Lurching towards Markets for Power:

China's Electricity Policy 1985-2007

Xiaoli Zhao[i , iii, *] , Thomas P. Lyon[ii], Cui Song[i , iii]

Abstract

China's electricity industry has experienced two major stages of development: from 1949 to 1984, the industry was treated as a subordinate sector whose goal was to support the development of other industrial sectors; since 1985, a series of reforms in its governance mechanisms have been carried out. This paper applies transaction-cost analysis to provide a new perspective on the efficiency of these reforms, emphasizing changes in the areas of electricity prices and investment incentives. We argue that the governance reforms successfully ended the significant social welfare losses resulting from the severe power shortages of the previous 30 years, introduced real or potential competition, and encouraged technological progress. However, they also led to low operational efficiency and excessive investment in power generation plants. Our empirical analysis, uses panel regression models, shows that by 2003 the reforms led electric capacity to increase tremendously. Meanwhile, the electricity price reform in 1996 promoted power generation corporations more responsive to electricity demand and price signals to some extend. However, it can not be proved that the electricity price reform in 2003 (and the dismantle reform at the end of 2002) affect electricity generation corporations in the same way.

Key words: Power market reform; Electricity policy; China; Efficiency; Transaction cost economics

JEL Classification：Q43

[i] School of Economics and Management, North China Electric Power University, Beijing, China.
[ii] Erb Institute for Global Sustainable Enterprise, University of Michigan, Ann Arbor, USA. E-mail: tplyon@bus.umich.edu
[iii] Institute for Low Carbon Economy and Trade, North China Electric Power University
* Xiaoli Zhao, corresponding author, E-mail: email99zxl@vip.sina.com; Tel: 86-13910778294

1. Introduction

Due to rapid economic development and increasing energy consumption, the Chinese government faces growing pressure to maintain a consistent balance between energy supply and demand [1]. A growing shortage of electricity in China forced decision-makers to begin making major changes in electric utility investment and price policies in 1985. Since then, China's electricity industry has gradually moved from a strictly state-owned industry to an industry characterized by investment from various sources including local governments, private enterprise and collective ownership. From strict state-controlled prices, China has moved to markets with competitive wholesale prices. Although the economic literature suggests that governance choices can have potentially large effects on efficiency [2], economists have made few attempts to quantify the effects of these major changes in China's governance practices on performance. In this paper we take a first step toward filling this gap.

Investments in the electric utility industry are characterized by asset specificity and large sunk costs, which invite regulatory opportunism. That is, once a public utility has made a sunk investment in facilities, it is vulnerable to being held up by regulators trying to keep prices as low as possible [3]. At the same time, regulated firms may attempt to opportunistically push through excessive investments at inflated prices, since they possess information not known to regulators. Thus, it is to be expected that the design of regulation may have significant impacts on investment patterns, and hence economic efficiency. It is on these effects that we focus.

The rest of the paper proceeds as follows. Section 2 reviews the existing literature;

Section 3 explains the history of China's electricity market reforms; section 4 analyzes the impact of China's electricity market reforms on efficiency from a transaction-cost economics (TCE) perspective; section 5 introduces the panel regression model we use to empirically study the impact of electricity market reform on efficiency improvement; and section 6 concludes.

2. A Literature Review

A number of studies have examined the development of the electricity industry in China. These studies can be placed into three different groups. The first group focuses on the characteristics and efficiency of electricity market reforms. Ma and He (2008) characterized China's electricity market reforms as falling into five distinct stages [4], while Philip et al. (2003) divided them into four stages, taking Guangdong province as an example [5]. Philip and Dow (2000) emphasize that China's electricity industry is larger and more complex than that of any other developing nation. [6].

The second group of studies focuses on pollutant emissions associated with the development of the electricity industry [7-10]. One of the key conclusions from these papers is that high levels of perfluorocompound and greenhouse gas emissions from electricity generation in China are largely due to the dominant role of coal in the power generation sector, and the relatively low efficiencies in all the sub-stages of the industry from resource extraction to final energy consumption [8].

The third group of papers focuses on the relationship between economic growth and electric industry development [11-14]. This work finds unidirectional Granger causality running from electricity consumption to real GDP but not vice versa during the period 1971 to 2000 [11], and the same conclusion was obtained for the period 1978 to 2004 [12]. During the 1990s, rapid growth in power demand from the residential, commercial and industrial sectors contributed substantially to power shortages, but supply side factors were even more important, particularly the slow response of power plant construction to demand growth. [14]

The foregoing studies of electricity and industry development in China provide many valuable insights into the importance of electric power capacity for China's economic growth. However, they have not studied how the various Chinese reforms of pricing and investment mechanisms affected the rate of power plant construction. In this paper we apply TCE to assess the reforms and their impact on electric utilities after 1985, focusing on how they influenced investment strategies for private firms and for firms owned by local governments.

3. Review of China's Electricity Market Reforms

China's electric utility industry has gone through two major stages. During the first stage, from 1949 to 1984, the industry (like other energy industries) was treated simply as a means to an end, that is, as a subordinate sector whose goal was to support the development of other industrial sectors. Its own performance and improvement in management efficiency received little attention, and a highly centralized administrative mechanism was deemed suitable for such instrumental aims.

3.1 Stage One: 1949 - 1984

Within this first stage of the electric industry, four critical phases can be identified that had great impact on the management of China's power generation and distribution during this first stage of industry growth. The first occurred in the 1950s, when the Soviets had a major influence on the country, leading to a highly centralized administrative mechanism that dominated China for years to come. The second was the disastrous Great Leap Forward period, from 1958 to 1960, when the Chinese government required vast increases in iron and steel production, and energy consumption increased rapidly. The third key phase was the Cultural Revolution from 1966-1976, during which China's economic development was largely blocked, and energy demand increased slowly. The fourth was the market reform of 1978; from then on, China's economy embarked upon a rapid development path, and power supply shortages became increasingly severe.

Throughout the first stage of the industry, China's electricity prices were held below average costs [15], making it impossible for the sector to finance its own investment, and ultimately seriously hindering the industry's development. The socialist economy was organized into work units (*danwei*), which paid for the electricity used not only at work, but also in the *danwei* housing where workers lived. Electricity was considered an entitlement, and as a result of the very low electricity price, people used power profligately. Like the government-supplied water coming out of the taps, which was also essentially unpriced, it was simply there to be used.

In the mid 1980s, the shortage of power became increasingly serious, and began to have serious negative impacts on industrial production, as well as on the living standards of the citizenry [16]. For example, homes and places of work were required to minimize their use of power during the day so factories would have enough power. In the late 1980s, even in large cities, students were often unable to read the books in university libraries in the late afternoons due to a lack of electricity.

3.2 Stage Two: Reform

In order to mitigate the huge imbalance between the quantity demanded at below-cost prices and available capacity, the Chinese government issued a series of important electricity regulatory policies. In 1985, the policy documents entitled “Interim Provision on Promotion Fund-Raising for Electricity Investment and Implementing Multiple Electricity Prices” and “The Measures of Implementing Multiple Electricity Prices” were issued. The major elements in these two policies were presented by Ma and He (2008) [4]. These two policies succeeded in changing the shortage situation of China’s electric capacity. Indeed, from the mid-1990s to the first decade of the 21st century, China experienced a surplus in electricity supply [15]. This was due in part to the rapid growth in electricity supply unleashed by the new investment policies. The other factor was the electricity demand reduction caused by the Southeast Asian Financial Crisis in 1997. Regardless, the excess supply led to a strict control of electricity investment by the Chinese government from 1998 to 2001, which resulted in a renewed electricity supply shortage in 2002[15].

The new period of short supply was short-lived. In fact, the breakup of the vertical monopoly held by the State Power Corporation (SPC) that was pursued in 2002 promoted a second investment rush in electricity generation. In December 2002, the SPC was dismantled and five big independent power generation corporations were set up. The competition of pursuing resources between the five corporations that was thereby promoted greatly accelerated investment in power capacity in 2003, as can be seen in Figure 1. However, coal prices rose sharply in 2003, which led to a drop in new power capacity in 2004. From 2004 to 2007, however, the number of new power generation plants in China jumped by over 400%.

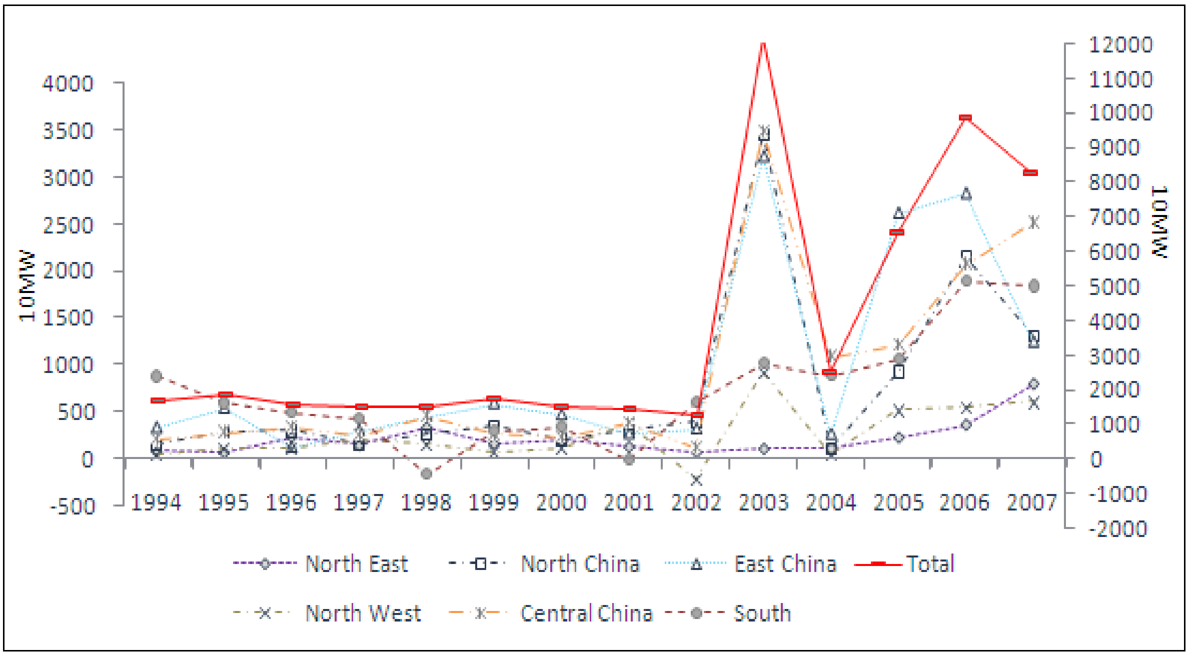

Figure 1: New power capacity in China[1]

("Total" is measured against the right side units, and the others are on the left.)

With rapid growth in electricity capacity, the electricity supply shortage was mitigated to some extent. However, the shortage was not resolved completely because of a related shortage in the supply of coal. This shortage had several causes. First, a lack of railway capacity made it difficult to ramp up delivered supplies to accommodate the growth of new coal-fired power plants. [17]. Second, until the early 1990s, the Ministries of Coal, Railways and Power held annual meetings at which the quantities of coal produced and sent to power plants were negotiated, and prices set. The lack of a market mechanism meant that coal supplies were unresponsive to shifts in demand. Third, when coal price reform was finally started, it was uneven. The price of coal was reformed to float with demand but electricity prices were still largely fixed, and hence power corporations were not able to pass the continuously increasing costs of coal on to their customers. Thus, many thermal plants simply refused to buy coal, leading directly to shortfalls in production. Another ramification of the uneven pricing reforms was that coal could be sold to buyers other than power generation companies on the spot market. Mines therefore had incentives to limit sales to power plants and divert supplies to other, more profitable, sectors.

In sum, during the second half of the twentieth century, China's centralized electricity management system led to severe problems in the allocation of energy resources, as would be predicted by standard price theory. By 1985, persistent shortages had motivated various reforms that helped to bring forth new generation capacity. Nevertheless, the continued reliance on government-controlled prices rather than markets led to dramatic swings from power shortages to excess supply and back again. Chinese officials were also slow to recognize that price controls in the coal market would be reflected in the market for electricity.

4. The Impact of China's Electricity Market Reform on Efficiency: Analysis from TCE Perspective

4.1 Electricity Price Reform and Efficiency

4.1.1 Reform of delivered price and efficiency

Since early 1980s China has stressed to introduce market oriented mechanism to improve the efficiency in electricity utility. In 1980, China introduced the time of use power price (the price is higher than normal in the period of peak power using, while it is lower in the period of trough power using) on final demand side on pilot. And in 2003, China launched the policy entitled "Notice on Adjustment of Power Price (SDRCE[2], 2003[124])" to extend the scope of time of use power price.

In 1993, China adjusted the catalog price from 6 groups to 8 groups. Under the new catalog price, commercial price , agriculture irrigation and drainage price of impecunious county were added. Internal transfer price was cancelled. This adjustment helped to balance supply and demand, but also allowed for opportunistic behavior on the part of some commercial customers since the residential power price was much lower than industrial and commercial price (subsidies is given to residential power price, and thus residential house or apartment would be used for commercial behavior to enjoy lower power price). As China transitioned (and continues to make this transition in the central and western regions) from a planned economy to a market socialist economy, there was (still is) room for a lot of power theft. Homes and businesses of course want to enjoy the subsidized price of power for as long as possible.

Another reform in delivered price was the implementation of discriminated price for high energy-intensive industries. Since 1980s, the power demand of industries has increased at great rapid speed (Figure 2). One of the major drivers behind such rapid growth (especially after 2002) was the quick development of energy-intensive industrial sectors. In order to lower the excessive increase speed of energy-intensive sectors, the discriminated price policy was published. The major associated document was "Notice on

Further Implementation of Discriminative Power Price and Charges on Self-owned Power Plant (SDRCE 2004 [159])", which aimed to reduce the growth rate of high energy-intensive sectors by increasing electricity price used in energy-intensive sectors.

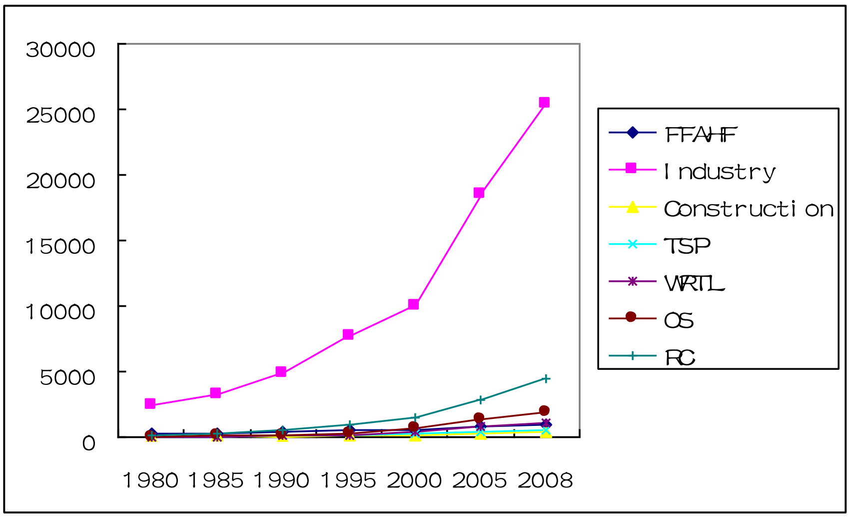

Figure 2: Electricity use at sector level (100GWh)
Data source: China Statistical Yearbooks (1996, 2010)
FFAHF: Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy;
TSP: Transport, Storage, Post;
WRTL: Wholesale and Retail Trade, Lodging and Catering;
OS: Other sectors
RC: Residential consumption

4.1.2 Reform of on-grid power price and efficiency

In order to resolve the serious shortage in electricity supply before 1985, the Chinese government carried out "Capital and Interest Price" in 1985 and "Operation Period Price" in 1996 for new power plants. Both the two types of price belong to cost-plus regulation price (or rate of return price). Under such price mechanism, the profit can be guaranteed and thus the investment in power generation plants was encouraged greatly. However, on the other hand, the new power generation plants had the opportunism to overstate their cost in order to get higher on grid price. Most plants built during that period were high cost and low energy efficiency. Especially, under the capital and interest price, the repayment of investment cost could be recovered in short time, most investors at that time chose small units to be built since small units needed less capital and simpler approval procedure although small units were low efficiency. At the end of 1996, the average thermal power unit capacity was only 46MW [18] (According to the data of China Electricity Council: by the end of 2009, the thermal power unit capacity with 300MW has accounted for about 70% of the total thermal power capacity, and most thermal power units with less than 100 MW have been shut down in order to improve energy efficiency).

The Chinese government has carried out yardstick power price since 2004. Yardstick power price has been proved by TCE as an efficient governance structure. These was a growing support among both academics and policy practitioners for price-cap regulation (Yardstick power price has the characteristic of price-cap power price) as an alternative to rate-of-return regulation in the relative regulatory policy discussions [19, 20]. Joskow (1991) argued further that incentive mechanisms aimed at promoting efficient supply had focused on “yardstick” comparisons for specific components of electricity costs [3].

4.2 Electricity Investment Reform and Efficiency

4.2.1 Investment reform in principal and efficiency

In 1985, the policy document of “Interim Provision on Promotion Fund-Raising for Electricity Investment and Implementing Multiple Electricity Prices” was issued. One of its important content was to encourage various investors, such as private investors, local government investors, and foreign investors to get access to electric power generation plants. In order to induce more investment into power generation, the Chinese government allowed very high earned rate of return on power generation plants [4]. Especially, the earned rate of return of foreign investment was about 13% to 18%, even 20% [7], much higher than the average earned rate of return at that time.

The most significant contribution of the investment reform in principal in 1985 was to attract vast capital in power generation plants construction in short time. One of the remarkable effects of the investment reform in principal and efficiency would be the construction of the Ertan Hydropower Station, which was started to be build in 1991 and was completed in 2000. The investors of Ertan Hydropower Station included the State Development Investment Corporation, Sichuan Investment Group Corporation, and Sichuan Electric Power Corporation. The other famous Hydropower station in China was the Three Gorges Project (the largest hydro project in the world). Much investment of the Three Gorges Project came from the public by the ways of issuing bond and stock.

Since mid-1980s, China's new power capacity has increased quickly [21] and within 10 years the severe shortage in power supply had been ended temporarily. The shortage before mid-1990s had ever caused huge economic losses. In 1993, $27.6 billion of industrial value added was lost due to power shortages, the equivalent of seven percent of GDP [22]. Hence, the rapid growth in power generation investment has stopped such huge economic losses since the mid of 1990s.

On the other hand, in order to avoid the complicated central government approval process for large plant and to minimize risk, the power generation plants which were no more than 200MW ranked the first place, while large scale power generation plants which were more than 600 MW (including 600 MW) took up the least proportion before mid-1990s (Figure 3). From this aspect, the investment reform in principal in 1985 has also negative impact on social and economic efficiency improvement to some extent.

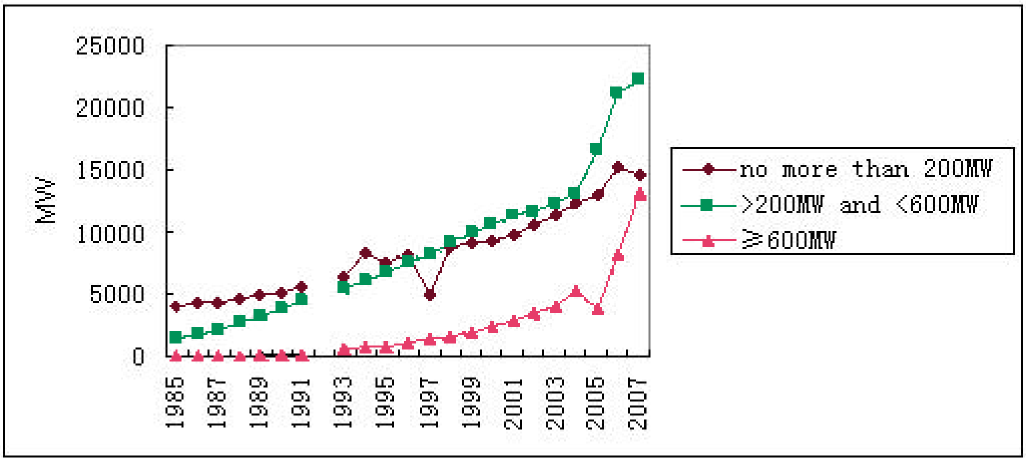

Figure 3: Change of Size of generating units[3]

Data source: China Electric Power Yearbooks; Collections on Electrical Industries Statistics

4.2.2 Investment reform embodied in the break of vertical monopoly and efficiency

The break of vertical monopoly at the end of 2002 promoted the second investment rush in power generation in China. From 2003 to 2007, new power generation plants increased at a very high growth rate in China. The new established Big Five Power Producers (FPGCs: Huaneng Group, Datang Group, Huadian Corporation, Guodian Corporation, and Power Investment Corporation), whose assets came from the previous SPC and has been totally independent from the State Grid Corporation since 2003, had great enthusiasm in investment in power plants driven by competition.

Another result of the investment reform embodied in the break of vertical monopoly in 2002 was the efficiency of China's electricity utility has been improved greatly. The new power plants built after 2002 focused on big scale generation units (Figure 3). Figure 4 shows that since 1997, China's SO2 emission in electric power industry has taken on rapid decrease trend. Especially after 2005 the decrease began to accelerate. Such change was attributed to two factors: one was policies. China's electricity reform after mid-1990s has attached more importance to the improvement of efficiency rather than to improve power shortage only. The other factor was corporation's pursuance of benefits. With the enforcement of yardstick on grid price and competition on grid price, corporations with higher efficiency would obtain more benefits. The energy efficiency in power generation has been improved remarkably.

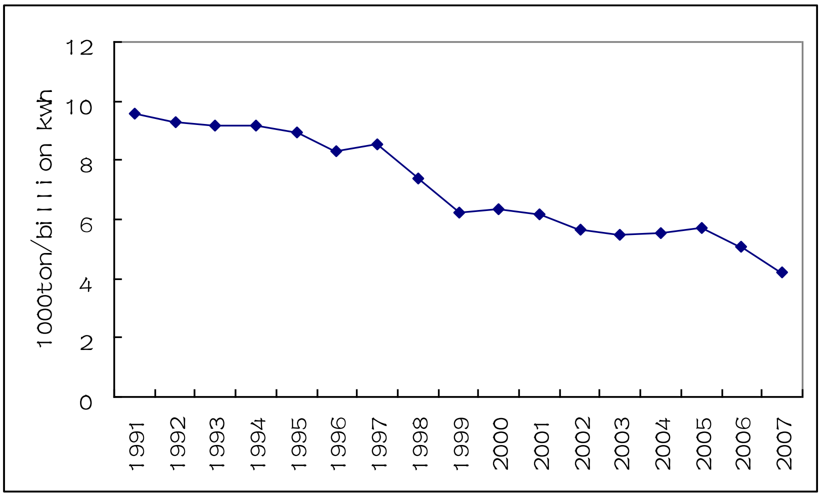

Figure 4: SO2 emission in Chinese thermal electric power industry

Data source: China Statistic Yearbooks

4.2.3 Investment reform in technological progress and efficiency

There existed high complex or unpredictable contexts for the investment in technological progress in electricity utility. Crocker and Mastern (1996) argued that "In complex or unpredictable environments, transaction costs are likely to be minimized by removing exchange decisions from the market context and substituting the continuous oversight that regulatory mechanisms entail."[2] The Chinese government has taken many encouragement measures on technological progress in electricity utility to improve economic efficiency.

Two types of investment in electricity utility would need to be given more attention. One was the investment in extra-high voltage grid network. China's coal mines are concentrated in West regions, while electric power load center is in eastern coastal regions. In order to reduce energy loss during the transmission of power, the State Grid Corporation started to consider construct extra-high voltage grid network in 2004. It was planned that more than 400 billion RMB Yuan investment were to be spent to construct the Super-grid Network within 15 years in China[4].

The whole national Grid was grouped into 6 Regional Grids in China: South Grid, North East Grid, North China Grid, East China Grid, North West Grid, and Central China Grid. Among these Regional Grids, electricity shortage existed in the South Grid, North China Grid, and North East Grid; balance in East China Grid in general; while electricity surplus in North East Grid and North West Grid. However, it was difficult for deficit regions to get power from surplus areas due to the barriers from Grid structures and exchange mechanism. It is definite that the construction of extra-high voltage grid network favors power exchange across different Regional Grids and energy efficiency improvement during power transmission process. However, the potential technical and safety issues would be still a challenge faced by China.

The other important technological progress investment was the one in the renewable energy (RE) development fields. In many countries around the world policies have been formulated with the objective of decreasing carbon dioxide emissions and many countries have also formulated policies to increase the share of renewable energy [23]. China has abundant solar energy resources. More than two thirds of China receives an annual total solar energy that exceeds 1,639 kWh/m^2 with more than 2,200 hours of sunshine a year. Wind energy potential in China is about 3,200 GW, of which 253 GW is deemed technically exploitable [24]. The Chinese government acknowledged the importance of RE for its energy security and has voiced ambitious targets. The share of RE in the total installed electricity generation capacity is supposed to be raised to 15% in 2020 [25].

5. Empirical Investigation of China's Electricity Market Reform Impact on Efficiency

5.1 Method and Data Collection

5.1.1 Pooled regression model

In this part, we focus on the impact of electricity reform policy on increased capacity (major represent the social efficiency improvement). As we know, China's electricity market is regulated by central government, and local government has little power on publishing relative policies, hence we take all the provinces as a similar part of the whole country. That means we choose the pooled regression model to analyze the problem. The measurement model is given as follows:

$$y_{it} = \beta_1 + \sum_{k=2}^{K} \beta_k x_{kit} + \mu_{it} \qquad (1)$$

Where β means the coefficient of each province, μ means the remaining random effect of other factors which may not be considered. Or,

$$Y = X\beta + U \qquad (2)$$

Where,

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_N \end{bmatrix}_{NT\times 1}, X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_N \end{bmatrix}_{NT\times K}, \beta = \begin{bmatrix} \beta_2 \\ \beta_3 \\ \vdots \\ \beta_K \end{bmatrix}_{K\times 1}, U = \begin{bmatrix} U_1 \\ U_2 \\ \vdots \\ U_N \end{bmatrix}_{NT\times 1} \tag{3}$$

In order to identify the impact of electricity market reform on electricity capacity, we set up the pooled regression model as Eq. (4). We choose the variables of change in GDP, ΔGDP, change in population ΔPP, capacity utilization $\Delta CapUtil$, industrial structure change ΔSTR——Many studies, have proved industrial structure played a dominant role on energy demand [26, 27], and it is defined as the change in proportion of industrial added value to GDP; change in electricity price ΔPR; year trend variable T and market reform policy D_1, D_2. We define D_1 and D_2 as follows:

D_1 = 1 for the years 1996-2002 and 0 otherwise (in 1996, the "operation period price" was implemented);

D_2 = 1 for the years 2003-2007 and 0 otherwise (in 2003, the "yard stick power price" was implemented; and at the end of 2002, the SPC was dismantled).

Meanwhile, in order to identify the impact of policy on electricity investment, the interacting variables of price and utilization with the policy variables are also included in the model. Choose ΔCAP, power generation capacity change as explained variable. Then the equation is as follows:

$$\begin{aligned} \Delta CAP_{it} = f(&\Delta GDP_{it}, \Delta PP_{it}, \Delta CapUtil_{it}, \Delta STR, \Delta PR, D_{1t}, D_{2t}, T, \Delta CapUtil_{it} * D_{1t}, \\ &\Delta CapUtil_{it} * D_{2t}, \Delta PR * D_{1t}, \Delta PR * D_{2t}) \end{aligned} \tag{4}$$

Where i and t indicate the chosen provinces and the study period respectively.

We estimate ordinary least squares (OLS) and both random- and fixed- effects models of the effect of China's electricity market reform policy on capacity growth. We start by pooling all the results without fixed or random effects, and then include provincial random and fixed effects. The Hausman test shows that the results of fixed-effects are preferred than that of random-effects (Appendix 2).

In an effort to further ensure the robustness of our findings, we explore the consequence of relaxing the assumption that past behavior has no effect on current investment. We do this by including one lag of the dependent variable to allow previous investment decisions ΔCAP_{it-1} to affect current investment behavior, as has been found to occur in a variety of other investment settings. This dynamic specification is as shown in Eq. (5):

$$\begin{aligned}\Delta CAP_{it} = f\,(&\Delta CAP_{it-1}, \Delta GDP_{it}, \Delta PP_{it}, \Delta CapUtil_{it}, \Delta STR, \Delta PR, D_{1t}, D_{2t}, T, \\ &\Delta CapUtil_{it} * D_{1t}, \Delta CapUtil_{it} * D_{2t}, \Delta PR * D_{1t}, \Delta PR * D_{2t})\end{aligned} \quad (5)$$

5.1.2 Data collection

The Electrical Industry Statistical Yearbook (EISY) has not been published until 1993; hence our study period is 1993 to 2007. The data of industrial added value and GDP is collected from China Statistics Yearbooks (1993-2008). The data of industrial added value and GDP is converted to the constant price based 1993 using ex-factory price index of industrial products and GDP index respectively. The data of capacity change ΔCAP is obtained from the Electrical Industry Statistics Compiles (EISCs) (1993-2007). The data of average working-hours of power plants is also from EISCs (1993-2007). The electricity price is the ratio of the revenue and quantity of electricity sales, and the data of revenue and quantity of electricity sales is collected from EISYs (1993-2005) and the Annual Supervise Report of Power (2006-2007).

There are 31 provincial entities in China. Chongqing municipality was separated from Sichuan in 1995, for the sake of consistency, we combine Chongqing with Sichuan. As a result, the number of provincial entities that should be included in the final analysis is 30. Constrained by the data collection of electricity price, only 17 provincial entities can be analyzed with electricity price. In order to illustrate the representativeness of the sample, we provide the comparative results of the Capacity, Real GDP, Population, Share of GDP contributed by Industrial Sector and Capacity Utilization in 17 provincial entities used for estimation to national average in Appendix 1. Meantime, Yuan (2006) divided China into 7 zones according to the economic development level, and these 17 provincial entities locate in the 7 zones respectively.

The data descriptive statistics of relative variables is reported in Table 1.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
Capacity (MW)	255	1042.73	779.66	89.72	5112
Real GDP (Million RMB Yuan)	255	1197.74	863.47	83.94	3489.01
Population (Ten Thousand)	255	3739.16	2721.64	467	11847
Capacity Utility (TWH)	255	5006.59	1245.69	2115	10011
Portfolios of Industrial Added Value to GDP	255	0.0984	0.0466	0.0414	0.2785
Electricity Price (RMB Yuan/Mwh)	255	338.27	124.06	105.165	725.17
Change in Log of GDP	238	0.0162	0.035	-0.9945	0.1849
Change in Log of Population	238	0.0043	0.0078	-0.3182	0.0553
Change in Log of Capacity Utility	238	0.0016	0.0335	-0.1423	0.0891
Change in Portfolios of Industrial in GDP	238	0.0933	0.0369	0.0414	0.2785
Change in Log of Electricity Price	238	0.0273	0.0747	-0.2576	0.4668

5.2 Result and discussions

In this section, we present a series of regressions that explore the determinants of investment in electric generation capacity in China over the period of 1993 to 2007. In Table 2, estimation (1) and (2) report the results of static model, while estimation (3) and (4) present the results of dynamic model. Estimation (1) shows province-level fixed effects of the rate of growth in power generation capacity. These variables explain 36.3 percent of the variation in power capacity growth. Industrial structure change has the most relatively important positive relation with the growth. On the other hand, the capacity utility change has negative relation with the growth. Such a result seems conflict with what we expected. However, in China more than 90% of power capacity was controlled by government, about 6% of power capacity was administrated by private or foreign investments [4]; such property structure means that most power corporations in China (which are owned by central and local government) pursue more market share while ignore comparatively profit rate. As a result, power generation capacity increases amid utilization decreases.

We have more interests in the impact of policy on the power generation capacity growth. In our study, the dummy D_1 represents the electricity market reform implemented in 1996; D_2 represents the yardstick price reform in 2003 and dismantlement reform at the end of 2002. The P value of D1 in Table 2 shows that after the year 1996 ("Operation period price" was carried out), the power capacity change was insignificant. However, the P value and coefficient of D_2 show that after the dismantlement reform at the end of 2002 and yardstick price reform in 2003, the power capacity increase was promoted. The competition introduction by breaking-up of the vertical monopoly encouraged the FPGCs to expand their market share, and as previous discussion, this would be one of the significant drivers behind China's electricity investment rapid increase after 2003.

Table 2: Static and Dynamic Models of Power Capacity Growth[5]

	(1) Static	(2) Static	(3) Dynamic	(4) Dynamic
D1	-0.004	0.003	0.000	0.004
	[-0.537]	[0.303]	[0.020]	[0.413]
D2	0.027***	0.045***	0.033***	0.044**
	[3.986]	[2.762]	[4.121]	[2.590]
dlogCAP(-1)			-0.010	-0.012
			[-0.141]	[-0.170]
dlogGDP	0.101	0.100	0.060	0.064
	[1.284]	[1.270]	[0.680]	[0.720]
dlogPP	0.233	0.231	0.246	0.243
	[0.904]	[0.897]	[0.927]	[0.919]
dlogPR	0.018	0.018	0.013	0.014
	[0.580]	[0.566]	[0.315]	[0.339]
dlogCapUtil	-0.488***	-0.503***	-0.618***	-0.616***
	[-3.875]	[-3.988]	[-4.040]	[-4.046]
dSTR	0.262***	0.292***	0.192*	0.216*
	[2.806]	[3.028]	[1.807]	[1.947]
dlogPR*D1	0.125**	0.132**	0.129*	0.132*
	[1.983]	[2.086]	[1.875]	[1.924]
dlogPR*D2	-0.025	-0.044	-0.021	-0.035
	[-0.300]	[-0.512]	[-0.224]	[-0.370]
dlogCapUtil*D1	0.221	0.288*	0.376**	0.405**
	[1.463]	[1.791]	[2.104]	[2.220]
dlogCapUtil*D2	0.014	0.014	0.159	0.145
	[0.080]	[0.078]	[0.795]	[0.727]
Constant	0.007	0.008	0.009	0.010
	[0.795]	[0.932]	[0.950]	[1.039]
Year trend (T)		-0.002		-0.001
		[-1.193]		[-0.718]
Observations (OBS)	238	238	221	221
Province Effects	Fixed	Fixed	Fixed	Fixed
Adjusted R-squared	0.363	0.365	0.353	0.352
Number of groups	17	17	17	17
F-Statistics	6.012	5.860	5.298	5.120
Prob. of F- Statistic	0.000	0.000	0.000	0.000
AR(1) test			0.022	0.041
AR(2) test			0.057	0.050

“dlog” represent “difference log”; * , ** , *** Significant at 10%, 5%, 1% respectively.
AR (1) and AR (2) test denote Arellano-Bond first and second-order autocorrelation tests.

The interacting analysis of electricity price and capacity utility with the policy variable D1 shows that electricity industry becomes more efficient after the reform of year 1996. Estimation (1) implies that power generation corporations are more responsible to the electricity price signals after the reform in 1996. However, the reform of year 2003 (and the reform at the end of year 2002) has little such role to promote power generation corporations more responsible to the price signals. The possible reason would be that after the year 2003, power generation corporations concern much more on the expanding market share, and pay comparatively little attention on the electricity price signals.

Estimation (2) adds a year trend variable, and it turns out that the impacts of capacity utilization, industrial structure, and the reform in 1996 on electricity investment are strengthened. At the same time, the interacting effect of capacity utility with policy variable D1 becomes statistically significant, that means power generation corporations became responsible to the demand signals after the reform in 1996. The above results probably were caused by the following reasons: first, over the study period 1993 to 2007, the Chinese government had carried out a series of energy market reforms to increase the coal, electricity and oil price step by step (Zhao, et al, 2010). These measures promoted relative energy supply including power capacity increase. Second, with the deepening of power market reform over the study period 1993 to 2007, especially after the year 1996, power generation corporations have paid more attention on the power demand signals. However, the interacting effect between capacity utility and policy variable D2 keeps still statistically insignificant. That implies once more that after the power market reforms in 2003 (and at the end of 2002), power generation corporations concern much more on the expanding market share, and not only pay comparatively little attention on the electricity price signals, but also on power demand signals.

Estimations (3) and (4) provide the dynamic models of capacity growth. The models offer strong support for the results found in our static regression. Estimation (3) is a fixed-effects regression of the rate of growth in power capacity without the year trend variable. These variables explain 35.3 percent of the variation in power capacity growth. In this model, the impact of change in capacity utility, industrial structure, and interacting effect of capacity utility and policy variable D1 is greater than estimation (1). Estimation (4) presents the model with the year trend. We found that the impact of change in industrial change and interacting effect of capacity utility and policy variable D1 are much greater. Another interesting finding is that the interacting impact of electricity price and policy variable D1 has become more statistically significant both in estimations (3) and (4) comparing with that in estimations (1) and (2).

In the model of estimation (3) and (4), the coefficients on dlogCAP(-1) are close to zero. This would be caused by the potential downward bias on the persistence parameter. In order to correct the possible potential downward bias, we use Arellano and Bond (1991) estimator to correct it [28]. And we report the parameter estimates in Table 2 in accordance with Yu and Chen (2011) [29].

Overall, our empirical results offer robust and consistent evidence that China's industrial structure change has great positive impact on power capacity increase. And after the power market reform of 2003 (and the dismantle reform at the end of 2002), the capacity increase is faster than that of previous the reform. Meanwhile, the electricity price reform in 1996 promoted power generation corporations more responsive to demand and price signals to some extend. However, it can not be proved that the reform in 2003 (and the dismantle reform at the end of 2002) affect electricity generation corporations in the same way. At last, an interesting finding is that the impact of capacity utility change is negative, and it seems adverse with what we imagined. However, it would be one of reflection of China's special reality (see both Figure 1 and Figure 5), and the drivers behind the surprising phenomenon would be the competition on possession of relatively rare resources (coal mine) and expanding market share between power generation corporations and soft constraints of profit performance (the loss will be burdened by the government instead of those corporations).

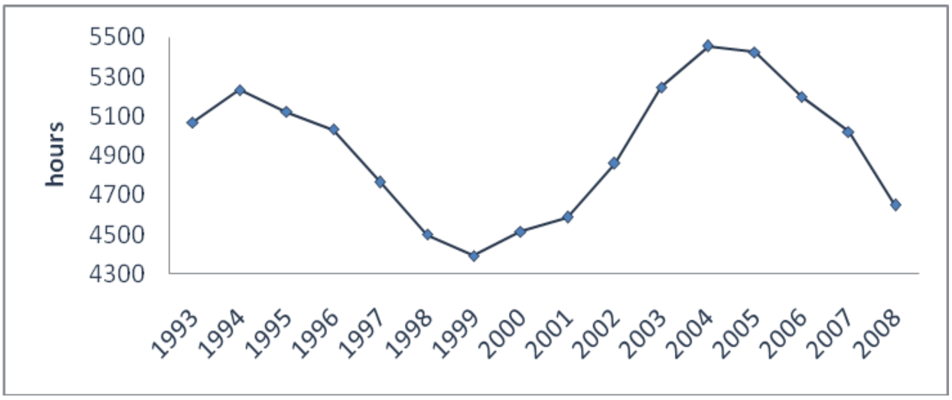

Figure 5: Power capacity utility (average utilization hours per year of thermal units) in China

Data source: Collections on Electrical Industries Statistics (1993-2008)

6. Conclusion

This paper has offered an initial analysis of the impact of governance structure changes on China's electric power sector from the perspective of TCE. China's delivered prices went through a major adjustment in 1993. This adjustment has helped to balance supply and demand, but has also allowed for opportunistic behavior on the part of some commercial customers. On-grid prices have experienced three stages of reforms. These reforms promoted the efficiency improvement through increasing electricity supply and reducing opportunism respectively.

China's investment reforms in electricity market have promoted efficiency improvement greatly. Since 1985, vast capital flowed into power generation market, and huge economic losses and social welfare losses from shortage in power supply before mid-1990s have been ended basically. The break of vertical monopoly in electricity industry in 2002 promoted the second investment rush in power generation. And this reform had more efficiency with focusing on big scale generation units building. With time going, Chinese government has paid more attention to investment incentive in technological progress which would promote efficiency improvement with better control of risks from irreversibility and asset specificity.

At last, a pooled regression model is set up to make the empirical investigation on the impact of electricity market reform on power generation capacity increase. The results present that the price reform in 1996 promoted power generation corporations more responsive to demand and price signals to some extend. However, it can not be proved that the reform in 2003 (and the dismantle reform at the end of 2002) affect electricity generation companies in the same way. Hence, in order to improve electricity industrial efficiency further, market-oriented reform should be promoted further in future in China.

Acknowledgements

This study is funded by the National Natural Science Foundation of China (Project number: 70773040; 71073053). The authors appreciate Professor Qingyou Yan for his valuable suggestions on the correction of empirical analysis, and Sufang Zhang for her help in the paper's grammar correction. The authors especially appreciate the anonymous reviewers for their careful and valuable comments, for their patience on the improvement of the empirical and theoretical analysis again and again, and we enjoy great benefit of their instructions. These comments and suggestions significantly improve our paper.

References:

[1] Liu Wen, Henrik Lund, Brian Vad Mathiesen, Zhang Xiliang. Potential of renewable energy systems in China, Applied Energy, 2011, 88(2): 518-525.

[2] Crocker J Keith., Masten E. Scott. Regulation and administered contracts revisited: Lessons from transaction-cost economics for public utility regulation. Journal of Regulation Economics 1996; 9: 5-36.

[3] Joskow, P. L. The role of transaction cost economics in antitrust and public utility regulatory policies. Journal of Law Economics and Organization 1991; 7: 53-83.

[4] Ma, C.B., He, L. From state monopoly to renewable portfolio: restructuring Chinese electric utility, Energy Policy 2008; 36: 1697-1711.

[5] Philip Andrews-Speed, S. Dow, A. Oberheitmann, B. Ramsay, V. Smith and B. Wei. First steps in power sector reform: the case of China's Guangdong Province. Utilities Policy, 2003 11 (3): 169-183.

[6] Philip Andrews-Speed and Dow, S. Reform of China's electric power industry. Challenges facing the government, Energy Policy, 2000, 28: 335-347.

[7] Ou Xunmin, Zhang Xiliang, Chang Shiyan, Guo Qingfang. Energy consumption and GHG emissions of six biofuel pathways by LCA in (the) People's Republic of China, Applied Energy, 2009, 86(1): S197-S208.

[8] Ou Xunmin, Yan Xiaoyu, Zhang Xiliang. Life-cycle energy consumption and greenhouse gas emissions for electricity generation and supply in China, Applied Energy, 2011,88 (1): 289-297.

[9] Zhou Wenji, Zhu Bing, Sabine Fuss, Jana Szolgayova, Michael Obersteiner, Weiyang Fei, Uncertainty modeling of CCS investment strategy in China's power sector, Applied Energy, 2010, 87 (7): 2392-2400.

[10] Liang Xi, Reiner·David, Li Jia, Perceptions of opinion leaders towards CCS demonstration projects in China. Applied Energy, 2011, 88 (5): 1873-1885.

[11] Shiu Alice, Lam Pun-Lee. Electricity consumption and economic growth in China. Energy Policy, 2004, 32: 47–54.

[12] Yuan Jiahai, Zhao Changhong, Yu Shunkun, Hu Zhaoguang. Electricity consumption and economic growth in China: Cointegration and co-feature analysis. Energy Economics, 2007, 29: 1179–1191.

[13] Lin Boqiang. Structure change, efficiency improvement, and electricity demand forecasting (in Chinese). Economic Research Journal, 2003, 5: 57-65.

[14] Elspeth Thomson, "Power Shortages in China: Why?", China: An International Journal, vol. 3, no. 1 (Mar. 2005): 155-71.

[15] Huang S. Zh. Review and forecast of Chinese electricity price reform. http://www.serc.gov.cn/jgyj/ztbg/200903/W0 20090309562275051444.pdf. Last access: 3rd July, 2009.

[16] Liu Shujie. Study of electricity price policy for promoting energy saving and renewable energy development. Project Group of Electricity Price Policy, Institute of State Development and Reform Commission, 2005, 6.

[17] Elspeth Thomson. The Chinese Coal Industry: An Economic History. London and New York: RoutledgeCurzon, 2003, 412.

[18] Ren Junsheng. Price Regulation of Chinese Public Utility. Economic and Management Press, January, Beijing. 2002.

[19] Baumol, W. J. and J. G. Sidak. Toward Competition in Local Telephone. Cambrodge. MA: The MIT Press, 1994.

[20] Liston, C. Price-cap versus rate of return regulation. Journal of Regulatory Economics 1993; 5: 25-48.

[21] Tan A. Development and prospects of Chinese electric power industry. Paper presented at International Business Communications Second Congress on Developing and Financing Power Projects in China, December, San Francisco, California. 1997.

[22] Li, B. and Dorian. J. Change in Chinese Power Sector. Energy Policy 1995; 23(7): 619-626.

[23] Henrik Lund, Poul Alberg Ostergaard, Ingo Stadler, Towards 100% renewable energy systems, Applied Energy, 2009, 88 (2): 419-421.

[24] Li Junfeng, Yih-huei Wan, James M. Ohi, Renewable energy development in China: Resource assessment, technology status, and greenhouse gas mitigation potential, Applied

Energy, 1997, 56 (3-4): 381-394.

[25] Schroeder Miriam. Utilizing the clean development mechanism for the deployment of renewable energies in China, Applied Energy, Special Issue of the Third International Green Energy Conference (IGEC-III), 2009, 86(2): 237-242.

[26] Zhao X. L., Yang, J. Comparable Analysis of Key Factors Affecting Industry Energy Consumption between China and Beijing (in Chinese). China Energy 2009; 5: 19-25.

[27] Ang, B.W. Multilevel Decomposition of Industrial Energy Consumption. Energy Economics 1995; 17(1): 39-51.

[28] Arellano Manuel, Bond Stephen. Some Tests of Specification for Panel Data: Monte Carlo Evidenc and an Application to Employment Equations. Review of Economic Studies 1991, 58: 277-197.

[29] Yu xiang Karl, Chen Zhongchang. Government expenditure and energy intensity in China. Energy Policy 2010; 38: 691–694.

Appendix 1: the representativeness of the sample of 17 provinces to national average

	17 provinces	National	Proportion of sample to national
Power Capacity (MW)	265895.2	535833.49	49.62%
Real GDP (Million RMB Yuan)	305424	708357.7634	43.12%
Population (Ten Thousand)	953486	1874495	50.87%
Average Capacity Utility (TWH)	5006.59	4879.36	102.61%
Portfolios of Industrial Added Value to GDP	0.0984	0.1048	93.89%

Appendix 2: Hausman test for Table 2

	Static model				Dynamic model			
	Without year trend		With year trend		Without year trend		With year trend	
Effects Test	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.	Statistic	Prob.
Cross-section F	2.5618	0.0012	2.6038	0.0010	1.8507	0.0274	1.8646	0.0259
Cross-section Chi-square	42.4357	0.0003	43.2597	0.0003	31.6982	0.0109	32.0755	0.0098

$P < 0.05$, Reject the null hypothesis, and cross-section choose Fixed effects.

---

[1] Author's calculation based on China Electric Power Yearbooks (1993-2007).

[2] SDRCE: State Development and Reform Commission Electricity

[3] The data of 1992 is absent.

[4] Data source: http://depute.blog.hexun.com/44528995_d.html, 2010, 1, 27.

[5] In Table 2, the variable of *STR* is a definition of percentage and it is not taken Log any more.