China's electric power industry reform: An empirical investigation

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Abstract.

Electric power has become the most widely used secondary energy. As a result, the electricity industry's development will, in turn, directly influence other industries, people's daily lives, and the whole economy. China is one of the most rapidly developing economies, making it one of the biggest consumer of electricity in the world. Thus, the development of electric industry in China is not only important for the development of China itself, but also the energy pattern all over the world.

In this study, we focus on analysing the market-oriented reform in China's electricity industry after the adoption of reforming and opening policies in 1978. By following the time path, the detailed content of the reform, as it was applied and modified over time, is first introduced. Then, an empirical investigation is conducted on the major policies in the process of China's electric power industry reform. Through quantitative measurement, the contribution of each major policy is clearly defined, so that conclusions concerning the reform in the past and suggestions for its future direction can be reached and made.

It is found that both successes and deficiencies occurred in the reform process, and that China's electric industry has made significant efforts to overcome obstacles as they have been identified. However, even though great progress has been made in China's electric power industry from 1978 to 2009, more efforts are still required to finally achieve market operation in the industry. It is expected that this study can positively contribute to the development of China's electric power industry, as well as to electric power industries in other countries.

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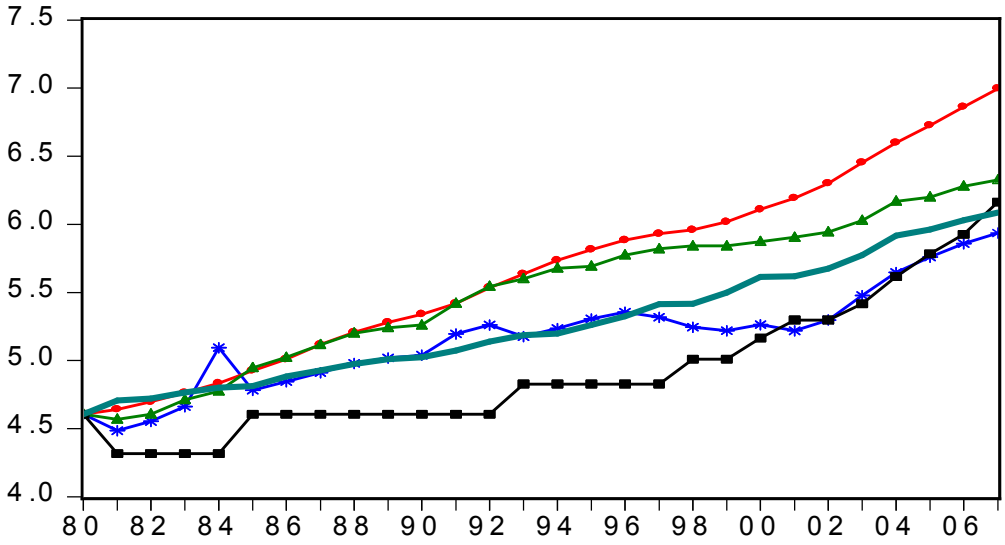
1. Introduction.

Electricity, as the most widely used secondary energy[1], is essential in both the economy and modern life in general(Xu, 2004). Electricity belongs to a relatively high level of the energy pyramid. It is cleaner and contains much more power (high density) than primary energy (Huber and Mills, 2005). In China, the electric power industry was historically designated as a driving force of economic growth (Huang, 1993; Shiu and Lam, 2004; Yuan et. al. 2007). Furthermore, in line with the rapid expansion of the Chinese economy after the late 1970s, there has been an increasing demand for electricity (Shiu and Lam, 2002). According to Steenhof and Fulton (2007a), China's GDP grew from $892 billion (US dollars) in 1980 to $1205 billion (US dollars) in 2002 - an average annual increase of 9.4% - and, as China has grown, the demand for electricity has risen on average nearly 8% per annum, which is higher than the increases in the demand for any other source of energy[2]. In 1980, nearly 90% of total energy needs were met by coal, but by 2002 this figure had fallen to 31%, while electricity as a fuel source had increased from 5% to 46%. Furthermore, Figure 3 shows that while energy intensity[3] has dropped dramatically, by more than half from 1979 to 2008, electricity intensity[4] has dropped by a mere 15%[5]. This suggests that, with an enhancement of energy efficiency, electricity has played an even more important role in the energy mix (Yuan et. al. 2007). If, as Steenhof and Fulton (2007b) predict, China has the world's largest economy by 2020, electricity demand will be 5-fold higher than current levels by then, fueled by the development of the country's industrial base and the growing affluence of its 1.6 billion citizens. The future pace of power demand growth in China will, therefore, depend on how the economic growth versus efficiency issue plays out. Thus, the performance of the electricity industry is crucial to accelerate the development of China. The electricity industry has become one of the most important industries.

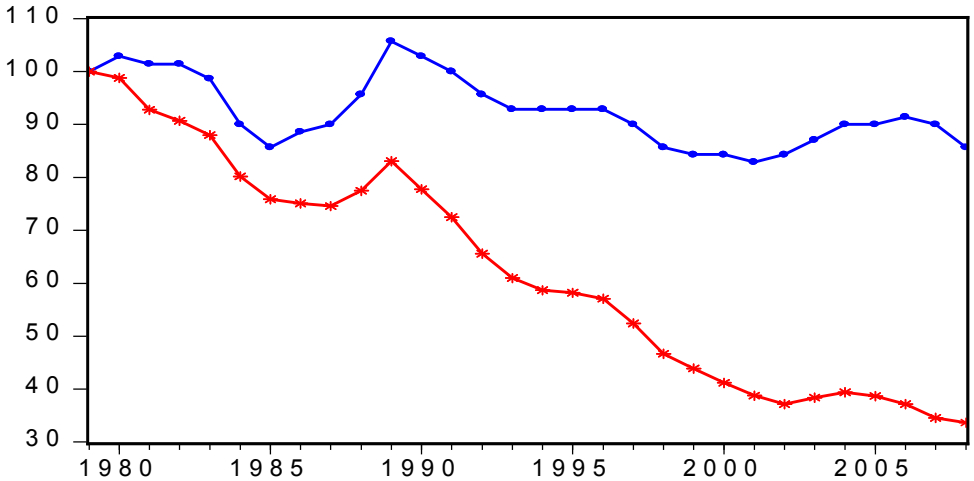
[1] Figure 1 in Appendices shows the fuel shares of total final consumption.
[2] See Figure 2.
[3] Energy intensity is total energy consumption divided by real GDP.
[4] Electricity intensity is total electricity consumption divided by real GDP.
[5] See Figure 3.

Figure 2. *Consumption of different energy sources in China (1980-2007).*



Source: *China Energy Statistical Yearbook* (1989-2008); *China Statistical Yearbook* (1982-2009).
Note: In order to compare the speed of increment in the demand of different energy sources, we set the values of five different energy consumption all equal to 100 in 1980.

Figure 3. *Energy intensity vs. Electricity intensity (1979-2008).*



Source: *China Statistical Yearbook* (1982-2009).
Note: In order to compare the decreasing speed of energy intensity and electricity intensity, we normalise the time series so that 1979=100.

The production of electricity can be divided into: generation, transmission, and distribution[6]. Because the electricity industry is characterized by huge capital investment and significant economies of scale and economies of scope, in most countries the electric power industry has been characterized by the conditions of a natural monopoly and, thus, was often, hither to, operated as a vertically integrated and state-owed monopoly. This mode helped maintain a high level of reliability of electricity supply in the early period, but it also had many drawbacks. These included a lack of investment, low efficiency of the industry, insufficient motivation to innovate new technology, poor service, cross subsidization, and heavy government subsidies. However, as electric power was more widely applied during the second industrial revolution, the shortcomings of the traditional monopolization of the electric power industry became clearer to firms and governments. In addition, with economic growth and R&D, the characteristics of natural monopoly in some segments of the electricity industry (especially generation) was weakened. In other words, the theoretical basis for the monopoly in the generation segment did not exist any more. As a result, the worldwide reforms in the electricity industry started.

The world electricity reform process began in the 1980s, with the front runners being Chile, the United States, and the United Kingdom. Subsequently, especially after the 1990s, market-oriented reforms in the electric power industry have been implemented in many countries to try to allocate resources more efficiently through market mechanisms. China followed this world trend and launched its reform of the electricity industry in 1985, with the primary objective being to get rid of its long-term electricity shortages (Xu and Chen, 2006). China's electricity industry reform has since this time, gone through several phases and made significant improvements. In 2009, the installed capacity and electricity generated

[6] The generation of electricity involves the creation of electric energy using falling water, internal combustion engines, steam turbines powered with steam produced with fossil fuels, nuclear fuel and various renewable fuels, wind driven turbines and photovoltaic technologies. The transmission of electricity involves the use of wires, transformers and substation facilities to effect the high voltage "transportation" of electricity between generating sites and distribution centers. The distribution of electricity to residences and businesses at relatively low voltages relies on wires and transformers along and under streets and other rights of way. The distribution function typically involves both the provision of the services of the distribution "wires" to consumers as well as a set of retailing functions, including making arrangements for supplies of power from generators, metering, billing and various demand management services (Joskow, 1997).

in China ranked the second in the world.

Market-oriented reform in the electricity industry is often described as a process of restructuring and deregulation. Even though this is the general direction and major content, electricity reforms in different countries are, however, usually associated with different targets. Countries also adopt different modes and steps to achieve their targets in accordance with their own circumstances.

Thus, the first question we are going to address in this study is how the electricity industry reforms were carried out in China. To answer this question, systematic analysis of the development of China's power industry will be done, including a discussion of motivation, targets, key policies, improvements, and deficiencies in each phase of reforms in the electricity industry. There has been some work already here. Andrews-Speed and Dow (2000) have analysed the objectives of, and key factors in, China's electric power industry reform. However, there was no clear explanation of the steps taken to implement the reform in their work, nor was there an appropriation that a different order of key steps was likely to lead to different effects. Xu and Chen (2006) briefly discussed the three phases of China's electric power industry reform, but little attempt was made to explain the key policies in each phase. Thus, it is not clear how the targets of reforms were achieved. The aim of this first question is to obtain the logic and connection between the different phases of the reform, so that we can have a integrated view of China's electric power industry reform. More importantly, by defining the specific targets and analysing the key policies of reform in each period, we can identify the key variables that should be considered when we assess the effects of electric power industry reform on the performance of the electricity industry.

Following the first question, the second question is how much improvement in the performance of electricity industry has resulted form the reform. This section examines empirically the effects of China's electricity industry reform on the performance of the electricity generation segment by using time series data up to 2009. There are three reasons why we use the performance of the generation segment, rather than the overall electricity

industry, as an indicator. First, costs of power generation are the largest component of end-use costs of electricity, which indicates the importance of the electricity generation segment. Second, Joskow (1998) stated that the changes in the structure of the electric power sectors are designed to foster competition in the generating segment. Therefore, power plants tend to be the first, and the most directly, affected by reforms. Thus, restructuring has a larger impact on generation than on other segments of the electricity industry, such as transmission and distribution, which are likely to remain more heavily regulated (Wolfram, 2005). Third, China's electric power industry reform has mainly focused on the generation segment at this stage. To this end, through quantitative measurements, the specific results of reforms will be identified, so that both a summary of past reforms and suggestions for future reforms can be given.

The thesis is organized as follows. Section 2 outlines the previous literature related to the world's and China's electricity industry. Section 3 discusses the theoretical basis of the different operating modes of electric power industry. Section 4 discusses the process of China's electricity industry reforms. Section 5 is an empirical investigation of the effects of major policies implemented during the process of China's electricity power industry reform. Section 6 analyses the main findings of this empirical investigation. Section 7 provides policy implications. Section 8 concludes.

2. Literature review.

Many researchers have focused on electric power industry reform. Most of them have confirmed the significant effects of reform on the development of the electric industry. The problems in the electric power industry were first recognized in 1970s. As stated by Czamanski (1999), the energy crisis beginning soon after 1973, affected electricity consumption and electricity consumption patterns. High electricity bills and financial difficulties in many utilities led to intense debate among utility economists, and soon reform in the electric power industry became a general trend all over the world. Consequently, there has also been much recent literature examining this. Gratwick and Eberhard (2008) discussed several front runners of electric power industry reform, including Chile, the United States, England and Wales, and Norway. Sioshansi and Pfaffenberger (2006) summarized electricity reforms in many different countries and regions, including, amongst others, Chile, Nordic Europe, Australia, New Zealand, Germany, Canada, and the United States. The most significant changes in the electric power industry started in the 1990s. According to Rothwell (2003), during the 1990s, a deep transformation in the electricity industry took place in many countries, as this sector moved, similarly to the transportation of telecommunication sectors, from a regulated monopoly to a more competitive industry. Many academic studies, which tend to either describe the process of electric power industry reform or examine its effects, have been published since the 1990s.

Joskow (1998) submitted that economical and reliable supplies of electricity make possible many of the goods and services that we associate with modern life, and have played an important role in economic development during the 20th century. Much of his work focuses on the reforms in U.S. electricity markets. In his 1988 paper, Joskow had already discussed the introduction of competition into the electric power industry in the United States, and stated that the electric power industry was likely to develop most quickly and efficiently if both new entrants and existing utilities with expertise in supplying electricity are encouraged to participate on an equal footing. He then explained the regulatory reform and

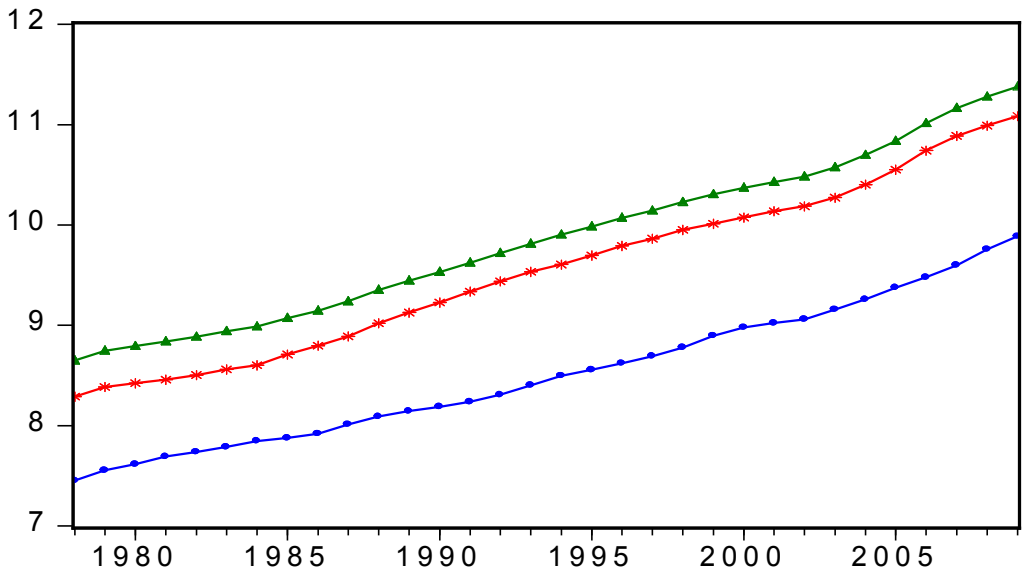
restructuring in the electric power industry in 1989 in “Regulatory Failure, Regulatory reform, and Structural Change in the Electrical Power Industry”. Subsequent systematic analysis of deregulation reforms in U.S. electricity market was performed by him (with White and Hausman) in 1996. According to this study, privatisation, dissolution of vertical integration, and introduction of competition have become the general modes of electric power industry reform. It has also been argued that restructuring of the electric power industry is always bundled with regulatory reforms, because markets cannot necessarily solve all the problems arising. For example, Yao (2001) declared that electric power industry reform cannot rely solely on the market. The case of California electricity crisis (2000-2001) shows that markets can fail, and, hence, government regulation and supervision are essential for market-oriented reform in the electric power industry.

Market-oriented reform in the electric power industry of other countries has also been widely analysed. Restructuring of Russia's electricity sector was discussed by Tompson (2004), Hammons (2006), Engerer (2009), and others. On the basis of these studies, the general effect of Russia's market-oriented reform of electric power industry is positive. Rudnick (1998) analysed the creation of competitive markets in electricity supply in South American countries, which further confirmed the generally positive effects of market-oriented reform. The problems associated with the reforms have also been identified, as a guide to the future direction of electric power industry reform. Lee and Ahn (2004) introduced the specific restructuring direction in the South Korean electric power industry and claimed that countries should search for a path appropriate to their circumstances in undergoing reform in electricity markets. Nevertheless, market-oriented reforms have been the general strategy pursued all over the world.

China's electricity industry is one of the largest systems in the world (Du, Mao and Shi, 2009), and its development has significant impacts on global energy and environmental issues. It is, thus, especially worthwhile to investigate the market-oriented reform of China's electricity industry. Electricity shortage was a serious problem in China for a long period before 1997 - the year when electricity supply first first caught up with electricity demand

(Yan, He and Guo, 2006; Lin, 2004; Zhang, 2008; Xu and Chen, 2005). Wang, Li and Sun (2001) claimed that the primary target of China's electricity industry in this phase was to attract investment from various sources, in order to accelerate the development of generation capacity, and to supply electric power of higher reliability and quality. Improvement of efficiency, which is the major goal of power industry reform in most OECD countries, was, however, the secondary target at the beginning of China's electricity industry reform, because the primary target was to develop the installed capacity (Wang et al. 2001, Feng, 2007). Nonetheless, China's electricity industry has rapidly developed as the process of market-oriented reform has continued. Figure 4 makes this evident by showing that the total installed capacity of power plants in China has increased dramatically from1978 to 2009. In addition, the growth rate of total installed capacity, installed capacity of thermal power plants and hydroelectricity have all being increasing, as the slope of all three curves becoming steeper shows.

Figure 4. *Installed capacity in China from 1978 to 2009.*



Source: *China Statistical Yearbook* (1982-2009); *China Electricity Statistical Yearbook* (1993-2005).

China's electric power industry reform started from 1985, and it is still in the process. Xu and Chen (2006) systematically analysed the development of China's electricity industry before 2002 and pointed out that phase one of the reform was from 1985 to 1997. The second round of power industry reform was from 1998 to 2002. The division of different phases of electric power industry reform is quite similar across different studies. However, little work has been done to analyse the reform of China's electricity industry in the most recent period (2002 to the present). Moreover, Ma and Oxley (2009) pointed out that previous studies related to China's electricity industry reform were often applied in an ad hoc, partial, and non integrated way. In the current study, we will fill this gap by discussing the historical development of China's electricity industry across the whole period, from 1978 to the present, which will also help answer the first question we posed above.

There are a few empirical studies, which aim to address the effects of electricity industry reform. Zhang and Parker (2007) examined electricity sector reform in developing countries by using panel data for 36 developing countries. They found that competition in electricity generation is more important than privatization or the establishment of independent regulation in bringing about performance improvements. Nagayama (2009) tested the effects of electric power sector reform on electricity price in developing countries by using data from 78 countries in four regions, and claimed that electricity industry reform does not necessarily reduce electricity prices. Du, Mao and Shi (2009) aimed to assess the impact of regulatory reforms on China's electricity generation industry by applying the method of differences-in-differences and using plant-level data for fossil-fired generation plants. It was found that regulatory reform led to efficiency improvement in labour input and nonfuel materials, but no evidence indicated that the reform could help to improve efficiency of fuel input. Yu, Yang and Yu (2006) studied the relationship between the "separation of generation and transmission" and the performance of power enterprises, and then declared that "separation of generation and transmission" led to the reduction of profitability and increase of debt of electricity enterprises.

Xiao and Sun (2006) examined the effects of regulatory reform in China's electricity

industry by using data from 1978 to 2005. They pointed out that the reform led to a significant increase in installed capacity and efficiency, while electricity price and monopoly profits decreased. Thus, the results of China's power industry reform are mixed in accordance with the previous empirical studies. The reason might be that electricity restructuring and regulatory reform is likely to involve both costs and benefits (Joskow, 1997), so that studies focussing on different aspects or periods tend to observe different results. Furthermore, due to the data constraints, there have not been many empirical studies of China's electric power industry reform. In fact, Ma and Oxley (2009) claimed that many previous studies simply introduce and describe the institutional reform programme of China's energy industry. In particular, these studies do not econometrically or analytically assess any potential effects of those reform programmes on the development of China's energy economy or the economic growth implications. It is even harder to find empirical evidence on the whole process of market-oriented reform in the electricity industry over the last three decades. In this study, we will fill this gap by answering the second question posited above.

The results of previous reform in the electric power industry show that electricity industry reform is still a work in progress throughout the world and faces many obstacles. Xu (2004) systematically described the reform of ownership, structure, and the regulatory sector in the power industry of China, India, and Russia, and brought forward several challenges against the basic rationale of the model of electric power industry reform. It was declared that the fundamental assumption of the reform process, that the electricity industry was no different from other industries, was wrong, because electricity is not the same as other commodities (for example, simultaneity of all the three segments during its production process, and simultaneity of production and consumption). Moreover, it was argued that the unbundling of vertical integration is problematic, due to the seriously undermining coordination present in this process, and that the one generic restructuring model cannot work everywhere, because each country has its own circumstances.

For example, France and Japan have had different reform models from the generic approach

to restructuring adopted in most countries. Thus, there is no agreement over the direction of market-oriented reform in the electricity industry around the world. These challenges, however, still send the message that electric power industry reform is still in process all over the world, and that countries (including China) are still researching and trying to find their own path to promote the development of their power industries. Therefore, and in this context, it is important to examine China's previous electricity reforms, in order to inform the direction of future reform. Another motivation of this study is that even though China's electric power industry has made impressive improvements, the situation of electric power supply in China is still strained. Sustained economic growth of an emerging economy requires an expanding and effective electrical power sector in order to support both the growth of industrial and commercial activity and a rising living standard (Andrews-Speed and Dow, 2000).

3. Natural monopoly and its relationship with electric power industry.

3.1. Definition of natural monopoly.

The market-oriented reform of the power industry is actually rooted in the concept of natural monopoly. The so-called natural monopoly industries are those ones where operations are concentrated in one or a few companies due to reasons such as economies of scale[7] in production and distribution, economies of scope[8], large sunk costs, or resource scarcity. DiLorenzo (1996) declared that a natural monopoly is said to occur when production technology, such as relatively high fixed costs, causes long-run average total costs to continuously decline as output expands. In such an industry, a single producer will eventually be able to produce at a lower cost than any two other producers, thereby creating a "natural" monopoly. On the other hand, if there is more than one producer in an industry characterized by natural monopoly, the production costs of firms will be higher, and in turn, ultimately harm the interests of consumers. The most favorable state is, therefore, to have a monopoly company to provide all products and services. These industries, thus, have an inherent tendency to develop towards economy of scale and economy of scope. A monopoly, which arises due to natural features and inherent characteristics of the industry, rather than legal or policy reasons, is therefore called a natural monopoly.

Originally, economies of scale were the primary indicator of natural monopoly. However, there was a significant change in the understanding of natural monopoly in the 1980s. Baumol first defined natural monopoly by subadditivity through the study of a multiproduct industry. Baumol, Panzer and Wiling (1982) created a new definition of natural monopoly by pointing out that the most significant feature of natural monopoly is subadditivity.

[7] Scale economies exist if average costs falls as output expands. As long as marginal cost is below average cost, economies of scale exist. (Carlton and Perloff, 1994).

[8] When it is cheaper to produce two products together (joint production) rather than separately, there is an economy of scope (Carlton and Perloff, 1994).

Subadditivity is realized if no combination of multiple firms can collectively produce industry output at lower cost than a monopolist (Gordon, Gunsch and Pawluk, 2003). This is different from economies of scale. Economies of scale focuses on the lowest point on the average cost (AV) curve. On the other hand, subadditivity could be expressed as:

$$c^*(Q_1 + Q_2) < c^* Q_1 + c^* Q_2 .$$

Hence, subadditivity exists if one manufacturer can provide all the products with lower costs. Its focal point is the total costs of production. Even if the average cost increases at some given amount of production, the industry could still possibly be a natural monopoly industry, as long as the total production costs are lower when produced by a single firm. This was later confirmed by Carlton and Perloff (1994), who stated a natural monopoly could occur even if average cost was not declining everywhere with output. For example, if a U-shaped average cost curve reached a minimum at an output of 100, it may be most efficient for only one firm to produce an output of 101 even though average cost is rising at that output. Thus, if there is the emergence of subadditivity for any given amount of production in the industry, then the industry is characterized by natural monopoly. Economies of scale are therefore now a sufficient, but not a necessary, condition for natural monopoly.

3.2. Natural monopoly industries and monopolization.

Creation of monopoly is required for the development of industries that are characterized by natural monopoly. First, the production of natural monopoly industries usually requires large amounts of fixed capital. Monopolization could bring forward large production scale, more consumers and lower per unit costs, and, in turn, take the advantage of economies of scale and help to repay the fixed capital. Second, for natural monopoly industries, producing multiple products within one firm could help the industry to benefit from economies of scope, so that the overall costs will be lower, and higher efficiency can be gained. Third, the production of natural monopoly industries needs large amount of

investment in equipment. The equipment is usually highly specific and thus unlikely to be used in other industries. Therefore, fixed costs involve a considerably high proportion of sunk cost. According to the three technical and economic features mentioned above, it is expected that the development of natural monopoly industries will therefore call for the construction of monopolization operation, to allow for monopoly positions and monopolistic interests to be maintained in natural monopoly industries.

Monopolization occurring in natural monopoly industries has a positive aspect for the community: there is a possibility to promote production efficiency and stimulate innovation. It also, however, has a negative effect involving waste of resources and social welfare losses (Yang, 2002). Moreover, natural monopoly enterprises are different from competing firms that attempt to reduce costs. Their operations are subject to less competition, which, in turn, leads to a loss of efficiency. Consumers may be forced to accept high prices, which results in a loss of consumer surplus and deadweight losses (Schumpeter, 1942). Technical and economic improvement may also stagnate.

3.3. Decline of natural monopoly in the electric power industry.

For nearly a century, the concept of a natural monopoly was almost a co-joined twin of the electric power industry (Cole, 2003). Carlton and Perloff (1994) declared that it was often argued that electrical, gas, telephone, and other utilities are natural monopolies. There is a nontrivial fixed cost of running an electric power line or a phone line to a home or firm, but constant or falling marginal costs of supplying the service. As a result, marginal cost falls as output increases. Cibinskiene A (2009) further pointed out that most of the natural monopolies were public utilities or, in other words, reticulated services. Those industries have a responsibility to provide goods and services, and meet the demand of the community. Public good is, therefore, a major concern, meaning such industries could not be operated in accordance with market mechanisms and rules. Government intervention was commonly

applied, and, as a result, regulated monopoly and government ownership emerged in those industries.

The characteristics of natural monopoly in the electric industry were mainly based on economies of scale in each segment of the electricity industry, as well as the continuity of the electric power industry and the resulting economies of scope. First, the electric power industry, like the water supply system, is characterized by subadditivity. It is a network economy, which requires production in a large scale. As stated by Kim and Horn (1999), network industries were often organized as vertically integrated public monopolies. In this paradigm, only if the scale of power enterprises was big enough, could the goal of lower production costs and higher profitability be achieved. Furthermore, a higher quality and more reliable electric supply could be achieved by having a grid with more capacity. Therefore, the electric power industry had long been characterized by natural monopoly. Consequently, monopolized operations were used to optimize electric power production systems, and achieve lower costs and improve efficiency. Second, electricity flows from power plants to end users. Throughout the process, there are several segments. Generally, electric power production can be divided into three parts: generation, transmission, and distribution. These three parts, while theoretically consecutive processes, are in practice virtually concurrent, due to the speed at which electricity travels. The next segment is the target market of the last segment. Upper and lower segments are closely related and form a continuous market. According to this specific feature of the electric power industry, vertical integration of different segments of power production was regarded as necessary, in order to maintain the safety and reliability of electricity supply. Moreover, large amount of electric power cannot be stored, which also creates demand for vertical integration to balance supply and demand, and avoid waste (Michaels, 2004).

However, monopolies in utility industries were usually created and operated by government before the 1980s, especially in developing countries (such as China). For a long period, the government was policy maker, supervisor and the only operator in monopoly industries. As a result, they were not monopolies created by the market based on the characteristics of

"natural monopoly", but government administered monopolies. Such a management system of utilities led to many defects, including a lack of enterprise autonomy and enthusiasm, low production efficiency, poor quality, lack of capital investment, and lagged development. Thus, development of utilities could not keep pace with the development of the economy. It was hard for utilities to provide goods and services timely with appropriate quality. Government failure, as was argued by Weisbrod (1988), became a serious problem in state-owned monopolies (including the electric power industry). Following from this, Vickers (1995) claimed that three advantages of competition could help to solve the problem of inefficiency. One is that competitive pressure makes organizations internally more efficient by sharpening incentives to avoid sloth and slack. The second is that competition causes efficient organizations to prosper at the expense of inefficient ones, and that this selection process is good for aggregate efficiency. A third is that competition to innovate is the major source of gains in productive efficiency over time. Accordingly, breaking up state-owned monopolies, and introducing competition in the electric power industry became a general trend. Deregulation and restructuring were therefore required.

In addition, technological developments have been the driver behind the transformation of certain natural monopoly markets to more competitive outcomes (Depoorter, 1999). White, Joskow and Hausman (1996) declared that technological changes reduced the economies of scale in power generation to a fraction of what they were in preceding decades, and that the technological impediments to decentralized production across a common delivery network are surmountable. Along with the development of electric power generation technology, energy technology, and the rise of electronic technology, natural monopoly in the electric power has been weakened. However, in the electric power industry, the evolution of economies of scale is different in different segments of the industry. In the transmission and distribution sectors, there are still significant economies of scale, even though economies of scale in the generation sector are weak. As a result, various sectors of the power industry should be operated in different forms. In the segments of transmission and distribution, monopolization may be adopted, in order to take advantage of economies of scale. In the power generation sector, it might be more appropriate to introduce the market mechanism.

To sum up, the natural monopoly in one segment (power generation) of the electric power industry has been weakened. As a consequence, there is no longer sufficient theoretical basis for a monopolized power industry, and this has made possible the restructuring of the electricity industry. As power generation is the primary sector of the power industry, and is not characterized by strong economies of scale, electric power industry reforms have usually started in the power generation segment.

4. Market-oriented reform in the electricity industry.

4.1. Worldwide electricity industry reform.

The world underwent great changes in the 1980s. Oil crises had led to increases in world oil prices and thus expanded state deficits. Under such circumstances, governments reduced subsidies to monopoly industries (including the power industry). Seeking new management mechanisms and improving industrial efficiency became a common concern of governments of developed countries. The reform of other monopoly industries also had a significant impact on the power industry. For a long time, economies of scale had required network industries to operate as monopolies. However, as a result of the deregulation and introduction of competition in telecommunications, shipping, railways and gas supply industries in many countries, consumers were allowed to have more choices and accessed lower prices and better service, which created demand for the power industry to introduce competition and improve efficiency as well. In addition, globalization led to more competitive industries, which motivated consumers to try to lower cost and to enhance efficiency. Thus, other industries became more sensitive to electricity price, and higher efficiency and better service from power industries was required. All of these factors contributed to the reforms that occurred in the electric power industry.

From 1980s to 1990s, a number of countries, such as Chile, the United Kingdom, the United States, and Australia, started their market reforms of power industry, and these were followed by other developed and developing countries. Although different countries have had their own specific targets, paths, and effects of their reforms, the universal purpose of market-oriented reform in the power industry has been to separate generation, transmission and distribution, conditional on the safety and stability of electricity production and supply. Competition has then been introduced into the power generation and retailing segments.

Firstly, an important part of the electricity industry reform concerns the ownership of power

industry property. As the generation of electricity is no longer conceptualized in terms of natural monopoly, power industry reforms in many countries began with the emergence of independent power producers (IPP). However, the former vertically integrated power companies could take advantages of their monopolistic position in transmission and distribution, and thus benefit their own generation sectors. Unfair competition was the inevitable result, and it was difficult for market competition to play its role in the power generation market due to the market power of dominant vertically integrated firms. As a result, vertical integration needs to be broken, as the transmission sector cannot, in these circumstances, own power plants. Independent property rights are, therefore, required in all aspects of the power industry, and generation, transmission, and distribution should be separate businesses, to introduce fair competition into the power generation sector. In this context, Joskow (1988) brought forward that competitive entry into the supply of generating service for resale could have important efficiency-enhancing effects on the provision of electricity supplies in the long run. Wolfram (2003) also stated that firms facing more competition might move closer to the technological frontier by figuring out how to generate the same amount of electricity with fewer inputs. However, for the sectors of transmission and distribution, where natural monopoly characteristics are more entrenched, governments have retained the monopoly structure and have tried to improve supervision and control.

The second important part of power industry reform is tariff reform. The reform of price, as the connection between the supply side and demand side in the market, and the key factor influencing consumption, is a central part of the overall power industry reforms. Prices of electricity should be determined by the market, or the relationship between supply and demand, rather than be set by governments. An effective market price mechanism in the power generation market is essential for the creation of a competitive power generation market. Thirdly, independent regulatory agencies are usually established, in order to help to guide reform in the electricity industry, and to accelerate the development of the power industry.

In fact, there have been a few exceptions that did not follow this model of market-oriented

reform, such as those of France and Japan. So far they still use vertical integration and monopolistic enterprises in the power industry. Nevertheless, most countries are carrying out the market-oriented reforms outlined above in their power industries, with the exception of a few African countries.

Although power industry reform has experienced both successes and failures, the market-oriented reform, as a whole, has been beneficial for the development of the power industry (Pfaffenberger 2006, Rudnick 1998, Woo et al., 2003). In late 1980s, the United States and Britain took the lead in power industry reform and succeeded in turning a vertically integrated structure into a market mechanism. As a result, both countries gained great economic and social benefits. For example, DiLorenzo (1996) stated that the potential benefits to the U.S. economy from demonopolization of the electric utility industry were enormous, and competition has initially saved consumers at least $40 billion per year, according to utility economist Robert Michaels. It has also spawned the development of new technologies that will be economical to develop because of lower energy costs. Zhang (2006) quoted the International Energy Agency (IEA) as believing that[9] market-oriented reform in the power industry should be able to improve economic efficiency and reduce electricity costs and selling prices, thereby improving competitiveness and promoting economic growth. Overall, reforms have brought forward higher efficiency and have resulted in a 60% increment in labour productivity, with a 40% reduction in generation costs. The efficiency of the transmission and distribution sectors has also been enhanced, and line loss rates have decreased. Furthermore, wholesale electricity prices have fallen by nearly 20%, and retail prices by 13%~19%.

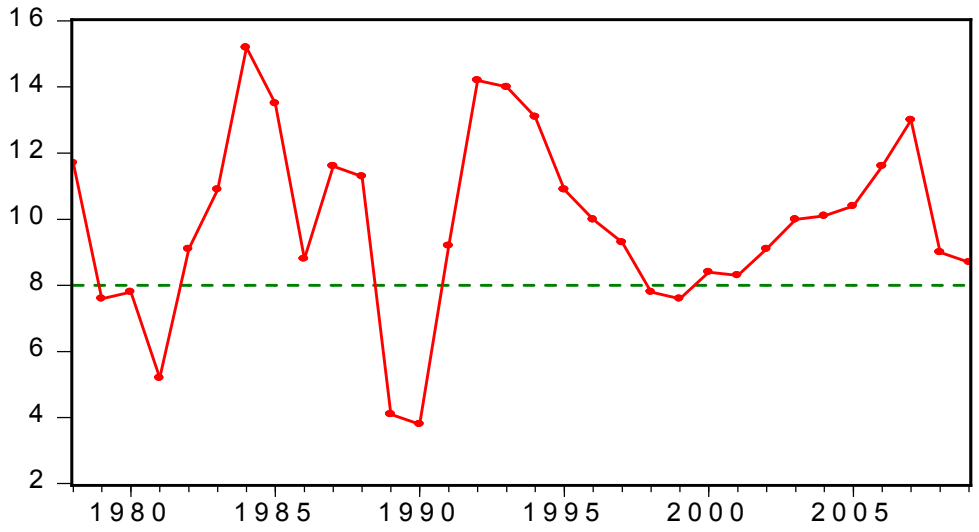
4.2. Electricity industry reform in China.

For China, as a country with rapid economic growth[10], supporting the electric power

[9] Statistics displayed below in this paragraph are all published by International Energy Agency (IEA).
[10] See Figure 5.

industry is essential. From 1882, when Shanghai lit the first light lamp in China, China's power industry has experienced rapid development. After the foundation of People's Republic of China, according to *China Statistical Yearbook*, total installed capacity increased from 1.85 million kilowatts in 1949 to 874.07 million kilowatts at the end of 2009. This means that China's installed capacity has been the world's second largest for more than a decade[11]. The installed capacity of hydropower is 196.79 million kilowatts, accounting for 22.5% of the overall capacity, while the installed capacity of thermal power is 652.05 million kilowatts, accounting for 74.6% of overall capacity. Installed capacity of wind power is 16.13 million kilowatts. In the first half of 2007, power outages caused by power shortages were only 6 minutes on average in all cities. Therefore, electricity demand is generally met by electricity supply. Undeniably, therefore, China's power industry has experienced rapid development in the past few decades. This is closely related to the market-oriented reforms in China's power industry. Steenhof and Fulton (2007a) argued, however, that analysis of China's electricity supply sector must account for government intervention, as state policies and plans will continue to play an important role in both influencing decision-making and contributing directly to how the sector evolves.

Figure 5. *Increase in real GDP in China from 1978 to 2009.*



Source: *China Statistical Yearbook* (1982-2009).

[11] Table 1 in Appendices shows the world's top 10 countries in terms of installed capacity in 2007.

In the rest of this section, motivations, key policies, tariff reform (in the power generation market) and outcomes of China's electric power industry reform will be our focal points. The development of China's electricity industry will be divided into three phases. The reform started from Phase Two. The separation of different phases is in accordance with the key missions and policies of those reforms. Nonetheless, we should also note that China's electric power industry reform is ongoing. More specifically, China's power reforms are still in the early stages compared to many developed countries, such as the United States. It is also important to note that China's electric power industry reform has mainly focused on the introduction of competition into the power generation market.

4.2.1. 1949--1984. Vertically integrated monopoly owned by state.

4.2.1.1. Former tightly controlled system in the electricity industry.

The main characteristics of this stage were the unification of several different functions under the direction of the government, including policy development, industry regulation, production and management of enterprises. Before 1978, the Chinese government practised a planned economy. All enterprises were tightly controlled by the central government, and the power industry was no exception. The central government's power ministry, as an administrative body of the State Council, was the policy maker, programme planner and administrator of the power industry. It was also the only operator in the power industry, and, consequently, had the responsibility for investment and construction of power projects, and setting the price of electricity and obtaining profits. From 1949 to 1978, China's power industry experienced three transitions of political control from the Ministry of Fuel, to the Ministry of Electric Power, to the Ministry of Water Resources within the context of a long-term planned economy. The Ministry of Electric Power was, however, the department which carried out direct supervision of the power industry for most of this period. It was responsible for organization of power production, power transportation, rationing, electricity sale, technology research & development, and power plant site selection, design and construction. Eventually a system of dominant central management, coupled with

regional electricity management emerged. However, the institutional framework with unified governmental and business functions and a state-owned monopoly, did not change.

This system, within a planned economy was determined by the specific political and economic circumstances during that period, and, as a result, it did have some advantages. For example, it helped the government gather resources and built a number of key projects. In addition, Williamson (1985) argued that an important purpose of vertical integration is to economize transaction costs, as an internal organization has access to distinctive governance instruments. On the other hand, there were also many disadvantages associated with this former power industry system, including unification of government and business functions, strict market access, and a state-owned monopoly. The most significant drawback, which resulted from these disadvantages, was, however, the limitation on investment from other potential investors. As a result, the development of both the installed capacity and the efficiency of the power industry became blocked, and the advantages of economies of scale could not be utilized. Reliability of power supply was also low, which resulted in a poor quality of service.

4.2.1.2. Outcomes of the highly centralized system.

China experienced electricity shortages for more than two decades after 1970, as electricity production under the old system could not keep pace with economic growth. Because of the tight control over investment, financing, and access to the power industry, the state-owned monopoly was, inevitably, the only operator, and the Ministry of Electric Power and the Ministry of Water Resources were the only investors in the power industry. To aid development, a certain percentage of fiscal revenue was distributed to investment in the power industry. However, taxes from the electricity industry were, in fact, the major source of fiscal revenue for the state as a whole. Taxes paid by power companies were, therefore, more than the part of the fiscal revenue distributed to them, and this, in turn, resulted in a serious shortage of electricity investment. Since the adoption of reforming and opening policies in 1978, China's economy began to take off. It was hard to meet the growing demand for power by relying on a single source of investment, namely the central

government. Zhao et. al. (2009) stated that the shortage of capital caused the Chinese government to recognize the importance of investment from the private sector, and particularly foreign participation in electric power development.

From the regulatory perspective, the overemphasis on the characteristics of utility led to excessive government intervention. Furthermore, the unification of government and business functions could not produce effective government regulation (Zhu, 1998). The price of electricity was tightly controlled by the government as a tool to maintain social stability, rather than as a signal of the relation between electricity supply and demand. By the early 1980s, electricity tariffs in China were far below the costs of generation and transmission. Low electricity prices forced power companies into deficit, and they had to be financed by extensive borrowing, drawing on capital funds available from the government and state banks at low costs, and by government subsidies (Lam, 2004). Therefore, the price system made electric power companies unable to accumulate capital to invest independently.

The inevitable resulting electricity shortages were consistent with the standpoint of Joskow (1998), who stated that countries are very likely to have electricity supply shortages and low levels of equipment performance where political pressures make it difficult to approve price increases that match increases in the costs of operating and expanding electricity supplies. As a result, electricity shortages became the main bottleneck constraining China's economic growth, and the primary motivation for market-oriented reform in China's electricity industry. Electric power industry reforms therefore began in China. Williams and Kahrl (2008) summarized the general direction of China's power industry reforms recently. They stated that, beginning in the mid-1980s, the Chinese central government initiated a series of policies that have transformed the former vertically-integrated, centrally-planned, state-owned electricity industry into one that is substantially more diverse and market based.

4.2.2. 1985---1996. Breaking of the highly centralized system and increased openness in the power industry.

4.2.2.1. Key policies in the electricity industry.

After initiating reforming and opening policies (1978), China's economy began to transfer from a planned economy to a market economy. Due to economic development and the advancement of the market mechanisms in the economy, larger amounts and a higher reliability of electricity supply became desirable. However, under the model of a vertically integrated power industry, with unification of generation and business functions, the installed capacity and electricity production of the early 1970s could no longer meet the needs of either production or consumers' daily lives. In order to remedy this unsustainable system in the power industry, and to accelerate its development, China launched market-oriented reforms of that industry. To break the monopoly, the introduction of competition and changes in the regulatory system have become the inevitable trend.

Because of the shortage of funds, the government relaxed the strict supervision of market access, in order to encourage local government, private sector and foreign investment, as well as investment from other economic entities. In 1985 the State Council decreed "the provisional regulations on promoting fund-raising for investment in the power sector and implementing different power prices," which signaled the beginning of the first round of China's electric power industry reform (Xu and Chen, 2006). The government kept the principles of "national power grid, divested ownership of power plants" and "investors and users of electricity being the ones who benefit". It was specifically set out that power plants could be operated independently. The prices of electricity were also diversified and allowed to fluctuate. As a result, a situation of rapid growth and a diversification of investors emerged. In October 1986, "interim provisions to develop small thermal power plants[12]" were jointly drawn up by the National Planning Commission and Ministry of Water Resources. After approval by the State Council, the government began to guide and support the development of small thermal power plants. Under the guidance of this policy, a number

[12] Small power plants indicate power plants with capacity lower than 5×10^4 kw.

of these plants were built in many different provinces and cities, which helped to ease power shortages and improve the local economy. In 1987, the State Council introduced guidelines for "separation of government and business functions, provinces as entities, creation of power pool, unified distribution, fund-raising" and principles of "act according to local circumstances", which gave a clear direction for China's electric power reform. Central government delegated administrative authority to provincial governments and made provinces independent entities, so as to promote the development of the local power industry. In 1992, the government further established the reform objectives of "corporate restructuring, commercial operations, law-based control". With this, the reforms of the investment and financing systems of the power industry entered a new era. Power enterprises proceeded to actively raise funds by listing as companies on the sharemarket.

4.2.2.2. Tariff reform.

Tariff reform is one of the key parts of electric power industry reform. It is usually used by the government as a tool to achieve the targets set for reform of the industry as a whole. In China, in order to attract investment, the central government not only relaxed access to the generation market, but also changed the pricing policy in this phase of market-oriented reforms (from 1985 to 1996). Prices of electricity generated by fund-raising enterprises could be set according to the policy of "repay capital and interest". For power plants built before 1985, and those built by the government between 1985 and 1992, selling prices were set in accordance with the cost of electricity generation, and the catalogue price[13] issued by the Ministry of Electric Power and the National Planning Commission each year. For power plants constructed by non-central government investment from 1986 to 1992, selling prices were set on the basis of "repay capital and interest" and "new power, new price" policies, which ensured the repayment of all the loans and interests within a relatively short period (usually 10 years) and a high level of return on investment. At the same time, the state also imposed a "markup for fuel and transportation" policy, which allowed electricity prices to be adjusted with changes in prices of fuel and transportation. This could be characterised as

[13] The central government sets different electricity prices for different kinds of industries. This is called catalogue price.

a cost plus policy.

Table 2. *Increase in total installed capacity from 1979 to 1996.*

Year	Increase in total installed capacity (%)
1979	10.3
1980	4.5
1981	4.9
1982	4.7
1983	5.6
1984	4.8
Average from 1979 to 1984	**5.8**
1985	8.6
1986	7.8
1987	9.7
1988	12.2
1989	9.6
1990	8.9
1991	9.8
1992	9.9
1993	9.8
1994	9.3
1995	8.7
1996	8.9
Average from 1985 to 1996	**9.43**

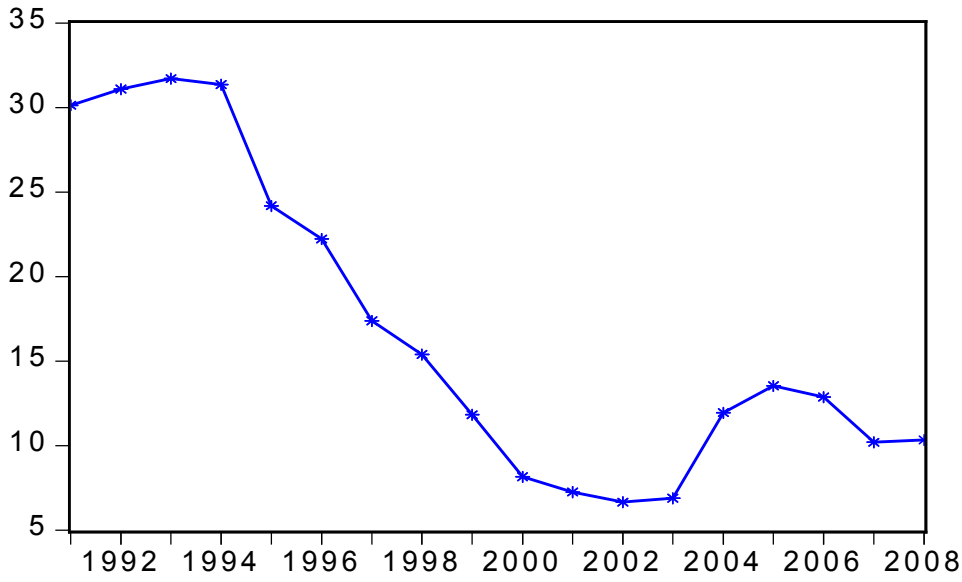
Source: *China Statistical Yearbook* (1982-1997).

All the pricing policies discussed above aimed to attract investment from various sources, in order to gradually remedy the problems of power shortages. Xu and Chen (2006) stated that the gradual opening of the power generation market, and the introduction of new investment and operational entities, relieved the power shortages that had been hindering the development of the Chinese economy. These changes led to a remarkably rapid development of China's power industry[14]. From 1985 to 1995, around 190-200 billion RMB was invested in China's power industry through local government funding and foreign

[14] Table 2 shows the comparison of growth rates in installed capacity between the period from 1979 to 1984 and the period from 1985 to 1996.

capital investment, accounting for half of the total investment in the power industry during that period, and installed capacity grew rapidly.

Figure 6. *Annual average hours of blackout in China.*



Source: *China Electricity Statistical Yearbook* (1993-2008).

4.2.2.3. Summary of outcomes of the reform.

Feng (2007) stated that China's power industry, as a developing industry, had as its main goals in the initial period of power industry reform, the building of sufficient installed capacity and the enhancement of the reliability of power supply. Improving generation efficiency was the secondary target. During this first round of China's electric power reforms, the highly centralized system began to be relaxed. Central government assigned more responsibility and authority to provincial governments, in order to encourage them to develop the electric power industry. The electricity market was also opened up, and new investors, both foreign and domestic, were allowed to enter the market for power generation. As a consequence, while total fixed investment in the electricity industry increased by only 37.43% from 1978 (3.505 billion) to 1984 (4.817 billion), it doubled within two years (1985 and 1986) immediately after the implementation of privatization. In this period, local

governments and foreign entities were encouraged to enter the electricity generation market, and investment diversification and multiple financing channels were formed. Andrews-Speed and Dow (2000) stated that, in 1980, the state directly provided some two-thirds of the investment in the power sector. However, by 1998 the principle contributors were state banks (50%), provincial and local government (20%), and foreign institutions and companies (17%). The State provided less than 5% via direct grants, and the provincial and local power companies about 10%. The resulting rapid increase of installed capacity and electricity production terminated the power shortage in China. Figure 6 shows that, as a result, the average time of blackouts in China decreased dramatically in this period. In addition, the existence of multiple investors in the power generation market was potentially helpful in breaking the monopoly position of state-owned power plants.

During the first round of China's power industry reform, however, the unification of government and business functions still existed, and the vertical integration of state-owned enterprises had not been altered. Therefore, the reform, at this stage, led to a coexistence of two types of participants in the power generation market. One was the origional vertically integrated enterprises operated by the Ministry of Electric Power. The other was the independent power plants, or, in other words, companies that were only engaged in the power generation market. The competition between the two kinds of operators was clearly unequal, which tended to cause conflict between the two parties.

4.2.3. 1997-current. Elimination of monopoly in the power generation market.

Electric power industry reform at this stage did not only focus on the development of installed capacity, but also on electricity generating efficiency, as the installed capacity could generally meet electricity demand by 1997. After the previous phase of electricity industry reform (1985-1996), many independent power producers had entered the power generation market. However, state-owned vertically integrated enterprises with monopoly characteristics still existed. In order to introduce fair competition, monopoly power had,

therefore, to be eliminated. This was achieved through adoption of two major policies of separating of government and business functions, and separating generation and transmission.

4.2.3.1. Separation of government and business functions (1997-2001).

Unification of government and business functions is usually associated with inefficient regulation and administration systems. In China, it significantly limited the autonomy and enthusiasm of enterprises. It was also one of the primary reasons for unfair competition in the electricity generation market, as the stated-owned monopoly was both the policy maker and programme planner in the electricity industry. Therefore, the status of state-owned and privately invested enterprises was not equal. To remedy this, and in order to allow for the commercial operation of state-owned enterprises and prepare for the introduction of competition into electricity generation market, the unification of government and business functions needed to be eliminated first. This followed the policy of "separation of government and business functions", which had been first outlined in 1987.

However, as long as the policy had not been applied to the state-owned enterprises, there was no major change to the unification of government and business functions, because of the dominant position of the state in electricity. As a result, the second round of power industry reform was launched in 1997. The most significant events at the beginning of this reform were the founding of the State Power Corporation and the withdrawal of the Ministry of Electric Power. The State Power Corporation took in charge of the state assets operated by the former Ministry of Electric Power and became an enterprise authorised by the State Council. In 1998, the former Ministry of Electric Power was disbanded, and its administrative functions were transferred to State Economic and Trade Commission and other departments. The separation of government and business functions was, therefore, first carried out at the level of the central government. From this time, China's power industry began to operate as a commercial system. In 2000, the State Council issued a "notice of questions related to electricity industry reform", which aimed to promote the separation of government and business functions at the provincial level. As a consequence,

at the end of 2000, two thirds of the provinces in China had achieved the separation of government and business functions, and the implementation of this policy was largely finished by 2001.

As the separation of government and business functions directly affected the administration system, the regulatory system of China's power industry was also altered. After the rescission of the former Ministry of Electric Power, the State Economic and Trade Commission mainly carried out the administrative functions, while the State Planning Commission took the responsibility of approving power projects, making pricing policies, and assessing electricity prices. The Ministry of Finance exercised the development and supervision of the system of financial affairs and accounting. The administrative functions of provincial power corporations were also removed, and the responsibilities of power control were gradually transferred from provincial governments to provincial Economic and Trade Commissions. The China Electricity Council and other associations were also founded and became the self-regulatory organazations within the power industry.

Through the implementation of the separation of government and business functions, the power of the former administrative monopoly was weakened, and market forces came to play a more important role in China's power industry. However, separation of government and business functions was not sufficient to eliminate the monopoly powers of the state within the industry. First, even though the separation of government and business functions had been achieved and State Power Corporation no longer had any administrative function, the vertically integrated state-owned corporation still existed. The only difference between the former monopoly and the new monopoly was that the old mainly resulted from its administrative function, while the new resulted from its market power. Second, as the vertical integration of the state-owned monopoly still existed, competition in the power generation market was unfair, because enterprises, which had both power plants and grid, had more market power. At the same time, there were no effective governmental institutions to regulate and supervise behaviours of participants in the power industry. Thus, as it could have been expected, private power plants found it hard to compete with state-owned power

plants. Third, provincial-level local protectionism was still a serious impediment to competition, which also led to big differences in electricity prices between different regions and cities. Optimization of electric resource allocation was, as a result, hard to achieve. Thus, separation of government and business functions was only the first step in the elimination of monopoly in the electricity market. In order to complete the task, other policies were, therefore, necessary.

4.2.3.2. Separation of generation and transmission (1999-2007).

At the same time as it separated the government and business functions, the government also implemented other policies, in order to further break the state-owned monopoly. In August 1998, State Power Corporation announced a strategy of "separation of government and business functions, provinces as entities, separation of generation and transmission, entering power grid through bidding", which divided China's short-term power industry reform into four steps.

Even though the Chinese government had tried to promote investment in the power industry from a variety of sources, and to separate the government and business functions, the State Power Corporation still owned 46% of total generation assets and 90% of total transmission assets, as of the end of the 20th century. The monopoly position of the state-owned monopoly had not yet been altered. After 2000, Ertan Hydropower Station[15] suffered huge losses right after its construction, which made the government realize the drawbacks of the lack of a market mechanism. Efficiency improvement, optimization of resource allocation and avoidance of blindness in construction of power plants could only be achieved by introducing competition and breaking monopolies. Market-oriented reform of power industry was consequently included on the agenda of the central government again. It was also issued in the "tenth five-year plan" (2001-2005), starting that the main mission of power industry reform were to implement separation of generation and transmission enterprises, form effective market mechanisms and regulatory systems, and introduce an

[15] Ertan power station is on the low reaches of Yalong River, in Sichuan Province, China. Its construction began in 1991, and it was completed in 2000. The maximum height of the dam is 240m. Total storage capacity is 5.8 billion m^3. Installed capacity is 3.3 million kw.

open and competitive power market.

In 1999, "Separation of generation and transmission, entering the power grid through bidding" was carried out, initially, in five provinces and one city - namely Zhejiang, Shandong, Jilin, Liaoning, Heilongjiang and Shanghai. The rules for the operation of these reforms were set by the State Economic and Trade Commission and the State Planning Commission. The aim of the programme was to explore how to break the vertically integrated monopoly in the power industry, and, in turn, find the means to achieve a competitive electricity market and to establish the rules of market competition. In 2002, the State Council issued its "Electricity Reform Programme" and decided to split the State Power Corporation. This was the most significant event in the process of "separation of generation and transmission".

On 29 December 2002, the former State Power Corporation was divided into several independent companies, comprising two power grid and five power generation corporations. The market share of each generation corporation could not exceed 20%, in order to prevent any generation corporation from enjoying excessive market power and generating monopoly profit. Separation of the generation and transmission sectors, therefore, started at the level of state-owned corporations, and the power generation market began to operate in accordance with the rules of the market mechanism. On 14 December 2007, as agreement on the "647 project[16]" was achieved, the generation assets of the National Grid were sold to seven different generation groups, which meant the separation of generation and transmission.

4.2.3.3. Tariff reform.

As mentioned above, tariff reform should usually be consistent with the targets of the overall industry reform. Thus, in China, pricing policies tended to be altered after the industry reform entered a new phase, because the major targets in each particular phase of

[16] In 2007, the State Electricity Regulatory Commission announced that 647×10^4kw generating assets belonging to the state power grid sector would be sold to seven power generating corporations. This project is called the "647 project".

the electric power industry reform were not the same as those in the previous phase. In the phase under discussion, the policy of "repay capital and interest" was replaced by "operation period price". "Operation period price" was the price set in accordance with the average costs of power plants and an appropriate return on investment over the period operated by the investors of power plants.

With the development of the power industry, the problem of power shortages was generally solved in the middle of the 1990s. While increasing installed capacity was still a major target due to the rapidly developing economy, production efficiency also became increasingly important. Thus, the drawbacks of the cost-plus pricing system attracted more attention from the government, as a guaranteed rate of return made it hard to optimize resource allocation.

The overall low efficiency of the power industry resulted from the lack of control over the costs of construction and the large amount of small thermal power plants. Andrews-Speed and Dow (2000) pointed out that the power generators as a whole were not receiving consistent incentives to reduce costs because no procedure for a merit order existed. Wolfram (2003) further stated that, under cost-plus regulation, allowed fuel costs were adjusted to reflect changes in fuel procurement costs, while rates were adjusted to reflect changes in operations and maintenance and capital costs. Given this, companies had little incentive to minimize costs. Moreover, the policy of "repay capital and interest", and the resulting low efficiency, had also led to high electricity prices. The average online electricity prices[17] of power plants built after middle of 1990s was about 0.4 RMB per kwh, while the retail price of electricity in United States was only about 0.57 RMB in 1996, which meant the retail price of the electricity generated by the newest power plants[18] in China was expected to be 25% higher than that in the United States. As China was still a developing economy, this was a significant gap. Therefore, in order to end this situation of

[17] Online electricity price is the price at which power plants directly sell their electricity to purchasers. Before 2009, the only direct purchaser of power plants' production was the power transmission segment. Generally, online electricity price accounts for about 50% of the retail price of electricity.

[18] Commonly, by holding all other factors constant, newer power plants are associated with higher efficiency.

producing power regardless of costs, the government launched the policy of "operation period price" in 1997. According to the new price policy, electricity prices were set on the basis of average costs for power producers. This changed the specific prices for each factory and each generator. Even though the price of electricity was still set by the government, this tended to promote competition between power plants, as electricity prices were set according to average costs.

In the most recent period, the price mechanism of the power industry was modified again. "Operation period price" was replaced by a "yardstick price", which set price based on the average costs of power plants in each region of China. "Yardstick price" is consistent with the policies of "provinces as entities" and "act according to circumstances", which have tended to result in regional electricity markets developing. "Yardstick price" is more reasonable, at least in the short term, compared with operation period price, because China is a country with many regions and provinces, each having its own circumstances.

Currently, bidding and yardstick prices coexist. However, in 1999, the policy of "entering the grid through bidding" was first carried out in the five pilot provinces and one pilot city. A limited proportion of the electricity produced (10%-15% of total electricity entering grid) is bid for on the market to set the prices, while the prices for the rest part is still set according to yardstick price. Because the development of the bidding system is still in progress, China has not yet formed a complete competitive price mechanism. Nevertheless, the tariff reform in the current period is undoubtedly an important part of market-oriented reform. In addition, in October 2009, the National Development and Reform Commission, the State Electricity Regulatory Commission, and the National Energy Board jointly approved a direct sale of electricity from Yimin power plant to Fushun aluminium, which was the beginning of a pilot programme of direct trades between big electricity users and producers. The aim of the direct trade system is to end the situation of there being only one buyer (the state power grid) of electricity and to introduce further competition into the power generation market.

4.2.3.4. Summary.

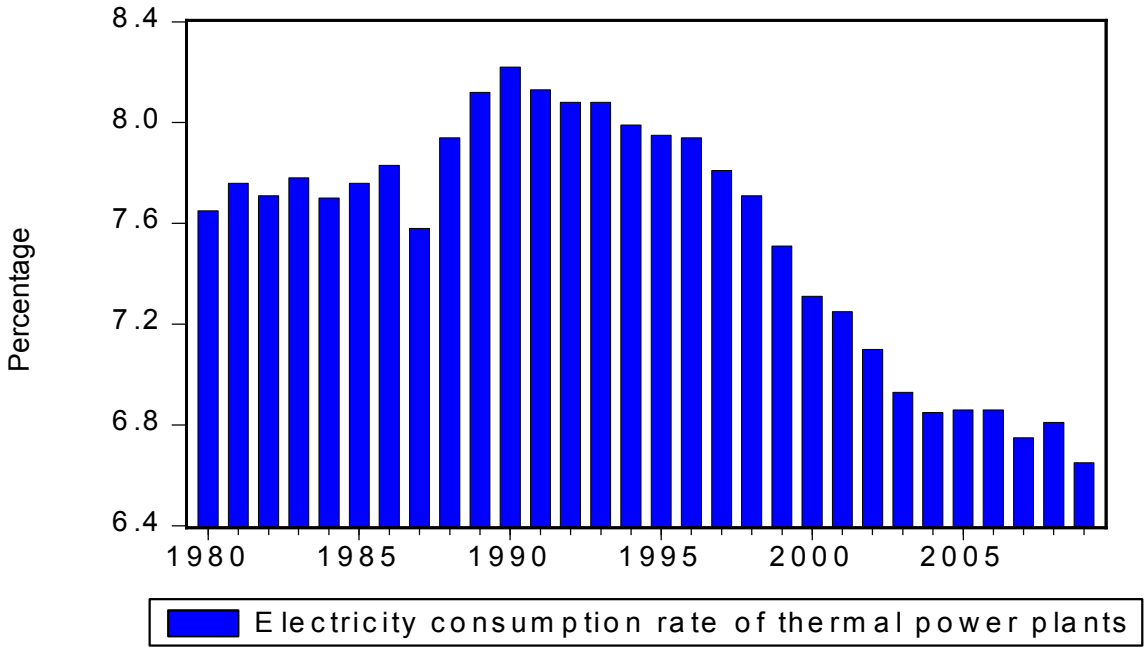
To sum up, the main targets of the reform are the breaking up of the state-owned monopoly, and the introduction of market price mechanisms and fair competition. Market mechanisms have been gradually constructed, which promote improvements in efficiency and the optimization of resource allocation in the power industry. At the same time, the central government began reforming the regulatory system. The State Electricity Regulatory Commission was founded in 2003 under direct supervision of the State Council. The State Electricity Regulatory Commission regulates the nation's power industry and exercises its administrative functions in accordance with the law and regulations. The establishment of this commission in 2003 marked the end of the period of government administration and the foundation of law-based control in China's power industry, and, as a result, regulatory chaos, which had been long-standing, was terminated.

Table 4. *Increase in total installed capacity from 1997 to 2009.*

Year	Increase in total installed capacity (%)
1997	7.5
1998	9.1
1999	7.7
2000	6.9
2001	6
2002	5.3
2003	9.8
2004	13
2005	15.2
2006	19.1
2007	16.4
2008	12.1
2009	10.4
Average from 1997 to 2009	**10.65**

Source: *China Statistical Yearbook* (1998-2009).

Figure 8. *Electricity consumption rate*[19] *of thermal power plants from 1980 to 2009.*



Source: *China Statistical Yearbook* (1982-2009).

Today, market-oriented reform in China's electricity industry has made great progress, as both installed capacity and electricity production in China rank second in the world[20]. The average increase in the total installed capacity from 1997 to 2009 was 10.65%[21], which was higher than that of the period from 1985 to 1996 (9.43%), even though installed capacity was the only major target of the power industry reform during this earlier period. Furthermore, the standard coal consumption rate of electricity generation[22] decreased from 375 g/kwh in 1997 to 317 g/kwh in 2009. As power generation efficiency had become the major target of the market-oriented reform from 1997, we should expect that the standard coal consumption rate would decrease faster after 1996 than during the period from 1985 to 1996, and the data is consistent with this expectation. The average decrease in the standard coal consumption rate of electricity generation was 0.45% from 1985 to 1996, while it was

[19] Electricity consumption rate of power plants is electricity consumed by power plants divided by the their own electricity production.
[20] See Table 1 & 3 in Appendices.
[21] See Table 4.
[22] Standard coal consumption rate is the total coal consumption of power generation segment divided by the total electricity generated. It is an indicator of efficiency of coal-fired power plants.

1.32% from 1997 to 2009[23]. Moreover, the electricity consumption rate of power plants decreased from 6.8% in 1997 to 5.85% in 2009[24]. In addition, performance of power generating equipment has been largely enhanced. The equivalent availability coefficient (EAC)[25] increased from 85.53% in 1998 to 92.93% in 2007, and due to significant improvement in both installed capacity and efficiency of electricity generation, the reliability of electricity supply improved a great deal. Average blackout hours were 17.39 hours in 1997, but only 10.347 hours in 2008.

4.2.4. Conclusion.

The whole process of market-oriented reform in China's electricity industry is segment by segment, from top to bottom. In December 24 1998, the State Council issued "the viewpoints of the State Economic and Trade Commission on deepening the reform of the electricity industry", which proposed finishing the "separation of generation and transmission, entering the power grid through bidding". Following this, separation between transmission and distribution will be carried out. Introduction of competition in the retailing sector is the last step.

Nonetheless, throughout the process of market-oriented reform of China's electricity industry from 1985 to the present day, which has been discussed above, the power generation segment has been the central focus of the market-oriented reforms. The path, taken by the Chinese government to introduce competition into the power generation market, is clear. First, independent entities were created, because competition could not be achieved without sufficient independent entities. Then, the former state-owned monopoly in generation market was split, so that no enterprise could dominate the power generation market. Thus, fair competition could be introduced. At the same time, tariff reform has also

[23] See Figure 7 in Appendices.
[24] See Figure 8.
[25] Equivalent availability coefficient is the number of hours when power plants are available to work divided by total hours.

always been a major tool in this process, which has helped the government to achieve its targets in each phase of the reforms. In addition, the general direction of the tariff reform has been to achieve a market price mechanism. However, the government is still trying to find an adequate way to achieve this goal through pilot projects. Finally, the foundation of independent regulatory department, the State Electricity Regulatory Commission, provides a better regulatory framework for the reform and development of the electric power industry. Law-based management has replaced the former administrative management.

5. Empirical investigation.

According to the figures and tables displayed above, there is no doubt that China's electric power industry has made great progress forwards electricity industry reform. However, it is still not conclusive that the rapid development of the power industry in China could be attributed to industry reform without empirical evidence. Therefore, the focus of this section is to examine the effects of China's electric power industry reform. More specifically, we are going to identify how much the electricity industry reform (from 1985 to the present day) has contributed to the development of China's electricity industry.

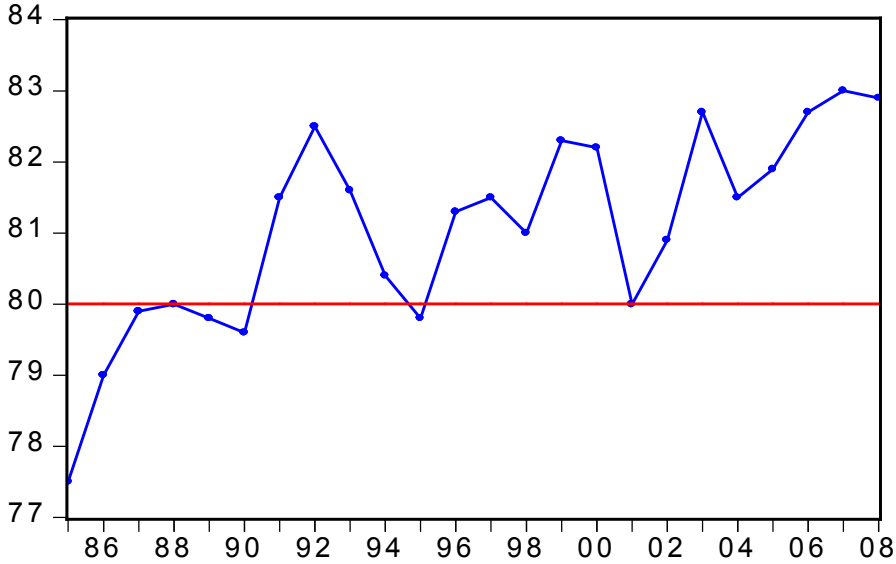
5.1. Method.

By reviewing previous empirical studies evaluating policy changes, difference-in-difference (DID) seems to be a popular method to quantify the effects of the policies adopted (Du et al., 2009). Wooldridge (2009) also introduced DID as a policy analysing method. However, in this study, we follow the common searching procedure and build Ordinary Least Square (OLS) regression models, which will be used to examine the effects of the key policies throughout the whole process of electric power industry reform simultaneously. The reason is that the DID method tends to be unreliable. Even though specification problems, such as omitted variables, could exist in all regression models, when either OLS or DID method is applied, there are probably more problems associated with the DID method. "Difference-in-difference" is used to examine the effects of a specific treatment, meaning both a control group and a treatment group are essential. The two groups are assumed to experience identical changes in all other aspects, except the treatment. However, such an assumption is not supportable when we consider the more than three decades of reform in China, because three decades is such a long time.

China's electricity industry, which is, undoubtedly, one of the largest and most complicated

electric industries in the world. It is also an industry closely related to politics and many other factors, as electricity industry is a utility industry. Thus, it is hard to determine an appropriate control group. In addition, our study will not apply the models used in any previous study, even though we do consider the important dependent and independent variables involved in those studies. This is because our study investigates the integrated process of the whole reform process in electricity industry, and it seems there is no similar previous study. Thus, it is unreasonable in this context to apply the same or similar models used in other researches.

Figure 9. *Electricity generated by thermal power plants as a percentage of total electricity generated in China from 1985 to 2008.*



Source: *China Statistical Yearbook* (1986-2009).

5.2. Variables.

It has been mentioned earlier that the power generation segment has been the focal point of China's electricity industry reform. Therefore, the effects of electricity industry reform will

be quantified by observing its contribution to the performance this segment. Indicators of the performance of the power generation segment will, in turn, be involved in our regression models as dependent variables.

More specifically, we focus on coal-fired power plants, rather than on the whole electricity generation segment. There are several reasons why we do this. First, policies, such as privatization, have mainly been applied to thermal power plants rather than those producing hydroelectric or nuclear power. Thus, performance of thermal power plants could be the best indicators of the effects of electricity industry reform, as it is the type of power plant that tends to be most affected by the policies involved in the reform of the electricity industry. Moreover, if data for other kinds of power plants are involved in the tests, the results could be diluted. Second, thermal power plants have long been the major means of electricity generation in China. This is evident in Figure 9, which shows that electricity generated by thermal power plants account for around 80% of total electricity generation during the last three decades. In addition, thermal power plants can be further classified into three different kinds of power plant: coal-fired power plants, oil power plants, and gas-turbine generators. In China, coal-fired power plants have been the major component of the thermal generation sector. The reason is probably that coal is abundant in China, while natural gas is scarce, and China has also long been one of the major oil importers in the world. The dominant position of coal plants among thermal power plants is evident from Figure 10[26]. In 2007, China was the world's leading generator of electricity produced by coal plants, while the amount of electricity produced by both oil and gas-turbine generators in China does not rank in the world's top 10. In addition, Steven (2002) pointed out that fuel costs must always be taken into account when evaluating the choice of generators. Coal plants are usually built because of their lower cost of fuel per unit of energy output. In accordance with the long era of electricity shortage in China, it would not therefore be surprising that coal-fired power plants became the major type of thermal power plants in China. Therefore, we believe that changes in the performance of coal-fired power plants can reflect the situation of the whole power generation segment.

[26] See Appendices.

In this study, the three key indicators of electricity generation performance are considered to be the amount of electricity generated by coal-fired power plants ($PROD$), the fuel input efficiency of coal-fired power plants (F) and real electricity prices (P_e). These were chosen on the basis of the targets of the electric power industry reform. They are all factors which tend to be closely related to the performance of the electricity generation segment and are affected by the reform. These three factors will therefore be used as our dependent variables.

In order to test the effects of the reform, we will also create four key policy variables: privatization (PV), separation of government and business functions (SGB), separation of generation and transmission (SGT) and market price mechanism (MPM). Their implementation processes and importance have been analysed in section four. The parameters of these policy variables will indicate the effects of the reform on the performance of electricity industry.

Table 5. *The evolvement of pricing policy and the value of* MPM .

Year	pricing policy	value
Before 1996	Government controlled price or cost-plus price	0
1997	operation period price	0.15
1998		0.15
1999-2003	operation period price & entering grid through bidding	0.3
2004-2008	yardstick price	0.4
2009	yardstick price & first direct sale of electric power from power plants to enterprises	0.6

Note: The detailed process of the evolution of pricing policy in electric industry is from P32-34.

To calculate the value of PV , we divide the value of power generation property owned by private sector by the value of total power generation property. The value of the other three

policy variables will be assigned according to the process of their implementation with the range of [0, 1]. The value of MPM is shown in Table 5.

Separation of government and business functions was launched in 1997, and finished in 2001. Therefore, its value is 0 before 1997, and 1 after 2001. In 1997, the foundation of the State Power Corporation marked the achievement of the separation of government and business functions at the central government level. This is a big step, as the central government had full control of the electric industry. Thus, the value of "separation of government and business functions" is 0.6 in 1997. Then, from 1998 to 2001, there was a gradual process to achieve separation of government and business functions at the provincial level. Therefore, the value of the policy increases by 0.1 each year, reaching 1 in 2001.

Separation of generation and transmission started around 1999 and generally finished in 2007. Thus, the value of variable SGT will take the value of 0 before 1999 and 1 after 2007. Its value is between 0 and 1 from 1999 to 2006. It will be recalled that "separation of generation and transmission, entering power grid through bidding" was carried out in five pioneer provinces and one city, comprising Zhejiang, Shandong, Jilin, Liaoning, Heilongjiang and Shanghai in 1999. However, there was no other major changes until 2002, when the former State Power Corporation[27] was divided into several independent companies. Thus, the value of "separation of generation and transmission" is 0.1 from 1999 to 2001, and 0.6 in 2002. From 2002 to 2006, separation of generation and transmission was implemented of both state and provincial level. Thus, the value of "separation of generation and transmission" increased by 0.05 each year from 2002 to 2006. In 2007, the generation assets of the National Grid were sold, which marked the completion of separation of generation and transmission. Therefore, the value of "separation of generation and transmission" achieved 1 in 2007.

[27] The State Power Corporation owned 46% of total generation assets and 90% of total transmission assets at the end of twentieth century.

Other variables, comprising time (T), real GDP (GDP), real price of coal (P_c), real per capita income ($RINCOME$), and installed capacity (CAP), are also involved in our regression models. Unit roots tests of all variables (except policy variables), which ensure that all regression models are balanced, are shown in Table 6[28]. In order to ensure that all the time series involved in our models are not moving in a non-stationary manner, the Johansen test has been applied. The result of this is shown in Table 7. The results of this test show that there is only one cointegrating relationship across all the series. Thus, we believe that our models tend to be reliable. However, due to the small sample size, the lags interval of our Johansen cointegration test is 1 to 3, rather than the preferable 1 to 6. The latter is preferred because one variable ($Ln(P_e)_{t-6}$) is lagged 6 periods. As a result, we must note that our small sample size might undermine the reliability of Johansen test.

5.3. Regression models.

As three dependent variables were chosen, we built three regression models:

1. *Production model*. First of all, production of electricity tends to experience exponential growth because of reasons such as population growth. Thus, time can be an appropriate variable in the model. Factors from both the demand and supply side can also affect the amount of electricity generated, meaning real price of electricity is an important factor which influences electricity consumption. Another demand side factor is real per capita income. From the supply perspective, production of electricity is directly limited by the installed capacity of power plants. The more the installed capacity, the more the electricity production. However, electricity production can also be calculated by using installed capacity times utilization and power generation efficiency. Thus, installed capacity could not be directly involved in the model, otherwise collinearity will result. Instead, we have lagged the price of electricity, as it is closely related to the investment of both the state and the power plants themselves in the previous period, and in turn, the installed capacity in the

[28] See Appendices.

current period. The long lags involved in the model are because of the time taken to construct power plants. This model can thus be expressed as:

$$LnPROD_t = \beta_0 + \beta_1 T + \beta_2 Ln(P_e)_t + \beta_3 LnRINCOME_t + \beta_4 Ln(P_e)_{t-6} + \beta_5 PV_t + \beta_6 SGB_t + \beta_7 SGT_t + \beta_8 MPM_t + \varepsilon_t$$

$PROD$ is amount of electricity generated by coal-fired power plants. T is time. P_e is the real price of electricity. However, there is no record of electricity prices back to 1978 in China. Thus, we instead use the "electricity industry products price indices" recorded in *China Statistical Yearbook* to replace the prices of electricity. Electricity industry products are those products with the cost of electricity being the major component of the total cost of its production (for example, aluminium). Thus, it is reasonable to believe that "electricity industry products price indices" can reflect changes in the price of electricity. $RINCOME$ is real per capita income in China. PV is the level of privatization. SGB is the policy of "separation of government and business functions". SGT is the policy of "separation of generation and transmission". MPM is the introduction of market price mechanism in power generation market.

2. *Efficiency model*. The growth rate of fuel input efficiency can experience diminishing returns. Therefore, time is involved in the efficiency model. The fuel input efficiency of power plants is also directly affected by reinvestment in R&D by the government and the power plants themselves. Installed capacity and real price of electricity are thus involved in the model as proxies of reinvestment in technology, as they are closely related to the profit generated by electric power enterprises. The model used is thus:

$$D(LnF)_t = \beta_0 + \beta_1 T + \beta_2 LnCAP_t + \beta_3 Ln(P_e)_t + \beta_4 PV_t + \beta_5 SGB_t + \beta_6 SGT_t + \beta_7 MPM_t + \varepsilon_t$$

LnF_t is a transformed indicator of fuel input efficiency. The recorded efficiency in statistical yearbooks has the range of [0, 1]. In order to make sure that the dependent variable has the range of $[-\infty,+\infty]$, we set LnF_t equal to $\log(\frac{efficiency}{1-efficiency})$. The purpose of the transformation is to ensure that the error term is normally distributed. Then, we involve the difference of LnF_t in the model as the dependent variable, in order to make the dependent variable $I(1)$ and balance the model. CAP is the installed capacity of coal plants. P_e and the four policy variables (PV, SGB, SGT and MPM) are the same as in the production model.

3. *Price model.* GDP is an important factor which influences the price of electricity. Previous empirical studies indicate that an increase in income (GDP) will increase the use of, and demand for, electricity by households (Frontier Economics, 2007). In turn, the increased demand for the electricity is likely to push up the tariff. Thus, the price of electricity tends to be adjusted in accordance with changes in real GDP. In addition, lagged GDP increases are also likely to influence price of electricity, because increases in GDP in a previous period can result in more investment in the electricity industry, including investment in technology leading to higher efficiency and lower prices. As coal is the major input of coal-fired power plants, its price is another key factor that drives fluctuation in electricity prices. This price model can be expressed as:

$$Ln(P_e)_t = \beta_0 + \beta_1 LnGDP_t + \beta_2 LnGDP_{t-3} + \beta_3 Ln(P_c)_t + \beta_4 PV_t + \beta_5 SGB_t + \beta_6 SGT_t + \beta_7 MPM_t + \varepsilon_t$$

GDP is real GDP in 1978 prices. As there is no record of coal prices (P_c) in the early period, we use "coal industry products price indices" recorded in the *China Statistical Yearbook* to replace coal prices. Coal industry products are those products with the cost of

coal being the major component of the total cost of its production. Hence, we believe that "coal industry products price indices" are able to reflect changes in prices of coal. P_e and the four policy variables are the same as in the production model.

In our regression models, the variables will take different forms. Most variables take the form of a natural log. Generally, this has been done in order to build more appropriate models to better simulate cases in the real world. More specifically, we have two justifications for taking natural log forms for those variables. First, dependent variables, such as amount of electricity generated ($PROD$), price of electricity (P_e) and fuel input efficiency (F), need to take the form of a natural log, in order to overcome the problem of heteroskedasticity. This is because they are all growth variables which tend to increase over time. If we leave those variables in level form, they will have variances that grow with time, which will result in underestimated standard errors of OLS coefficients. Second, in Figure 11 and Figure 12, we separately graph the level and natural log of all the variables that appear in our regressions. The order of variables is the same in both figures. By comparing those graphs, we can observe that variables in a logarithm fit a linear model better compared with variables in level form. It is especially obvious for installed capacity (CAP), electricity production ($PROD$), real GDP (GDP) and real per capita income ($RINCOME$), which tend to increase over time. Thus, regressions with growth variables in a natural log are better specified. To sum up, it is more appropriate to use growth variables in a natural log in regression models.

5.4. Data.

The dataset is a group of time series data, comprising annual aggregate data from 1978 to 2009. Thus, 32 observations are employed to estimate our regressions. The length of data is carefully selected. First of all, the central government in China began reform in 1978. From then on, China's economy has experienced significant development. Therefore, by only

involving data after 1978, we are less likely to have a structural break within our dataset. Moreover, as a major purposes of the empirical study is to identify the effects of key policies involved in the electricity industry reform in China, we will focus on the parameters of the policy variables in our regression models. As all policy variables have a value of zero before 1985, there is no point involving too many observations before 1985. As a result, the year 1978 is an reasonable starting point of our dataset. In addition, we aim to investigate the whole process of the reform until the present day, so the end is set as 2009.

Our major sources of data are publications of China Statistical Bureau, including *China Statistical Yearbook* (1982-2009), *China Electric Power Year Book* (1993-2005), *China Energy Year Book* (1989-2008), and *China's Electricity Industry Report 2009*. There were also, however, other sources used, such as the database of International Energy Agency (IEA), and the Electronic Industries Association (EIA). Even though the quality of China's data has always been doubted by researchers, because of political interference and inconsistencies amongst other reasons (Ma HY, Oxley L, Gibson J, 2009b), we believe that the data employed in our study is reliable. This is because, firstly, we use national level data rather than data collected by local government agencies, so that the data are less likely to be affected by political factors. Secondly, the China Statistical Bureau is the statistical agency with the greatest authority in China, and the quality of its publications tends to be of high.

6. Results and analysis.

The reader should note that, while the causative linkages postulated in Chapter 6 represent one possible interpretation of the evidence, an econometric study such as this does not permit definitive statements to be made about causation, and other causative relationships seem at least equally probable.

This section involves two parts. The first is a brief analysis of statistics on the basis of our estimations. By investigating the results of the three models, we can have a general idea of how the performance of the electricity industry (especially the power generation segment) was affected by major policies adopted as part of the electricity industry reform, as well as other variables. The other part is a systematic analysis of the reasons why policy variables influenced the performance of electricity industry in certain directions. This part includes an evaluation and further suggestions.

Table 8. *Estimation results of the three models.*

Dependent variable	LnPROD	D(LnF)	LnPe
Sample	1984 2009	1979 2009	1978 2009
C	2.265 (0.148)	- 0.773 (0.000)	5.481 (0.000)
LnCAP		0.086 (0.001)	
LnGDP			0.241 (0.200)
LnGDP(-3)			-0.617 (0.003)
LnPc			0.437 (0.011)
LnPe	- 0.153 (0.082)	0.019 (0.243)	
LnPe(-6)	0.479 (0.003)		
LnRINCOME	0.606 (0.018)		
T	0.056 (0.002)	- 0.006 (0.003)	
PV	1.030 (0.002)	- 0.101 (0.057)	1.366 (0.002)
SGB	- 0.142 (0.052)	- 0.009 (0.543)	0.578 (0.000)
SGT	- 0.011 (0.902)	- 0.016 (0.147)	- 0.029 (0.809)
MPM	- 0.255 (0.157)	0.029 (0.438)	0.134 (0.723)
Included observations	26	31	32
R-squared	0.999	0.721	0.931
Durbin-Watson stat	1.953	2.218	1.896
Akaike info criterion	-3.985	-6.823	-2.476

Note: standard errors in parentheses.

6.1. Statistical results.

6.1.1. Production model.

In the production model, changes in electricity production could be explained by the variables involved in the model. The Durbin-Watson stat (D-W stat) is 1.95, which is very close to 2. This indicates that there is no autocorrelation.

Time (T) is significant at a 0.2% significance level, which indicates that electricity production does experience exponential growth. The logarithms of lagged real electricity price ($LnP_e(-6)$) enters the model as a proxy for investment in installed capacity, which directly limits electricity production. It is statistically significant at a 0.3% level. Consistent with our expectations, it is positively related to the amount of electricity production. The log of real price of electricity in the current period (LnP_e) is significant at 8.2% level. Its negative coefficient is as expected, by virtue of the law of demand. Moreover, the magnitude of the coefficient of LnP_e (-0.15) shows that demand is inelastic. The log of real income per capita ($LnRINCOME$) has a t-stat of 2.61.

The policy of privatization (PV) is statistically significant even at a 0.2% level. Holding all other variables constant, a one percentage point increase in privatization will lead to a 1.0% increase in electricity production. The magnitude of the coefficient of PV is therefore the biggest among all the variables in the production model. Thus, the effect of privatization on electricity production is considerable. This is consistent with our expectations, as the primary purpose for adopting privatization is to encourage investment and solve electricity shortages. The policies of "separation of government and business functions" (SGB) is significant at a 5.2% level. Holding all other variables constant, one percentage point improvement in separation of government and business functions will lead to 0.1% decrease in electricity production. The negative coefficient of SGB means that the adverse impact of the policy dominated at least in short term. "Separation of generation and transmission"

(SGT) and introduction of market price mechanism (MPM) are, however, unlikely to have impacts on the amount of electricity production, as neither of them is significant even at a 10% significance level.

6.1.2. Efficiency model.

In the efficiency model, changes in the efficiency of electricity generation could be explained by installed capacity, real price electricity, time, and by the other four policy variables. R^2 is 0.721, which is reasonably high. In addition, as the D-W stat (2.22) is close to 2, there is no autocorrelation.

The time variable (T) is statistically significant at a significance level better than 0.5%. This is consistent with our expectations, as R&D tends to be subject to diminishing returns. These diminishing returns from technological research tend to decelerate the rate of technological progress (Li, 2001). In turn, it therefore becomes harder to maintain the same growth rate in efficiency. Installed capacity ($LnCAP$) is statistically significant at better than 0.1%. There are several reasons for the the strong relationship between installed capacity and the growth rate of efficiency. One reason is that the newly built installed capacity is usually associated with better technology and thus higher efficiency. The second reason is that increases in installed capacity could lead to increases in the profits of the electricity industry, in taxes paid, and, in turn, the amount of reinvestment in the electricity industry. However, from the profitability perspective, the price of electricity (LnP_e) is expected to have the same effect as installed capacity, while LnP_e is, in fact, not statistically significant in the efficiency model. This could be due to the priority given to the major goal of the electricity industry reform in China. In other words, in these reforms, efficiency improvement in the electricity industry was not under consideration until the electricity shortage issue was largely solved in 1997. Therefore, the profits generated from higher prices were more likely to be distributed to the development of capacity rather than

efficiency. It is therefore reasonable that LnP_e is not significant.

Of the four policy variables, only one (PV) is significant. Privatization (PV) is statistically significant at a 6% level. The significant influence of privatization over power generation efficiency is consistent with our expectations. However, the negative coefficient of PV cannot be explained by common economic rationales, as privatization in most other countries is usually associated with more competition and, thus, higher efficiency. This could therefore be a specific feature of China's electricity industry reform, and the reason for this will be further discussed in the second part of this section. The major purpose of the other three policy variables (SGB, SGT and MPM) was to accelerate the development of power generation efficiency, but our results show they did not affect the changes in the growth rate of power generation efficiency. In other words, these three policies were unsuccessful in this context.

6.1.3. Price model.

In the price model, the variables involved in the model can explain the changes in the real price of electricity. R^2 of the model is about 93%, and the D-W stat (1.90) is very close to 2, so that we believe there is no problem of autocorrelation in the estimate.

The logarithm of current real GDP ($LnGDP$) is significant at a 20% level. The sign of $LnRGDP$ is consistent with normal economic rationales. Real GDP is closely related to living standards, and the electricity industry, as a utility industry, tends to adjust the prices of its product in accordance with the standard of living. Thus, increases in real GDP are likely to result in increases in electricity prices. $LnGDP(-3)$ is significant at better than the 1% level. As a proxy for investment in the electric industry, increases in $LnGDP(-3)$ tend to lead to higher efficiency in the electricity industry. This is not only because of direct investment in R&D, but also became of the higher efficiency associated with new power

plants. Thus, prices of electricity will go down as $LnGDP(-3)$ increases. The log of real prices of coal (LnP_c) is significant at a 1.1% level. A 1% increase in the real price of coal will result in 0.44% increase in the real price of electricity. It is not a surprise that increases in the real price of coal could lead to a significant increase in the real price of electricity, as the cost of fuel input usually accounts for more than 50% of the total costs of coal-fired power plants.

Two of the four policy variables tend to significantly contribute to fluctuations in real electricity prices. The policy of privatization (PV) is statistically significant at a 0.2% significance level. The magnitude of its coefficient (1.37) indicates that the privatization had a major impact on real electricity prices. The positive effect of privatization on the real price of electricity is consistent with the estimated efficiency model. As the policy of privatization led to lower power generation efficiency in China's electricity industry, the resulting higher electricity prices were a logical outcome. Thus, the policy of privatization in China's electricity industry reform is a special, and probably unique, case. Systematic analysis of the results will be given out in next part. "Separation of government and business functions" (SGB) is the other policy variable which is significant with a t-stat of 5.70. The positive effect of SGB on the real electricity price is consistent with our expectations, as government intervention has long been the major reason for the depressed electricity prices. "Separation of generation and transmission" (SGT) and market price mechanism (MPM) are not significant, so neither of them is likely to have an impact over fluctuations in real electricity prices.

6.2. Further analysis of major policies.

6.2.1. Privatization (PV).

According to our results, the policy of privatization should be regarded as a major policy that aimed to contribute to the development of installed capacity rather than power

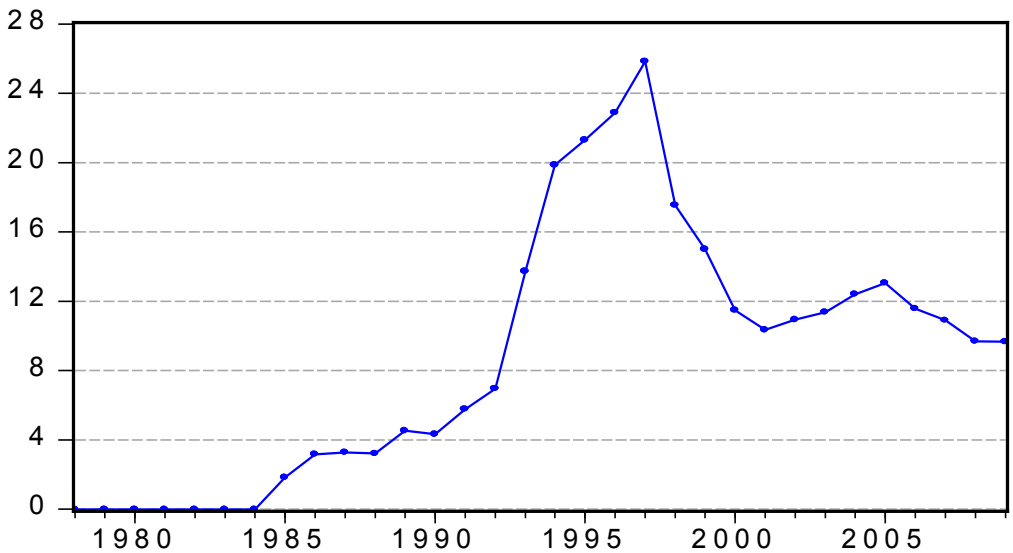
generation efficiency. Therefore, the effects of privatization in China's electricity industry, particularly as a policy adopted in the electricity shortage era, should be determined by first investigating its influence on electricity production. The production model indicates that privatization is the variable which made the most important contribution to the increases in electricity production. Thus, the policy of privatization could be regarded as a successful policy during China's electricity industry reform from an electricity production perspective. Moreover, the considerable effects of privatization in China's electricity industry are closely related to the specific way privatization proceeded in China. In other countries, privatization was mainly achieved by the sale of state power generation properties, as well as by direct investment and construction of new power plants. However, privatization in China was achieved largely through the process known as Build Operate Transfer (BOT)[29]. A big advantage of BOT is that capital investment from different sources is used to build new power generation capacity, rather than purchasing power plants already built. Therefore, BOT is a efficient way of turning capital investment into more installed capacity. This also explains why privatization in China's electricity industry had such a remarkable influence upon the development of electricity production.

Nevertheless, the implementation of BOT also led to a relatively lower level of privatization in China's electricity industry, which means that even though the effect of a 1% change in the level of privatization could be considerable, the total influence of the policy on electricity production could be limited. This low level of privatization was due to three reasons. First, the majority of power generation property has been retained by central and local governments, rather than sold to the private sector. The second reason is that central and local government has been the major source of the capital investment in the electricity industry even after the adoption of privatization. This meant that, with the rapid growth of China's GDP, central and local governments' investments in the electricity industry were expected and able to maintain high growth rates. Third, the low level of privatization could

[29] Build Operate Transfer (BOT) means operating concessions are awarded to collective or private enterprises (including foreign enterprises), so that they can legally finance, construct and operate specific public facilities. These enterprises are allowed to collect fees or sell their products to consumers, in order to pay off loans and make profit. When the concessions expire, facilities will then be transferred to state government for free.

also be attributed to the motivation behind implementing privatization in the power generation segment. As the primary reason for privatization was to solve electricity shortages rather than to promote competition, the level of privatization increased when electricity supply was insufficient. On the other hand, the level of privatization would go down once the demand of electricity was met by supply. This is evident when examining Figure 13. As electricity shortages in China were a problem until 1997, Figure 13 shows there was, consequently, a dramatic increase in the proportion of capital investment in the private sector before that date. In 1997, privatization reached the highest level (25.8%). However, the figure decreased gradually from this time, and was only 10.4% in 2001. Then, since the problem of electricity shortages arose again from 2002 to 2004, privatization increased in this period accordingly. When these electricity shortages ended, it decreased from 2005 until 2009. In 2009, the level of privatization was, thus, lower than 10%.

Figure 13. *The level of privatization of power generation property in China's electricity industry from 1978 to 2009.*



Source: *China Statistical Yearbook* (1982-2009).

Besides the three reasons stated above, however, there is another important reason for the dramatic decline in the level of privatization after 1997. Since 1997, the situation of China's

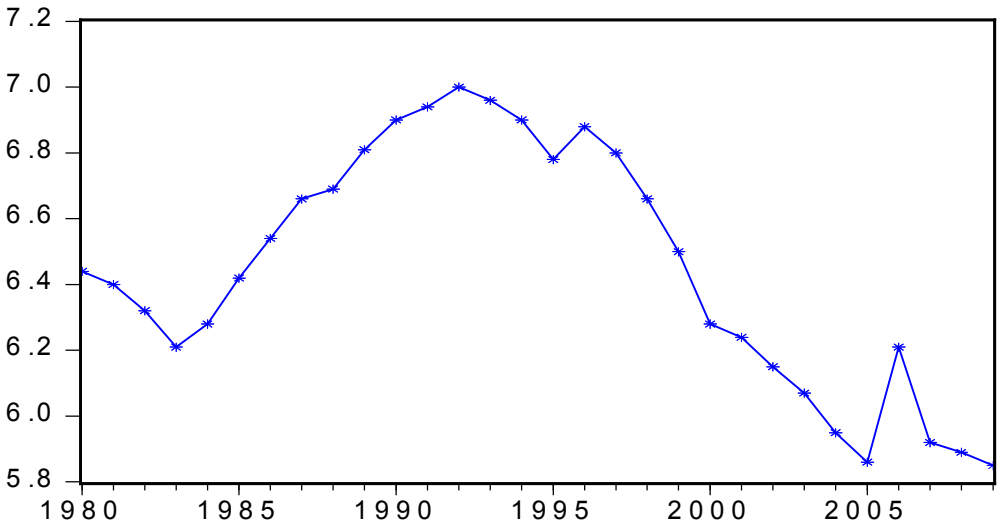
electricity industry gradually turned from shortage to surplus. However, power plants constructed by the private sector (both local and foreign investors) were no longer treated equally with the power plants of the state-owned vertically integrated power enterprises, since the demand of electricity was met by supply. State-owned power plants had priority in trading with power grid enterprises, and, as a result, electricity prices and utilization of privately owned power plants could not be guaranteed. Many private power plants were therefore sold, which contributed to the decrease in privatization.

It can be seen, therefore, that privatization in China's electricity industry has had both advantages and disadvantages. While privatization did contribute to significant increases in electricity production in China, it also led to a lower growth rate of fuel input efficiency. Furthermore, even though the negative relation between privatization and the growth rate of efficiency is unusual, it is, in fact, an inevitable result of China's electricity industry. First, privatization in China's electricity industry not only encouraged investment from various sources, but also the construction of power plants of different sizes, including smaller plants. As a result, both installed capacity and competition in the power generation segment should have increased. However, even though competition could help to improve the efficiency of power generation, this does not necessarily follow when small power plants were constructed. In the process of introducing competition into the electric power industry, a contradiction between economies of scale and competition emerged (Marshall's dilemma). While both of these are important to the development of the electric power industry, the larger the scale, in most cases, the lower the level of competition, and vice versa. This is because, due to technical factors, small power plants are associated with lower efficiency, especially in thermal power plants. Hence, in the process of introducing competition in electricity generation, the size of power plants should, ideally, be regulated, in order to limit the development of small inefficient plants. In other words, the size of power plants and the level of competition should be balanced. Unfortunately, in China's case, the construction of small power plants was encouraged due to an overemphasis on installed capacity, and the efficiency of power plants was totally neglected, especially in the period from 1985 to 1997. Thus, it is not a surprise that privatization in China's electricity industry actually led to

lower fuel input efficiency.

Furthermore, not only was the growth rate of fuel input efficiency negatively affected by privatization, but the overall performance of the power generation segment was poor during the main period of privatization implementation (from 1985 to 1996). For example, Figure 14 shows that the electricity consumption rate[30] of power plants increased dramatically from 1985 to 1992. Even though it slightly decreased from 1993 to 1995, there is no doubt that the general trend of the electricity consumption rate from 1985 to 1996 was upward. Our explanation for this overall poor performance of the power generation segment is the adoption of privatization, as privatization was the major policy, and change in the power generation segment from 1985 to 1996, and this led to the emergence of many small power plants.

Figure 14. *Electricity consumption rate of power plants from 1980 to 2009.*



Source: *The report on the development of China's electric power industry* (2009).

Given the fact that privatization seems to have led to poorer performance of the power

[30] Electricity consumption rate is the difference between the amount of electricity generated by power plants and the amount of electricity sold to transmission segment, divided by total electricity generated by power plants. It is an important indicator of the performance of power plants.

generation segment, it is inevitable that the price of electricity increased along with the adoption of privatization. In addition, along with the increasing level of privatization from 1985 to 1997, the cost-plus price mechanism adopted during the same period further eliminated the motivation for power plants to improve overall efficiency. Due to irrational price mechanisms, and a lack of effective regulation of electricity price, fluctuations in price and illegal mark-ups became more serious, which led to the abnormally high retail price of electricity. At the same time, the restriction on investment and production costs was weak due to the same cost plus pricing system. Therefore, power production was characterized by high costs, high prices, and low efficiency. High prices of electricity, in turn, resulted in the low per capita electricity consumption. By 1997, annual per capita electricity consumption in China was only 900 kilowatt-hours, which was 1/3 of the average annual per capita electricity consumption for the entire world.

6.2.2. Separation of government and business functions (SGB).

The policy of separation of government and business functions (*SGB*) was implemented to help establish a more reasonable market mechanism to replace the government's administrative management of the electricity industry. The policy began in 1997 when electricity shortages in China had largely been eliminated. It focused on the market structure and regulatory reform of the electricity industry. Improvements in the efficiency of the electricity industry, through the weakening of the state-owned monopoly and increased competition, could have also been a goal of the separation of government and business functions. However, as the policy could not, of itself, terminate the dominant position of the monopoly in the electricity industry, it did not actually influence the growth rate of fuel input efficiency of power plants. Therefore, the price and production of electricity are the two factors which were significantly affected by separation of government and business functions.

There are two major reasons for the positive relationship between *SGB* and price of

electricity. First, the electricity industry, as a natural monopoly industry, has responsibility to provide goods and services, and meet the demands of the community. Public good is a major concern. Therefore, the respective targets of enterprises' business functions and public goals are difficult to coordinate. The target of their business functions is to set monopoly prices and maximize profit, while their utility characteristics force natural monopoly industries to set prices lower than the monopoly price to benefit the public. As a result, such industries cannot be operated solely according to market mechanisms and rules, and government intervention is commonly applied. However, the central government in China not only intervened in the electricity industry, it had complete control of it. Such an excessive intervention by the government led to a very low level of enterprise autonomy. As a result, when the government functions were gradually separated from the business functions, power enterprises had more authority. As commercial corporations, they were likely to raise the tariff, in order to cover their costs and generate more profit. In addition, as mentioned in the the previous part, privatization in the power generation segment before 1997 led to a poorer performance of the electricity industry. Therefore, when *SGB* was combined with the fact that the state-owned monopoly was gradually turned into commercial enterprises, higher electricity prices would be an inevitable result.

Second, separation of government and business functions weakened the central government's extent of macroeconomic control. For example, under unified government and business functions, the operations of the electric industry were directly under the central government's control. This made it easier for the industry to rearrange its interaction, and cooperation, with the fuel industry, transportation industry, and other sectors. Transaction costs could, consequently, be lowered. On the other hand, when power enterprises became independent commercial enterprises after the separation of the government and business functions, negotiation and cooperation between the electric industry and other industries were associated with more inconveniences and difficulties. Their transaction costs went up. In order to cover these higher costs, the price of electricity, in turn, increased. Moreover, the production of electricity also tended to be affected adversely in short term, due to the poorer cooperation between industries.

However, even though separation of government and business functions led to an increase in electricity prices, it could not be regarded as a failure. In the short run, the increases in electricity price corresponded to the increases in the costs of electricity production. In other words, it was a measure to keep power plants in operation, and the smooth operation of power plants is the most important guarantee of stable electricity supply. Furthermore, in the long term, one result of the commercial operation of power enterprises is that market mechanisms will play a more important role, and combined with the weakened state-owned monopoly, the electricity market will be more competitive than before. This is good for the improved efficiency of electricity generation and for enhancing the overall performance of the industry. Market mechanisms could also help balance the demand and supply of electricity, and prevent over-capacity.

In addition, we should also realize that the goal of "separation of government and business functions" is not just to remove governmental intervention from the industry, but to introduce a more reasonable way to govern and guide the electricity industry, and lead to its better and healthier development. Thus, at the same time as weakening the central government's complete control over the electricity industry, regulation related to the electricity industry should be improved. Andrews-Speed and Dow (2000) argued that whatever structures are chosen for the power market and power industry, none of the objectives can be achieved without effective regulation. Though deregulation is mentioned frequently during the market reforms in the power industry, market-oriented reform should not intend to eliminate government regulation. This is because if demand is very inelastic, market power could be a potential problem even with a relatively large number of suppliers, under certain demand and supply conditions (Joskow, 1997). Borenstein and Holland (2005) stated that electricity deregulation has proceeded with support from many economists on the belief that competitive markets will produce more efficient outcomes than regulation. That still may turn out to be true, though in many locations, most notably California, there is significant evidence that the markets have not been sufficiently competitive. Thus, the relationship between deregulation and regulation is actually the relationship between market and government, which need to collaborate with each other.

Consequently, as regulatory reform is such an important component of the process of market-oriented reform of the electricity industry, the State Electricity Regulatory Commission was set up in 2003 - two years after completing the separation of government and business functions. Its foundation was, in fact, part of a continuous process following the separation of government and business functions, and a mark of the introduction of law-based control in the electricity industry. The termination of the central government's complete administrative control was an important step, especially when we consider the inequity existing between privately-owned power plants and state-owned power enterprises at the end of 1990s that was mentioned above. Moreover, the end of electricity shortages in 1997 also led to the emergence of more regional protection. Thus, demand for law-based control of China's electricity industry was urgent. Without an appropriate regulatory system, fair and competitive market mechanisms are hard to achieve.

However, there were still some deficiencies in the process of the adoption of law-based control of the electricity industry in China. Prominent here would be the "Electric Power Law" itself. This law was promulgated in 1996, and it has been the major law regarding the operation and development of the electricity industry since then. However, it was written under the circumstances of the former vertically integrated management of the electricity industry in the time of electricity shortages. Development of installed capacity was still a major concern, and industry efficiency and market mechanisms were underemphasized. Thus, it is not an appropriate structure for a law-based operation and application of a market mechanism in the electricity industry. Another deficiency is that even though the independent regulatory department - the State Electricity Regulatory Commission - was founded, it was not given enough authority. For example, the National Development and Reform Commission still retains authority related to market access, electricity price, and penalties. This insufficient authority of the State Electricity Regulatory Commission could limit or undermine its contribution to the electricity industry. Thus, the regulatory reform following separation of government and business function is still not complete. Further adjustment will be required.

6.2.3. Separation of generation and transmission (SGT).

After privatization and separation of government and business functions, separation of generation and transmission segments is the final step before the introduction of a market mechanism in the electricity generation market. Its aim is to eliminate the monopoly power of the former state-owned power enterprises. However, according to our empirical study, the policy of separation of generation and transmission did not have significant impacts on electricity production, the growth rate of fuel input efficiency, and electricity price. These results could be due to several reasons. First, after electricity shortages had generally been solved in 1997, separation of generation and transmission was launched. Therefore, the primary purposes of the policy laid more emphasis on the efficiency of the electricity industry and the introduction of a market mechanism. Amount of electricity generated was unlikely to be significantly influenced by separation of generation and transmission in the short term. Second, separation of generation and transmission was only completed in 2007. There might not, therefore, have been enough time for the policy to display the full range of its effects on power generation efficiency and, thus, electricity price. Especially for a complex system like the electric power industry, it would be unrealistic to expect policies to take effect instantly. Third, separation of generation and transmission has had a negative impact on the integrity of the electricity industry. As the electricity industry is still characterized by economies of scope, the policy is likely to lower the performance of electricity industry. Especially in the short term, these negative effects of the policy could offset its contribution to the electricity industry. As a result, the empirical study does not reveal its significance.

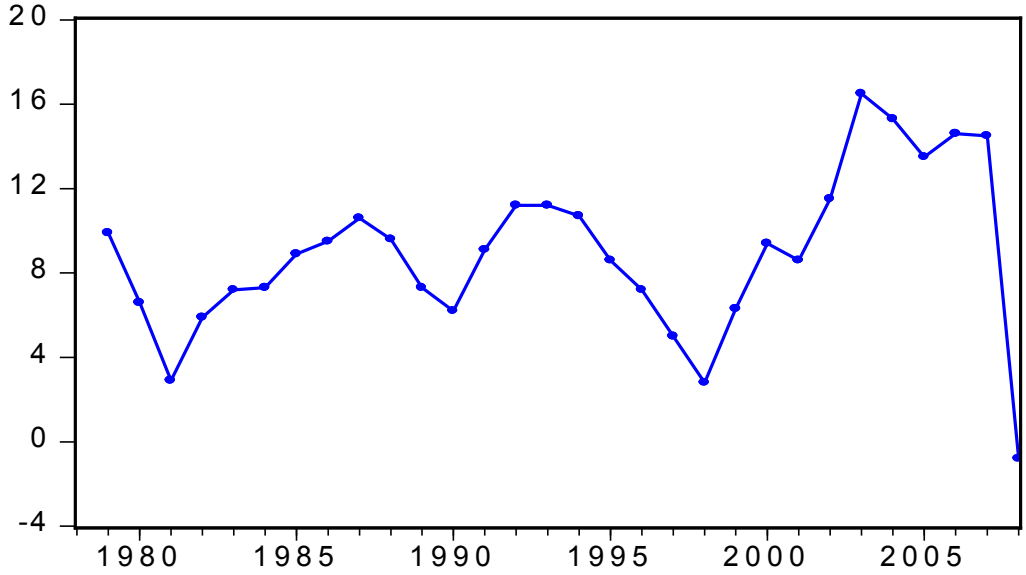
Even though the negative effects of separation of generation and transmission might dominate or offset its contribution to the electricity industry in the short term, due to its adverse impact on the integrity of the electricity production process, it does not mean the implementation of the policy was unsuccessful. First, separation of generation and transmission is important to ensure equity during competition between power plants. The privatization in China's electricity industry led to various sources of investment emerging in

the electricity generation market. Thus, state-owned, collectively-owned and privately-owned (including foreign-funded) power plants existed in the electricity generation market at the same time. However, their status could not be equal before the completion of the separation of generation and transmission, as the completely state-owned power grid gave priority to electricity generated by the state-owned power plants. As mentioned earlier, this was also the major reason for the withdrawal of foreign investors from the electricity generation market, and the resulting dramatic decline in the level of privatization. Therefore, separation of generation and transmission and, consequently, the equal status of all types of power plants, no matter what their ownership, is important for investors to regain their confidence in the development or future of China's electricity industry. This is certainly a beneficial effect.

In fact, as separation of generation and transmission was the policy which finally eliminated the advantages of the former state-owned monopoly, the completion of it led to more competition in the electricity generation market, even though there is still no complete market price mechanism. First, we should notice that the amount of electricity production and its sale is directly related to the profitability of power plants. Power generation is a capital intensive industry characterized by economies of scale. Holding all other factors constant, the more electricity is sold, the more profit is gained by power plants (Wang, 2000). This is especially true for thermal power plants. Before power plants and the power grid were separated, the sale of electricity produced by power plants of the vertically integrated state-owned monopoly was guaranteed. Power grids would prioritise the electricity produced by their own power plants. Thus, there was no competition in the amount of electricity, and the inevitable result was that power plants had little incentive to improve the quality or the reliability of electricity. However, after the power grid companies became independent enterprises, the situation changed. The amount of electricity produced in all power plants was not guaranteed any more. Power grids now bought the cheapest and most reliable electricity first, and competition in the sale of electricity was fully promoted. As a result, power plants placed more emphasis on R&D and management systems, and both efficiency and reliability of power plants tended to increase rapidly.

Separation of generation and transmission not only influenced the development of power generation enterprises, it also affected power grid companies. In China, because electricity shortages had, before 1997, long been the major consideration, the development of the power grid did not receive enough attention. In 2005, only 32.1% of the total investment in the electricity industry was to the power grid. However, in long term, underemphasis on the power grid in terms of investment is not good for the development of the electricity industry. First, the ability of the power grid to transmit electricity directly limits the amount of electricity production and consumption. In other words, lagging development of the power grid not only has negative effects on its own expansion, but also harms its upstream industry (the power generation segment) and all electricity consumers.

Figure 15. *Growth rate in electricity production from 1979 to 2008.*



Source: *China Statistical Yearbook* (1982 -2009).

Second, production of electricity is a continuous process. During this process, the power grid takes the responsibility of transmission. A poor quality power grid tends to lower the overall reliability of power supply, even though installed capacity is sufficient. For example, the unexpected big snow in the south of China in 2008 led to serious damage to the power grid, and, thus, widespread blackouts. This is also an important cause for the dramatic

decline in the growth rate of electricity production in 2008[31]. In this context, separation of generation and transmission could make power grid owners concentrate on expansion, as without power generation business, their profits come solely from power transmission services. Even though cooperation between the two segments is still important, the power grid, as independent enterprises, will now have its own interests. In addition, without priority given to electricity produced by their own power plants, power grid companies can choose the most economic options for themselves (for example, they can first trade with the nearest reliable power plants), in order to achieve higher profitability and reliability. Thus, development of the power grid tends to be promoted by the policy of separation of generation and transmission.

6.2.4. Market price mechanism (MPM).

The introduction of a market price mechanism in the electricity generation market is a central part of the market-oriented reform in China's electricity industry. Of the four policies investigated, this is the only unfinished policy. In fact, the three policies already discussed could all be seen as preparation for the introduction of the market price mechanism. However, according to our empirical study, the introduction of market price mechanism was unlikely to influence amount of electricity production, growth rate of fuel input efficiency of power plants, and the electricity price.

In the production model, MPM is statistically significant at a 15.7% level. It is not a confident level to confirm its negative effects on the electricity production, while the negative coefficient is indeed reasonable. The introduction of a market price mechanism could have contributed to a decline in electricity production in several ways. First, it is important to remember that electricity prices were separately set for every power plant and generator from 1985 to 1998. This price mechanism encouraged investment in the power generation market, as the profit of each individual power plant was guaranteed. In the long

[31] See Figure 15 above.

term, however, this cost-plus mechanism was not good for the development of the whole electricity market, because efficiency of power generation would be underemphasized in this system.

The introduction of a market price mechanism started with the adoption of operation period price in 1998. Since then, electricity prices have been set in accordance with the average costs of advanced power plants. The yardstick price and "entering grid through bidding" adopted later also attempted to set electricity prices on the basis of the costs of advanced power plants. As a result, profits of power plants could no longer be guaranteed. In the long run, the new price mechanism is good for the development of electricity industry. However, in the short term, power plants, especially those with low efficiency, may have been unable to cope with the new price policy, as their profits, and, in turn, future investment and development would have been negatively affected. This would, then, explain the decline in electricity production.

Second, excess capacity has become more serious since 1997, which was the year that electricity shortages were largely solved in China. The blind construction of power plants had led to unreasonable distribution of resources and operating deficits in power plants. A market price mechanism was then introduced, and one important purpose of this was to balance demand and supply, and thus solve the problem of excess installed capacity. Therefore, the introduction of a market price mechanism might have had negative effects on the amount electricity producted due to these negative impacts on installed capacity.

Third, Ma HY, Oxley L, Gibson J (2009b) found relatively strong evidence for regional electricity markets. There was no comprehensive analysis in this study of the reasons why regional electricity markets emerged. However, our conjecture is that in addition to the different circumstances in each region of China, the formation of regional electricity markets was closely related to various policies adopted in China's electricity industry, particularly the introduction of a market price mechanism. During the process of introducing this market price mechanism, the yardstick price, used from 2004 to the present

day, set electricity prices according to the average costs of advanced power plants in each region of China. Such a price mechanism was very likely to lead to regional electricity markets, which could then lead to regional protectionism, as trade of electricity between regions might be affected. The regional electricity markets also tended to induce more pressure on the reliable operation of the power grid, as it would be more difficult for grid companies to apply centralized dispatch. The amount of electricity consumption and production were thus likely to be adversely influenced.

As the major purpose of the market price mechanism is to promote competition in the electricity generation market and improve efficiency, the empirical finding that the market price mechanism through 2009 did not have a statistically significant effect on the growth rate of coal plants' fuel input efficiency is unexpected. However, given that electricity production declined because of the difficulty power plants had in coping with the new price mechanism in the short term, profit and investment in R&D could have been negatively affected. The contribution of market price mechanism to efficiency might have, consequently, been offset. It is, therefore, not a surprising result, in this context, that transformation from cost-plus price to market price did not increase the growth rate of fuel input efficiency in the short run. This, however, should be attributed to the architecture of the electricity industry rather than the policy itself. As the electricity industry is such a complex system, the full benefits of the introduction of a market price mechanism will take a long time to emerge, while during the process of transition, some negative effects are inevitable, especially in the short run.

We also would contend that the power plants, which found it hardest to cope with the new market price mechanism, would be those small coal plants constructed in large numbers under the former cost-plus pricing policy, as it would be especially difficult for them to adapt to market pricing. Because of the existence of scale economies in electricity generation, small thermal power plants have a limited ability to improve their efficiency and to compete with large plants (Wang, 2000). Their poor performance could thus be a major reason for the statistical insignificance of the implementation of a market price mechanism.

This can also be further inferred from the changes in the structure of installed capacity in China's electricity industry. In 1998, when the market price mechanism was adopted, thermal power generating units with a capacity lower than 200,000 kw comprised about 45.1% of the total capacity of thermal power plants. However, by 2008, this figure had decreased to 25.6%. Therefore, compared to large generating units, the proportion of small plants decreased dramatically in the last decade. This data indirectly indicates that small thermal power plants are less competitive and more likely to drop out of the market.

However, the elimination of a large amount of power plants with low efficiency takes time. Thus, the central government in China also made plans to actively close those small thermal power plants in the five-year plan. For example, in the eleventh five-year plan (2006-2010), smaller power plants, with a combined capacity of 50 million kw, were slated to be shut down. Moreover, those power plants which have been or will be closed do not only include those officially defined as small (plants with a capacity lower than 50,000 kw), but also those with a capacity lower than 200,000 kw. From 2005 to the middle of 2009, the capacity of closed smaller power plants was already up to 54.1 million kw. Nevertheless, at the end of 2008, the proportion of power plants with capacity lower than 20×10^4 kw was still high (25.6%). Their poor performance could still therefore dilute the contribution of the market price mechanism to improving the efficiency of electricity generation.

Besides all the factors analysed above, we should also note that the implementation of a market price mechanism is still in progress. All the pricing policies (from 1998 to 2009) were adopted as temporary measures to assist in achieving a complete market price mechanism. These intermediate pricing mechanisms had limited effects, as they could not result in completely competitive outcomes.

Improved efficiency is certainly important for the healthy development of the electricity industry, but also a major factor in lowering electricity prices and, consequently, benefiting electricity users. Thus, the inefficacy of the market price mechanism on efficiency is consistent with the result that it also did not contribute to lower electricity prices. However,

if the negative impacts of the market mechanism on electricity production and the insignificant effects of it on power plants' fuel input efficiency and the electricity price could be explained by the bankrupting of small power plants, then we could see the implementation of market price mechanism as a success rather than a failure. Therefore, we contend that, after the process of survival of the fittest, the advantages of the market mechanism (including balancing demand and supply, sharpening incentives to avoid sloth and slack, more competition to innovate, gains in production efficiency, and lower electricity prices) should emerge and lead to the healthy development of the electricity industry.

6.2.5. Summary.

To sum up, the four major policies implemented during the process of market-oriented reform in China's electricity industry had both positive and negative effects. Privatization in the power generation market led to substantial increases in installed capacity and helped to end electricity shortages in China. It also caused, however, an overall lower efficiency of electricity production and unhealthy development in the electricity industry. Separation of government and business functions helped to attenuate the dominant power of the former state-owned monopoly and to transform it into commercial enterprises. However, a undeniable fact is that the complementary regulatory reform lagged behind. The independent regulatory department has not been granted the requisite authority, and the "Electric Power Law" need to be revised, in order to be consistent and support the implementation of the market mechanism in the electricity industry. In short, more effort is required to achieve the law-based control of the industry. Separation of generation and transmission finally broke the monopoly power of the former state-owned monopoly, and, thus, introduced more competition in the electricity industry through attracting investment from various sources. Both electricity production and efficiency tended to increase in the long term as a consequence. On the other hand, its instant adverse impact on the integrity of electricity industry should also be realized. Thus, its overall contribution to the development

of the electricity industry has not been significant to date. The introduction of a market price mechanism promoted a degree of competition in the electricity industry, but its superiority might be hard to appreciate in the short run.

In fact, the effects of the policies are closely related to the situation in which China's electricity industry finds itself right now. The benefits of the policies (for example, separation of generation and transmission, and the market price mechanism) may not have emerged yet, as it takes time for the new mechanism to work well. For example, from a production perspective, after the elimination of the state-owned monopoly, the equal status of power plants funded by different sources should be more secure. However, there is a considerable time span between this new investment and the production of new capacity, as construction of power plants takes years. Thus, expected improvements in electricity production, competition, and production efficiency could be hard to detect. From a regulatory perspective, the process of legislation is extremely complicated, and time-consuming. However, as the law will have wide-reaching effects, it should be thoroughly thought through and discussed. The foundation of an adequate regulatory system, consistent with the development of a market mechanism in China's electricity industry, can not be achieved in only one decade. Therefore, the specific situation at this stage suggests that some policies may not have had enough time to take full effect.

Nevertheless, China's electricity industry reform has made great progress. The end of electricity shortages is a major success. Though power production efficiency was sacrificed in order to promote the development of installed capacity before 1997, the growth of small power plants has been controlled in recent decades because of the competition promoted by various policies. The healthy development of China's electricity industry has begun, laying the foundation for the introduction of a complete market mechanism.

7. Policy application.

Even though China's electricity industry reform has developed rapidly in the past three decades, power industry reform in the 12th five-year plan (2011-2015) is still of primary importance. In recent years, electricity industry reform has resulted in separation of government and business functions, and separation of generation and transmission. Electric power enterprises now have more authority and autonomy, and competition in the power generation market has been significantly enhanced. Tariff reform, as an important part of electric power industry reform, has also been modified frequently, so that it is consistent with the changing goals of the reform, and, generally, it has promoted greater competition in electricity generation. Regional electricity markets have emerged. In addition, regulatory reform has provided support and better circumstances for fair competition in the electricity industry. However, all of these improvements can only be regarded as temporary successes. The reform is incomplete, and there still remain many obstacles in China's electricity industry. For example, while they considerably increased installed capacity, the small power plants that have emerged need to be controlled and, ideally, shut down, so the increasing rate of installed capacity and scale of power plants can be balanced. Other problems include a low proportion of renewable energy sources, lagged development of the power grid, lack of environmental protection, and deficiencies of the regulatory system. While we insist on the correctness of the market mechanism, how to solve these problems and deficiencies in the electric power industry is important for the success of reform in the next period.

Through answering the two questions claimed in Section 1, we have analysed the process of China's electricity industry reform in an integrated manner and quantified the contribution of the major policies implemented. By considering the content and effects of those policies and the situation of China's electric power industry, we will make suggestions for future reform, as this is another important purpose of the study.

7.1. Accelerating the formation of a competitive electricity market.

First, the regulation of small power plants should persist. Even though the Chinese government has put great effort into controlling small power plants, one quarter of power plants still have capacity lower than 200,000 kw. Thus, in the period of the 12th five-year plan, strict control of small power plants is necessary. By speeding up the foundation of a competitive electricity generation market, the power grid should be able to prioritise lower price when purchasing electricity, so that advanced and larger power plants will tend to be protected. The efficiency of these plants is likely to improve rapidly, while at the same time, smaller power plants will find it hard to survive and will be eliminated. Construction of new power plants should be strictly verified to ensure that they meet the technical and scale indices. For those small power plants constructed under the policy of "return capital and interest", the government should help them deal with the new competitive market or negotiate with them and revise the contracts. The principle should be that, given the promised interests of investors, the closure of small power plants be accelerated as much as possible.

Second, attention should be paid to harmonious development. As the production of electricity is a continuous process, each segment within the process is important to guarantee the reliability of electricity supply. Investment in the electric industry is usually categorized into two parts: investment in installed capacity and investment in the power grid. In China, the proportion of investment in installed capacity has long been larger than investment in the power grid, as *The Report of the Development of China's Electric Power Industry (2009)* recorded in 2005, the proportion of investment in installed capacity has been about 67.9%, which was more than twice the investment in the power grid. As the supply of electricity in China has risen recently to meet the demand for it, more attention should therefore be paid to the construction of the power grid. The power grid across different regions and provinces is especially important for the trade of electricity between regions, provinces and cities, and an integrated national electricity market requires a well

constructed grid system. In addition, given the unexpected and variable climate in recent years (such as the widespread snowfall in the south of China in 2008), improvement in the power grid is extremely important to ensure the reliability of electricity supply.

Third, regional market construction should be accelerated. By taking advantage of the market mechanism, electricity trading across provinces and regions should be pushed forward, so that resources can be distributed more efficiently. The construction of regional markets was first launched in the northeast and east of China. While implementing pilot projects, however, appropriate approaches to developing regional electricity markets should also be studied. Then, the construction of regional electricity markets should be carried out nationwide. In addition to developing the power grid across regions, the price mechanism should also be used as a tool to promote the development of regional electricity markets. Electricity prices are now set in accordance with the average costs of advanced power plants in specific regions (usually provinces). This "specific region" can gradually be widened, so that competition can be carried out over an increasing area. In the short term, the development of regional markets is useful to promote competition and eliminate local protectionism. In the long term, the final target should be the construction of a nationwide integrated electricity market.

Fourth, competition should not only be introduced during the process of electricity production, it ought to be promoted even before the production of electricity. Before 1998, profits of power plants were guaranteed under cost-plus mechanism. As a result, the costs of power plant construction were not well controlled, meaning waste of resources was a serious problem in their construction. With the development of the market mechanism, the costs of power plants construction have been better controlled, but this could be further improved. As the designs of power plants are already audited and verified by a specific department of the government, construction costs and estimated electricity prices could also be taken into consideration by this auditing process. This would be helpful in controlling the costs of power plants, promoting the efficient allocation of resources, and enhancing the ability of power plants to survive competition in the electric industry. Consumers should

also benefit from lower electricity prices.

In addition, competition could be futher promoted at the stage of construction. For example, auctions could be introduced as a part of a power plant's construction. Once a power plant project is accepted by the government, both domestic and foreign companies should be allowed to bid to build it. Through a competitive approach, such as this type of auction, the costs of power plants construction are likely to be better controlled, and, as a result, the performance of the electric industry would tend to improve. Consumers would, once again, benefit from lower electricity prices and better services. In general, more competition should be introduced into the electricity industry, especially in the segments with little or no scale economy. By doing so, the vitality of the electricity industry will be greatly stimulated.

Fifth, the diversification of the purchasing channel should be further accelerated. Before 2009, the power grid was the only buyer of electricity generated by power plants, the electricity was then transmitted to a distribution centre, and consumers paid for the electricity thus distributed to them. Every locality had a monopoly retailer. However, an important improvement in the diversification of the purchasing channel is the pilot project involving direct trade between Fushun aluminium and Yimin power plants, launched in 2009. This is the first direct trade project between big electricity users and power plants. Besides big electricity users, households should also have the right to choose their preferred retailer. The monopsony position of the power grid should be terminated, as sales of electricity are not characterized by strong scale economies. If consumers have no options to choose, there are potentially problems with poor services from retailers due to lack of competition. On the other hand, by promoting more competition between retailers, better services will be enjoyed by customers. Thus, diversification of the purchasing channel is important for the improvement in the overall performance of the electric industry, and the market mechanism should be fully promoted in the wholesale and retail market for electricity.

7.2. Strengthening law-based control.

Law-based control is important to maintain fairness and equity during the transition to competition in the electric industry. It is the guarantee of the equal status of different kinds of investors, which helps to keep investors' confidence in the development of China's electricity industry. Especially while introducing the new market mechanism, the regulatory system should be consistent with the development of industry and periodically revised. An independent regulatory department should be formed, with responsibility to solve the obstacles which impede the introduction of competition and the market mechanism in the electric industry. At the same time, they should also prevent market failure in the electric industry, such as the case of California blackout in 2000. Generally, the mission of regulatory reform is to provide favourable circumstances for the introduction of market mechanisms and to accelerate the development of the electric industry, so that the interests of investors, operators and consumers in that industry can be protected. In this context, the foundation of the State Electricity Regulatory Commission in 2003 marked the movement of China's electricity regulatory system towards maturity.

However, the regulatory system still needs further modification. First, the revision of the "Electric Power Law" should be sped up. In applying law-based control, legislation is fundamental. The regulatory department has to be assigned with appropriate responsibility and authority, so that it can exercise supervision on the basis of the law and ensure that its supervision will be effective. Revision of the "Electric Power Law" is important to make the purposes of law-based control clear, and to make sure that it is consistent and helps achieve the goals of the market-oriented reform of China's electricity industry. Clear and precise legislation can help to keep the reform on track and avoid, or at least, lower the risk of the reform. Sophisticated legislation and regulation systems are also tools for maintaining the confidence of participants in the electric industry, and ensuring the healthy development of the industry. Conversely, without appropriate laws and regulations, the implementation of market-oriented reform could become compromised. As has already been mentioned, the

"Electric Power Law" was passed under the conditions of electricity shortages and the cost-plus pricing mechanism. It is then reasonable to suppose that some parts of the law are in conflict with the development of the market mechanism in the electric industry. Thus, the "Electric Power Law" needs to be revised as soon as possible.

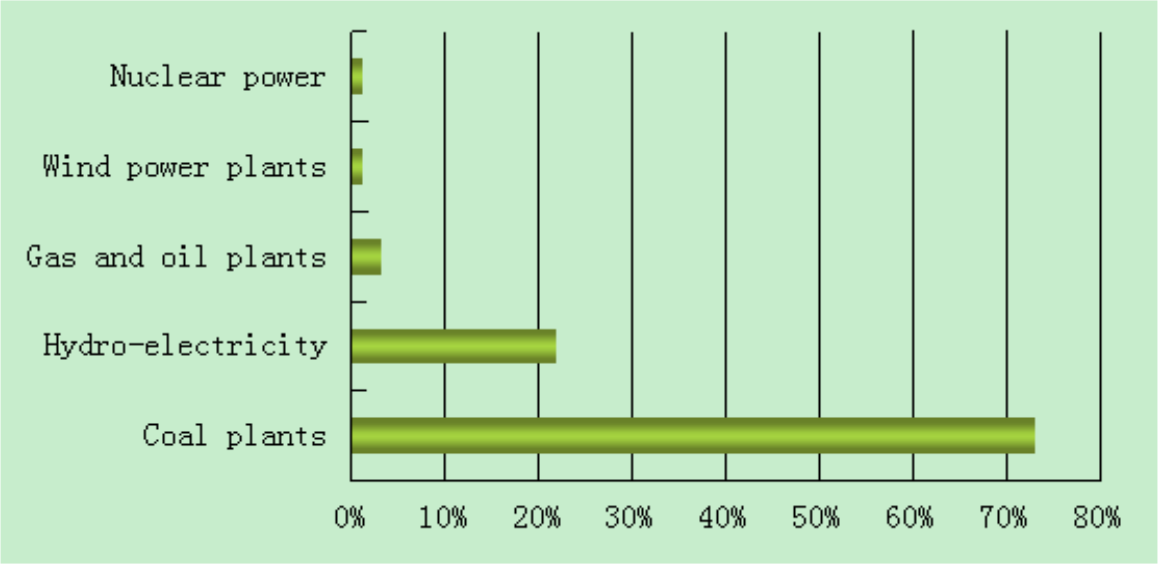
Second, an independent regulatory department should be created. Granting the State Electricity Regulatory Commission comprehensive responsibilities and authorities is the primary condition needed to ensure its effective operation. The State Electricity Regulatory Commission should be a completely independent department that follows the general direction set by the central government and exercises full supervision of the electric industry. However, some important powers have not been assigned to the State Electricity Regulatory Commission, such as supervision over the costs of electricity enterprises, market access, and electricity prices. Without such important authority, it could be hard for a regulatory department to be effective and efficient. Law-based control in China's electricity industry was launched at the beginning of the 21st century, which was relatively late in comparison with many developed countries. Even though significant improvements have been made in the electricity regulatory system, there are still many deficiencies. Due to the importance of law-based control, and government regulation and supervision, the enhancement of the independent regulatory department should therefore be a priority.

7.3. Modifying the structure of energy sources.

Recently, environmental protection and climate change have garnered much attention. Sustainable development has thus become an important consideration when judging an industry. In the electric power industry, different kinds of power plants lead to dramatically different amounts of pollution, and coal plants have been regarded as the possibly the worst polluters. However, Figure 16 shows that it is coal plants which comprise the largest proportion (73%) of the installed capacity in China. Thus, lowering pollution associated

with electricity generation has become an important long term mission of the electric industry.

Figure 16. *Structure of installed capacity in China (2008).*



Source: *The report of the development of China's electric power industry* (2009).

In the short term, the government should encourage the development of power plants with lower levels of pollution, such as hydro-electricity, wind power, nuclear power, and solar energy. At the same time, the emissions of power plants (especially coal plants) should be strictly controlled. Subsidies could be provided for power plants which actively install equipment to reduce their emissions of carbon and sulphur, as the installation of such equipment would normally lead to higher costs of electricity production. While coal plants are expected to dominate in the foreseeable future, as coal is relatively abundant in China, the proportion of seriously contaminative power plants could be controlled by adopting these measures.

7.4. Other suggestions.

First, as well as developing the electric industry itself, attention should also be paid to the demand side. Even though, China does not suffer from electricity shortages currently, the reliability of electricity supply during peak hours (especially in summer) still needs to be carefully managed. Price mechanisms, such as peak-load prices, can be used as a tool to help manage the reliability of electric supply. In addition, attention needs to be paid to energy use in the wider economy. Traditional extensive economic operations have resulted in a high levels of energy consumption and pollution, and low efficiency. Such operational mode should therefore be modified, as by enhancing the efficiency of all industries, their profitability will increase. In turn, they will be able to afford higher electricity prices, and this will, naturally, be helpful for the development of the electricity industry.

Second, we support the suggestion of Ma and Oxley (2009), as it is of crucial importance. Free downloading of official energy data and international participation in the investigation of China's energy economics should be encouraged. This suggestion should be taken seriously, as China's electricity industry is still a work in progress. Even though much can be learned from the experience of reform in other countries, China has its own circumstances, and the development of China's electricity industry cannot simply copy their methods. The process of reform is, in this sense, a research process, in which deficiencies cannot be avoided. Accordingly, studies of the reform of China's electricity industry are important for drawing lessons from the past and for informing the direction of future reform. Unfortunately, however, there is paucity of empirical investigations of China's electricity industry because of limits on access to data. Hence, to accelerate the academic contribution to the development of China's electricity industry, better data availability is required.

8. Conclusion.

In summary, great improvements have been made in China's electric industry, although deficiencies remain. As China's electricity industry is one of the largest and most complicated in the world, its reform is expected to proceed gradually and take a considerable time to complete. However, the process of reform does need to be sped up, because the situation in China's electric industry is strained. Even though China's electricity production ranked second in the world in 2008, its per capita electricity consumption was only about 2631 kwh, which was lower that the world's average level of 2723 kwh[32]. When it is remembered that China has maintained a high level of growth in real GDP, its consumption of electricity clearly has much room to increase, and the reform and development of China's electricity industry has, therefore, become an extremely important issue. In addition, China became a net importer of coal for the first time in 2007, which attracted worldwide attention, because increasing demand for coal in China could have a considerable influence on energy prices all over the world. The electric industry, as the biggest consumer of coal, is undoubtedly significantly responsible for this increasing consumption of coal. Therefore, reform of China's electricity industry is not only important to China, but also to the whole world.

There have, however, been some limitations with our study, and these could be used to point future researchers in potentially useful directions. For example, a major limitation of the current study concerns the data set, as only 32 annual observations are involved in our empirical study. Thus, the reliability of our estimates is limited. Future studies could, as a result, make improvements by using provincial data or plant-level data, in order to increase the effective degrees of freedom. This type of data can, however, be very hard to collect. In addition, the central government's attention has now begun to shift from the power generation segment to the downstream segments (transmission and distribution), as reform of the power generation segment has long been the focal point and has made greater

[32] See Table 3 in Appendices.

progress than the others. Therefore, future studies might put more emphasis on the reform or policies related to the transmission and distribution segments. Nevertheless, we hope that this investigation offers valuable suggestions and methods, capable of informing the future development of China's electricity industry.

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Appendices.

Table 1. *World's top 10 countries of installed capacity in 2007.*

Country	Rank	Total installed capacity (million Kilowatts)
United States	1	994.887
China	2	715.53
Japan	3	279.152
Russia	4	220.7
India	5	158.953
Germany	6	132.593
Canada	7	124.7
France	8	116.309
Brazil	9	100.449
Italy	10	93.599

Source: International Energy Agency.

Table 3. *World's top 20 countries of electricity production in 2008.*

Country	Rank	Electricity production (TWh)	National electricity production as a percentage of world electricity production (%)	Per capita electricity production (KWh)
US	1	42390	23.3	14298
China	2	34334	18.8	2631
Japan	3	11340	6.2	8856
Russia	4	9520	5.2	6659
India	5	6790	3.7	620
Germany	6	6190	3.4	13457
Canada	7	5940	3.3	18551
Fance	8	5750	3.2	9479
Brazil	9	4050	2.2	2178
UK	10	3990	2.2	6633
Korea	11	3950	2.2	8175
Italy	12	3020	1.7	5258
Spain	13	2920	1.6	6726
South Africa	14	2450	1.3	5443
Australia	15	2430	1.3	12126
Mexico	16	2330	1.3	2261
Ukraine	17	1850	1	3936
Saudi	18	1760	1	7056
Iran	19	1690	0.9	2488
Turkey	20	1620	0.9	2231

Source: International Energy Agency.

Table 6. *Unit root tests of all variables (except policy variables).*

Variable	No. of Unit Root	Trend	Significance level
LnPROD	1	Y	5%
LnF	2	Y	5%
LnPe	1	N	5%
LnRINCOME	1	Y	5%
LnRGDP	1	Y	5%
LnCAP	1	Y	5%
LnPc	1	N	5%

Table 7. *Johansen test of all variables involved in models.*

Sample (adjusted): 1982 2009
Included observations: 28 after adjustments
Trend assumption: Linear deterministic trend
Series: LnPROD LnF LnP_e
Exogenous series: PV SGB SGT MPM LnCAP LnRGDP LnRINCOME LnP_c T
Warning: Critical values assume no exogenous series
Lags interval (in first differences): 1 to 3

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.820505	74.10824	29.79707	0.0000
At most 1 *	0.573510	26.01525	15.49471	0.0009
At most 2	0.074063	2.154573	3.841466	0.1421

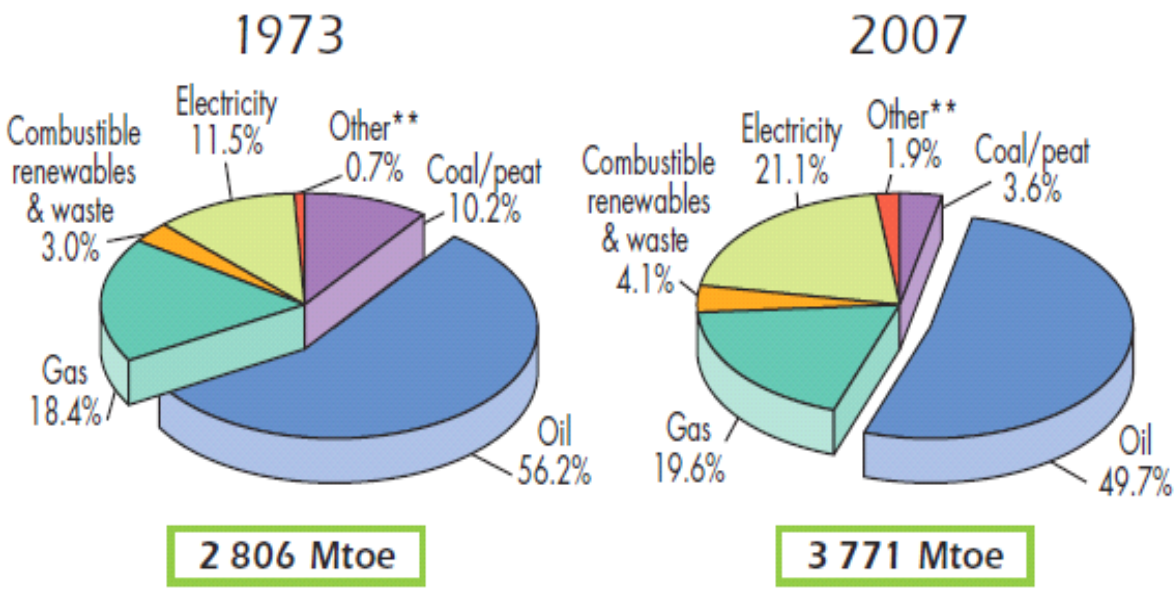
Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.820505	48.09299	21.13162	0.0000
At most 1 *	0.573510	23.86068	14.26460	0.0012
At most 2	0.074063	2.154573	3.841466	0.1421

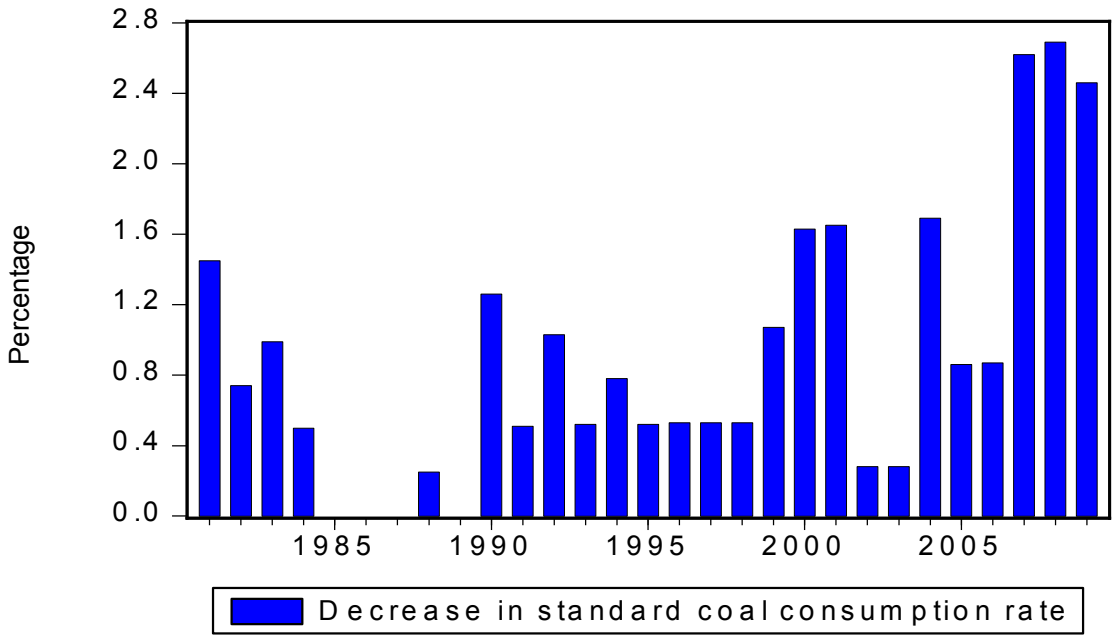
Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Figure 1. *World's 1973 and 2007 fuel shares of total final energy consumption.*



Source: *Key World Energy Statistics* (2009).

Figure 7. *Decreases in standard coal consumption rate.*



Source: *China Statistical Yearbook* (1982-2009).

Figure 10. *World's top10 producers of electricity from fossil fuels.*

Coal/peat	TWh
People's Rep. of China	2 656
United States	2 118
India	549
Japan	311
Germany	311
South Africa	247
Australia	194
Korea	171
Russian Federation	170
Poland	148
Rest of the world	1 353
World	**8 228**

2007 data

Oil	TWh
Japan	156
Saudi Arabia	104
United States	78
Mexico	52
Indonesia	38
Italy	35
Kuwait	35
People's Rep. of China	34
India	33
Iraq	33
Rest of the world	516
World	**1 114**

2007 data

Gas	TWh
United States	915
Russian Federation	487
Japan	290
Italy	173
United Kingdom	164
Islamic Rep. of Iran	160
Mexico	126
Thailand	97
Turkey	95
Spain	93
Rest of the world	1 527
World	**4 127**

2007 data

Source: *Key World Energy Statistics* (2009).

Figure 11. *Variables in level form.*

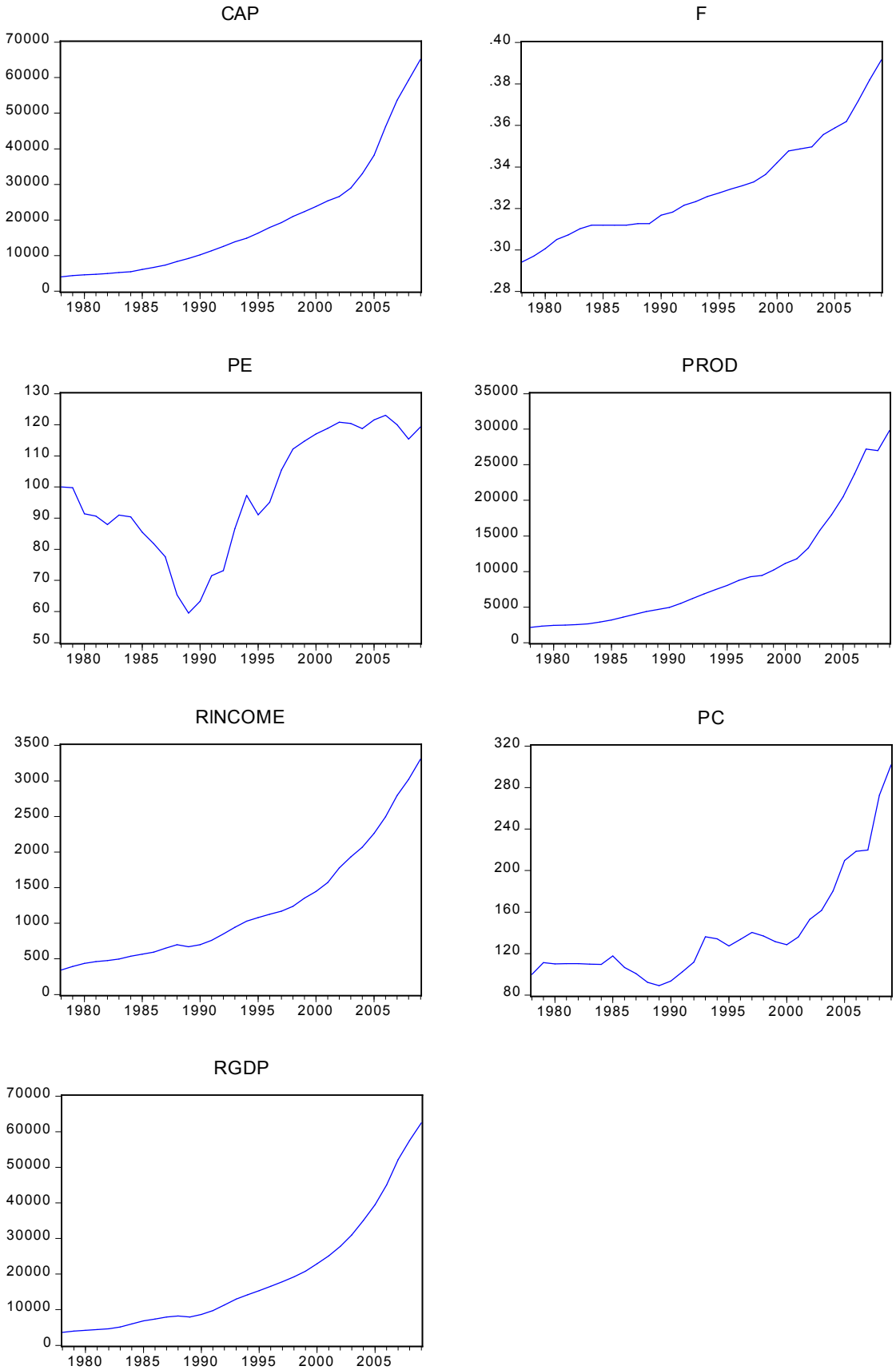


Figure 12. *Variables in logarithm.*