	-72.39%	-67.79%	-66.82%	-64.18%
Unit Transportation Expenses	%	NA	NA	NA	NA	NA	NA
Other Unit Costs	%	-75.39%	-53.41%	-61.14%	-70.65%	-82.45%	-72.34%
Unit Business Taxes	%	NA	NA	NA	NA	NA	NA
Unit Other Profit	%	NA	NA	NA	NA	NA	NA
Unit Administrative Expenses	%	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%	-90.27%
Unit Financial Expenses	%	NA	NA	NA	NA	NA	NA
Unit Interest Paid	%	-97.96%	-95.82%	-99.93%	-93.36%	-87.74%	-94.13%
Unit Interest Received	%	-99.50%	-99.45%	-99.48%	-98.02%	-98.81%	-84.65%
Investment Income	%	-100.00%	-100.00%	-100.00%	-100.00%	-100.00%	-94.53%

Unit Subsidies	%	NA	NA	NA	NA	NA	NA
Unit Non-operational Income	%	NA	NA	NA	NA	NA	NA
Unit Non-Operational Expenses	%	NA	NA	NA	NA	NA	NA
Unit Other Costs and Expenses	%	-92%	-83%	-100%	-84%	-69%	-92%
Electricity Price	%	-70.17%	-53.68%	-58.31%	-46.81%	-51.08%	-54.71%
Total Unit Cost	%	-62.62%	-30.53%	-44.42%	-34.05%	-42.17%	-42.82%
Profit Before Taxation	%	-86.95%	-105.15%	-89.20%	-75.20%	-70.91%	-81.18%
Unit Gross Profit	%	-90.90%	-101.56%	-92.47%	-82.39%	-76.77%	-84.70%
Unit Operational Profit	%	-90.35%	-103.67%	-91.67%	-81.49%	-78.27%	-84.07%
Unit Income Taxation	%	-100.00%	-100.00%	-126.10%	-132.25%	-114.44%	-120.38%
Unit Minority Interests	%	NA	NA	NA	NA	NA	NA
Unit Profit	%	-87.82%	-104.81%	-91.65%	-79.00%	-73.81%	-86.67%
Dark Spread	%	-67%	-60%	-63%	-51%	-53%	-61%
Unit Institutional and Managerial Costs	%	-69.92%	-54.73%	-58.27%	-17.42%	-38.84%	-38.56%
Interest Rate	pp	-79.05%	-37.56%	-99.51%	-8.22%	7.11%	-56.79%
Coal Equivalent Price	%	NA	NA	NA	NA	NA	NA
Coal Price	%	-72%	-52%	-47%	-25%	-35%	-43%

Source: 1) Annual reports 2004 and 2005 of Drax, and 2) Annual reports 2004 and 2005 of CPID.

Appendix 5.1 The Power Intensity by Sector of China and OECD Countries

Unit: kWh/USD		1971	1980	1981	1990	1991	2000	2006
China	Overall	1.3055	1.5428	1.5048	1.3224	1.3158	1.0481	1.28
	Industry	2.1619	2.4045	2.4243	2.0529	1.992	1.3222	1.7051
	Agriculture	0.4595	0.6599	0.6213	0.3987	0.4537	0.4189	0.437
	Service	NA	NA	NA	0.1555	0.1517	0.1605	0.1694
France	Overall	0.1906	0.236	0.2431	0.2598	0.2759	0.271	0.2666
	Industry	0.2921	0.2973	0.2935	0.3452	0.3483	0.3885	0.4019
	Agriculture	0.0168	0.0331	0.0345	0.0449	0.0534	0.0634	0.0988
	Service	0.052	0.071	0.0716	0.0917	0.0976	0.0925	0.0979
Germany	Overall	0.2755	0.3078	0.3072	0.2806	0.267	0.2375	0.2427
	Industry	0.307	0.3568	0.3597	0.3382	0.3251	0.3313	0.3495
	Agriculture	0.1477	0.2172	0.2205	0.2828	0.3745	0.2823	0.437
	Service	0.0758	0.0756	0.0776	0.0769	0.0842	0.0816	0.0836
Italy	Overall	0.1755	0.1831	0.1807	0.193	0.1944	0.2105	0.227
	Industry	0.2793	0.2764	0.2714	0.3049	0.3098	0.376	0.3926
	Agriculture	0.0222	0.0483	0.0551	0.1069	0.1027	0.1321	0.1864
	Service	0.0373	0.0411	0.0423	0.0548	0.0566	0.062	0.0785
Japan	Overall	0.2493	0.2537	0.2476	0.2514	0.2508	0.2798	0.2662
	Industry	0.385	0.387	0.3683	0.2818	0.2786	0.3266	0.285
	Agriculture	0.011	0.0154	0.0172	0.0211	0.0196	0.0265	0.0157
	Service	0.0327	0.0471	0.049	0.1203	0.121	0.135	0.1413
UK	Overall	0.3377	0.3171	0.3156	0.2856	0.2961	0.2687	0.2389
	Industry	0.2986	0.2693	0.2658	0.2894	0.3081	0.3213	0.3294
	Agriculture	0.1956	0.2369	0.2359	0.2042	0.224	0.3309	0.3086
	Service	0.112	0.1265	0.1288	0.1126	0.1156	0.1007	0.0882
US	Overall	0.4736	0.5018	0.5005	0.4712	0.4967	0.4505	0.4152
	Industry	0.528	0.5321	0.5155	0.5404	0.626	0.5935	0.4452
	Agriculture	0.1451	NA	NA	NA	NA	NA	NA
	Service	0.1807	0.21	0.2213	0.2079	0.2084	0.1952	0.1848

Source: Electricity Information 2009 (IEA) and UN data.

Table 5.2 Mix of the Installed Capacity by Types of Generators

	China			France			Germany			Italy			Japan			UK			US		
Year	Thermal	Hydro	Nuclear & Other	Thermal	Hydro	Nuclear & Other	Thermal	Hydro	Nuclear & Other	Thermal	Hydro	Nuclear & Other	Thermal	Hydro	Nuclear & Other	Thermal	Hydro	Nuclear & Other	Thermal	Hydro	Nuclear & Other
1990	73.86%	26.14%	0.00%	21.93%	23.93%	54.14%	70.02%	7.01%	22.97%	65.92%	33.19%	0.89%	64.18%	19.43%	16.39%	79.15%	5.32%	15.52%	73.16%	12.59%	14.25%
1991	74.99%	25.01%	0.00%	21.64%	23.71%	54.65%	73.61%	7.23%	19.15%	66.04%	32.96%	1.00%	63.60%	19.56%	16.84%	77.85%	5.98%	16.17%	73.28%	12.63%	14.10%
1992	75.57%	24.43%	0.00%	21.36%	23.62%	55.03%	72.81%	7.46%	19.72%	67.82%	31.39%	0.79%	63.80%	19.23%	16.97%	76.87%	6.24%	16.89%	73.37%	12.78%	13.85%
1993	75.62%	24.38%	0.00%	21.79%	23.15%	55.05%	72.26%	7.68%	20.06%	68.24%	30.97%	0.79%	63.05%	18.73%	18.22%	76.31%	6.15%	17.55%	73.33%	12.97%	13.70%
1994	74.41%	24.54%	1.05%	21.90%	23.31%	54.80%	71.95%	7.70%	20.35%	68.44%	30.77%	0.79%	62.56%	18.94%	18.50%	76.22%	6.11%	17.67%	73.54%	12.93%	13.53%
1995	75.01%	24.02%	0.97%	22.18%	23.22%	54.60%	71.72%	7.64%	20.64%	69.13%	30.10%	0.77%	62.48%	19.10%	18.42%	75.50%	6.02%	18.48%	73.64%	12.89%	13.48%
1996	75.62%	23.50%	0.89%	22.25%	22.86%	54.89%	70.91%	7.78%	21.32%	70.11%	29.11%	0.78%	62.59%	18.94%	18.47%	76.32%	5.77%	17.90%	74.02%	12.47%	13.51%
1997	75.68%	23.49%	0.83%	22.72%	21.98%	55.30%	70.92%	7.75%	21.33%	70.73%	28.32%	0.94%	62.87%	18.27%	18.85%	75.95%	5.86%	18.19%	74.12%	12.58%	13.31%
1998	75.69%	23.47%	0.84%	22.70%	22.29%	55.01%	70.18%	7.79%	22.03%	71.34%	27.66%	1.01%	63.65%	18.07%	18.28%	76.08%	5.81%	18.11%	74.42%	12.56%	13.02%
1999	74.78%	24.42%	0.79%	22.83%	21.89%	55.29%	69.16%	7.71%	23.12%	71.19%	27.68%	1.13%	63.91%	18.01%	18.08%	76.70%	5.65%	17.65%	74.70%	12.38%	12.92%
2000	74.39%	24.85%	0.76%	22.73%	21.91%	55.36%	68.25%	7.59%	24.16%	71.77%	26.94%	1.29%	64.48%	17.78%	17.73%	78.09%	5.45%	16.46%	75.08%	12.17%	12.75%
2001	74.53%	24.45%	1.02%	23.51%	21.70%	54.80%	66.09%	7.82%	26.10%	71.49%	26.85%	1.65%	64.57%	17.58%	17.85%	78.28%	5.54%	16.19%	77.23%	10.48%	12.28%
2002	74.47%	24.14%	1.39%	23.88%	21.65%	54.47%	64.23%	7.52%	28.25%	71.27%	26.81%	1.92%	65.04%	17.31%	17.65%	77.67%	5.70%	16.63%	78.79%	9.64%	11.58%
2003	74.03%	24.25%	1.72%	23.74%	21.59%	54.67%	64.26%	6.60%	29.14%	71.57%	26.38%	2.05%	65.13%	17.26%	17.61%	78.46%	5.46%	16.08%	79.35%	9.60%	11.05%
2004	73.72%	24.57%	1.71%	23.85%	21.46%	54.69%	62.94%	6.64%	30.42%	72.28%	25.50%	2.21%	65.02%	16.98%	18.00%	78.71%	5.34%	15.95%	79.70%	9.37%	10.94%
2005	75.56%	22.92%	1.53%	23.12%	21.60%	55.27%	61.08%	6.67%	32.24%	72.71%	24.55%	2.74%	63.92%	17.05%	19.03%	78.26%	5.26%	16.48%	79.75%	9.25%	10.99%
2006	77.82%	20.67%	1.51%	22.52%	21.61%	55.87%	59.98%	6.84%	33.18%	73.53%	23.55%	2.93%	63.79%	16.99%	19.22%	79.33%	5.11%	15.56%	79.63%	9.21%	11.16%
2007	77.73%	20.36%	1.91%	22.03%	21.56%	56.41%	58.63%	6.48%	34.89%	73.74%	22.56%	3.70%	63.91%	16.95%	19.15%	79.00%	5.05%	15.95%	79.27%	9.16%	11.56%

Source: National Bureau of Statistics of China and Electricity Information 2009 (IEA)

Table 5.3 Mix of the Power Production by Type of Generators

	China			France			Germany			Italy			Japan			UK			US		
	Thermal	Hydro	Nuclear & others	Thermal	Hydro	Nuclear & others	Thermal	Hydro	Nuclear & others	Thermal	Hydro	Nuclear & others	Thermal	Hydro	Nuclear & others	Thermal	Hydro	Nuclear & others	Thermal	Hydro	Nuclear & others
1990	79.67%	20.33%	0.00%	11.20%	13.63%	75.17%	67.73%	3.60%	28.68%	82.27%	16.20%	1.54%	63.14%	11.38%	25.48%	76.97%	2.25%	20.78%	68.72%	8.98%	22.30%
1991	81.58%	18.42%	0.00%	13.25%	13.49%	73.26%	68.15%	3.47%	28.38%	77.90%	20.56%	1.54%	61.95%	12.11%	25.94%	76.00%	1.90%	22.09%	68.42%	9.44%	22.14%
1992	82.56%	17.44%	0.00%	10.84%	15.64%	73.53%	65.30%	3.94%	30.76%	78.01%	20.24%	1.75%	62.87%	10.22%	26.92%	73.52%	2.22%	24.26%	69.12%	8.35%	22.53%
1993	81.67%	18.02%	0.31%	7.26%	14.36%	78.38%	65.45%	4.12%	30.43%	78.13%	19.96%	1.90%	58.63%	11.88%	29.50%	70.08%	1.78%	28.14%	69.74%	8.88%	21.38%
1994	80.50%	17.98%	1.52%	7.00%	16.99%	76.01%	65.37%	4.51%	30.12%	77.67%	20.59%	1.74%	62.05%	8.01%	29.94%	70.27%	2.01%	27.72%	69.83%	8.19%	21.99%
1995	80.18%	18.55%	1.27%	7.72%	15.37%	76.91%	64.87%	4.89%	30.25%	80.90%	17.35%	1.75%	58.92%	9.41%	31.67%	70.72%	1.91%	27.36%	68.36%	9.43%	22.21%
1996	81.36%	17.32%	1.32%	8.35%	13.68%	77.97%	64.58%	4.80%	30.63%	78.80%	19.26%	1.95%	58.73%	9.03%	32.23%	70.84%	1.41%	27.75%	68.00%	10.24%	21.75%
1997	81.57%	17.16%	1.27%	7.63%	13.37%	79.00%	63.28%	3.79%	32.93%	79.28%	18.51%	2.21%	56.84%	9.89%	33.26%	69.47%	1.61%	28.92%	70.04%	9.70%	20.26%
1998	81.09%	17.65%	1.26%	10.55%	12.92%	76.53%	64.55%	3.82%	31.63%	79.30%	18.23%	2.47%	55.55%	10.06%	34.39%	69.58%	1.86%	28.56%	70.80%	8.41%	20.80%
1999	81.48%	17.27%	1.26%	9.65%	14.65%	75.70%	62.75%	4.21%	33.04%	77.76%	19.49%	2.75%	58.43%	9.22%	32.36%	70.61%	2.24%	27.15%	70.21%	7.74%	22.04%
2000	80.96%	17.76%	1.28%	9.14%	13.28%	77.58%	62.69%	4.50%	32.81%	78.72%	18.40%	2.88%	58.65%	9.15%	32.20%	73.94%	2.06%	23.99%	71.12%	6.91%	21.97%
2001	81.17%	17.60%	1.23%	8.24%	14.32%	77.44%	62.22%	4.65%	33.14%	77.41%	19.33%	3.27%	58.37%	9.03%	32.60%	72.82%	1.68%	25.50%	71.71%	5.56%	22.74%
2002	81.74%	16.60%	1.66%	9.14%	11.79%	79.07%	62.29%	4.75%	32.97%	79.80%	16.57%	3.63%	61.50%	8.68%	29.82%	73.02%	1.92%	25.06%	70.56%	7.20%	22.24%
2003	82.88%	14.76%	2.36%	9.83%	11.35%	78.82%	63.18%	4.03%	32.79%	80.78%	15.07%	4.15%	65.01%	9.95%	25.04%	73.66%	1.50%	24.84%	70.82%	7.49%	21.69%
2004	82.64%	15.00%	2.36%	9.55%	11.33%	79.12%	61.48%	4.53%	33.99%	78.97%	16.45%	4.58%	62.05%	9.58%	28.37%	74.89%	1.90%	23.21%	70.93%	7.14%	21.93%
2005	81.55%	15.97%	2.49%	10.67%	9.80%	79.53%	62.15%	4.31%	33.54%	80.94%	14.13%	4.93%	62.13%	7.86%	30.00%	73.88%	1.97%	24.15%	71.69%	6.94%	21.38%
2006	83.35%	14.73%	1.92%	9.66%	10.64%	79.70%	60.92%	4.29%	34.79%	80.99%	13.82%	5.19%	61.26%	8.69%	30.05%	74.88%	2.12%	22.99%	70.89%	7.39%	21.72%
2007	83.08%	14.99%	1.93%	9.92%	11.17%	78.91%	62.06%	4.33%	33.61%	81.83%	12.42%	5.75%	67.52%	7.41%	25.07%	77.37%	2.28%	20.34%	72.04%	6.07%	21.88%

Source: National Bureau of Statistics of China and Electricity Information 2009 (IEA)

Table 5.4 Load factor by types of generators

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
China																		
Thermal	55.49%	55.55%	56.48%	56.38%	57.33%	56.56%	56.04%	54.89%	51.06%	51.33%	53.24%	54.35%	58.13%	62.20%	63.50%	59.97%	55.59%	55.55%
Hydro	39.99%	37.61%	36.90%	38.58%	38.81%	40.87%	38.39%	37.19%	35.84%	33.31%	34.97%	35.91%	36.42%	33.84%	34.59%	38.72%	37.00%	38.25%
Nuclear	0.00%	0.00%	0.00%	0.00%	76.65%	69.58%	77.73%	78.28%	71.23%	74.66%	82.21%	60.20%	63.19%	76.16%	78.27%	90.47%	66.08%	52.51%
Total	51.44%	51.06%	51.70%	52.20%	52.99%	52.92%	52.09%	50.93%	47.66%	47.11%	48.92%	49.90%	52.96%	55.57%	56.65%	55.57%	51.91%	51.97%
France																		
Thermal	23.72%	30.50%	25.51%	16.71%	16.23%	18.24%	20.06%	16.94%	24.09%	22.12%	21.64%	18.98%	20.91%	22.95%	22.43%	26.12%	24.21%	25.14%
Hydro	26.45%	28.35%	33.30%	31.09%	37.01%	34.69%	31.97%	30.71%	30.04%	35.01%	32.63%	35.75%	29.74%	29.13%	29.59%	25.67%	27.78%	28.92%
Nuclear	64.31%	66.62%	66.99%	71.21%	70.23%	73.59%	75.64%	71.80%	71.81%	71.23%	75.01%	76.08%	78.80%	79.46%	80.76%	81.48%	81.24%	79.35%
Total	46.45%	49.83%	50.28%	50.13%	50.77%	52.41%	53.43%	50.48%	51.84%	52.31%	53.83%	54.15%	54.62%	55.43%	56.04%	56.59%	56.45%	55.81%
Germany																		
Thermal	62.13%	48.25%	47.61%	47.47%	47.80%	47.73%	50.23%	49.27%	51.39%	50.21%	51.07%	52.47%	51.44%	54.45%	55.07%	57.65%	56.11%	58.01%
Hydro	32.98%	24.97%	28.05%	28.10%	30.85%	33.76%	34.01%	26.99%	27.38%	30.18%	33.00%	33.12%	33.49%	33.79%	38.47%	36.56%	34.65%	36.60%
Nuclear	77.68%	74.61%	80.20%	77.23%	75.74%	76.54%	79.73%	87.14%	82.69%	86.91%	86.45%	87.32%	80.41%	87.89%	92.80%	91.34%	94.49%	79.39%
Total	64.23%	52.12%	53.09%	52.41%	52.61%	52.77%	55.16%	55.22%	55.87%	55.34%	55.60%	55.73%	53.05%	55.38%	56.38%	56.66%	55.24%	54.80%
Italy																		
Thermal	54.56%	51.60%	48.20%	45.84%	46.80%	48.94%	45.92%	45.69%	45.45%	44.85%	45.87%	45.32%	47.66%	48.35%	46.51%	45.14%	44.14%	42.55%
Hydro	21.33%	27.29%	27.01%	25.82%	27.60%	24.11%	27.04%	26.64%	26.96%	28.91%	28.56%	30.13%	26.30%	24.46%	27.46%	23.34%	23.53%	21.11%
Nuclear	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Total	43.72%	43.75%	41.90%	40.04%	41.24%	41.82%	40.86%	40.76%	40.89%	41.06%	41.82%	41.86%	42.57%	42.84%	42.57%	40.55%	40.07%	38.34%
Japan																		
Thermal	48.56%	48.47%	48.02%	44.20%	48.31%	45.86%	45.24%	43.05%	40.46%	42.51%	42.18%	40.69%	42.59%	44.09%	42.59%	43.95%	43.27%	49.88%
Hydro	28.92%	30.82%	25.88%	30.13%	20.60%	23.96%	22.99%	25.78%	25.81%	23.79%	23.86%	23.12%	22.58%	25.45%	25.19%	20.84%	23.04%	20.65%
Nuclear	72.97%	72.95%	73.69%	73.83%	75.80%	80.40%	80.77%	80.52%	83.85%	79.88%	81.25%	79.54%	73.38%	59.90%	68.42%	70.17%	70.02%	60.88%

Total	49.36%	49.76%	48.73%	47.53%	48.71%	48.64%	48.21%	47.62%	46.36%	46.50%	46.37%	45.01%	45.04%	44.17%	44.63%	45.21%	45.06%	47.21%
UK																		
Thermal	48.48%	51.18%	51.93%	49.43%	49.82%	50.94%	50.59%	50.20%	51.60%	51.28%	51.99%	51.21%	54.09%	54.47%	53.34%	52.69%	51.62%	52.60%
Hydro	21.06%	16.70%	19.33%	15.55%	17.77%	17.29%	13.31%	15.10%	18.05%	22.05%	20.78%	16.74%	19.40%	15.92%	19.95%	20.90%	22.73%	24.28%
Nuclear	66.11%	70.93%	77.23%	85.76%	83.72%	79.58%	83.67%	86.54%	87.66%	83.82%	77.77%	82.37%	81.93%	85.42%	77.05%	78.61%	78.52%	64.86%
Total	49.86%	52.43%	54.30%	53.82%	54.03%	54.38%	54.51%	54.88%	56.42%	55.70%	54.91%	55.05%	57.54%	58.02%	56.05%	55.81%	54.69%	53.71%
US																		
Thermal	47.05%	47.09%	47.07%	48.69%	48.83%	48.90%	49.24%	50.76%	53.02%	52.27%	53.93%	44.81%	42.47%	40.22%	40.37%	41.23%	40.55%	41.79%
Hydro	35.71%	37.70%	32.67%	35.07%	32.55%	38.54%	44.03%	41.43%	37.30%	34.78%	32.32%	25.58%	35.43%	35.18%	34.56%	34.39%	36.53%	30.50%
Nuclear	75.59%	79.19%	77.95%	74.87%	77.71%	81.44%	83.60%	76.97%	82.71%	88.94%	92.09%	94.40%	97.71%	90.65%	94.35%	93.59%	93.85%	95.73%
Total	50.09%	50.43%	49.97%	51.19%	51.42%	52.67%	53.60%	53.71%	55.73%	55.61%	56.93%	48.27%	47.42%	45.07%	45.36%	45.87%	45.55%	45.98%

Source: National Bureau of Statistics of China and Electricity Information 2009 (IEA)

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