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Gains and Losses from Collusion: an Empirical Study on Market Behaviors of China's Power Enterprises

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Abstract:

Purpose: Collusion is a common behavior of oligarch enterprises aiming to get an advantage in market competition. The purpose of the research is to explore positive or negative effects from the electricity generation manufacturers' collusion through statistical analysis approach. To be exact, these effects are discovered both in market economy at a macro-economic level and in enterprise behaviors at a micro-economic level.

Design/methodology/approach: This research designs a model as an extension of Porter's model (Green & Porter, 1984). In this model FIML is applied. Taking *price bidding* project launched in China's power industry as an example, this paper conducts an empirical research on its relevant price data collected from subordinate power plants of China's five power generation groups in the pilots.

Findings: It is found in this paper that power generation enterprises are facing collusion issues in the market. To be exact, it is such a situation in which non-cooperative competition and collusion alternate. Under the competition, market is relatively steady, thus forming a lower network price. It is helpful to the development of the whole industry. However, once Cartel is formed, the price will rise and clash with power enterprises and transmission-distribution companies concerning the interests conflicts. At the same time, a higher power price will form in the market, making consumers suffer losses. All of these are bad for industry development.

Not only the collusion of power enterprises affects power price but also the market power that caused by long-time Cartel will reduce the market entrant in electricity generation. Market resources are centralized in the hands of Cartel, causing a low effective competition in the market, which has passive effects on users.

Implications: The empirical research also indicates that collusion undoubtedly benefits the power enterprises that involved. As a cooperation pattern, collusion can lead to the synergy between relevant companies. However, collusion harms the benefits of other market entities. During the process of enterprises creating common interests cooperatively, collusion may bring harm to the outside industry.

Originality/value: Using empirical research method, the paper takes China's power industry as an example to show the gains and losses of collusion from two aspects, namely market economy and strategic management.

Keywords: power generation market, market power, regional market, collusion, cartel

1. Introduction

Collusion often occurs among oligarch enterprises. They seek higher profits by entering into agreement and alliance in the price, production, and sales of commodity. But this behavior will have adverse effects on other market participants, even the whole market. Porter (1982) put forward the concept of *collusion* and defines the non-competitive strategic behaviors accordingly. To indicate how the non-competitive strategic behaviors bring benefits to enterprises and how enterprises adjust their micro management methods for collusion combined with problems in terms of collusion among enterprises, the research will take power industry and power generation market as an example to give a conclusion through quantitative analysis.

In 2005 and 2006, the Northeast area of China was the first pilot carrying out generation-side bidding in regional power market. The bi-lateral power price market has been a pilot from January 1st, 2005 in Northeastern region. As a market entrant, Northeast China Grid company takes part in this pilot project with 17 power generation plants which are subordinate companies of five power generation Groups. The Grid Company dispatching department is in the charge of making market operation regulation, building operation system, organizing bidding transaction and settling accounts. According to the data feedback of dispatching center, in the first four months, the total electricity quantity after two-wheeled bidding is 86.278 billion kilowatt-hours. While the average price is 191.029 Yuan RMB per kilowatt-hour, which is higher than standard price. The equalization fund surplus is 118 million Yuan RMB and does not achieve the goal of 300 million Yuan RMB required by the project. After repairing technology platform, another 6 power generation plants, all of which belong to China Guodian Corporation, joined aiming at completing the prescribed 87.9%, but failed. In 2006, with the continuing implementation of price bidding policy, another 4 plants, all of which belong to China Huaneng Group Corporation, joined into the pilots. According to the feedback from dispatching center, the annual average power price of these price bidding units is 246.193 Yuan RMB per thousand kilowatt-hour, which goes over 41.47 Yuan RMB than standard price 207.723 Yuan RMB. The annual quantity of electricity is 82,854 million kilowatt-hour and the equalization fund deficit is 3,436 million Yuan RMB. Since the losses are more serious than that of 2005, the bidding transaction of Northeastern power market is suspended.

The failure of pilots puzzles the relevant departments. According the report provided by dispatching center, several reasons are summarized: 1) increase of power price causes great losses; 2) the market is not managed well and the corresponding policies are not sound; 3) there is a lot of room for market quoted price, and the risk prediction and information management are not well.

To combine theory with practice, this paper learns the successful reform experience from international power industry and, taking the price biding project of generation side in Northeast power market in 2005 as research sample, explores the root cause of the failure of price biding policy from the generation-side power market. Unlike the JEC case, power generation groups prefer secretly make contract when colluding. According to Nash equilibrium punishment model designed by Porter, this research uses time series model in price and gross output to conform to the basic structure of Porter model. On the basis of the established model, five power generation groups will be studied so as to deeply inspect collusion of electricity generation manufacturers in the market, and corresponding data sources will also be selected from the five groups and their relevant provincial affiliates.

The model proposed by Green and Porter (1984) has observed that the changes of manufacturers' behaviors are dynamic, including competition and cooperation. Following the research method of Green and Porter (1984), the original hypothesis is designed as *During the work period of big consumers purchasing electrical pilot directly, external demand and cost change can lead to fluctuation in power price and electricity output, which has nothing to do with collusion among the five power generation companies.* This research will test this hypothesis empirically and reveals the collusion among enterprises in electricity generation part, which is demonstrated to be the main obstruction of implementing the price biding policy. And finally, we put forward some conclusions and suggestions to help establish a benign environment for competition.

In this research, we put a sort of literature review to point out relevant theories in chapter 2. Then, the model will be established in chapter 3, which actually suggests new theories. The relationship between Chapter 4 and chapter 5 are close, which is analysis based on collected data. Chapter 6 is summary which points out the idea.

2. Literature Review

When analyzing enterprises' behaviors in imperfect market competition, scholars usually embark from enterprise commodity price to conduct the analysis. According to the feature that price can reflect various market information, macro entity including government and micro entities including enterprises will prudently consider the price and management methods on benefit promotion. Oligarch market is a typical imperfect market. The number of the enterprises that participate in the market activities is limited. Similarly, there is also a differentiation market power. Both of them will lead to the noncompetitive strategic behaviors of individual enterprises. While affecting the market average price, oligarch enterprises can promote their own benefits. The structure of electricity generation market can approximately be seen as an imperfect competition market monopolized by oligarchs. Therefore, many scholars adopt Bertrand model and Gounod model in research. These typical models can help scholars structure and analyze the pattern of the generation-side market so as to form a macro and micro acknowledgment of the manufacturers' behaviors in the market.

Research by Ventosa, Baíllo, Ramos and Rivier (2005) used Bertrand's price competition model to prove that monopolistic competitive market can establish a transaction system of *Power Pool* and form Nash equilibrium. Thus the competition among manufacturers can reach the level of a perfect competition, which forms the market trend. Actually, the power enterprises do quote price every day. The infinitely repeated game will probably lead to strategic cooperation among enterprises. Research by Khalfallah (2013) discussed about Britain power industry and pointed out that he has found such cooperation behaviors while doing the transaction practice. The secret contracting purchase for electricity caused by the cooperation leads the noncompetitive monopoly situation in Britain power supply section (Bensaid & Lesne, 1996). At last, due to the different ways of power generation and units' consumption, the marginal cost of power enterprises is also different. Research by Harrington, Hüschelrath, Laitenberger and Smuda (2014) proved that power commodity exists differences in space and quality. This also can lead to strategic cooperation among enterprises. Many scholars might be affected by the rigorous conditions of Bertrand assumption when applying the theory to research on oligopolistic market and their conclusions might have some faults. However, these researches revealed necessary conditions of collusion behaviors well.

Bertrand model makes enterprises the price-setters. But many scholars think the market competition of power enterprises depends on output and productivity decisions instead of price decision. Therefore they choose Gounod model to be their research basis. It also opens up a new research orientation: analyzing the output without limitation of the price. Research by

Fonseca and Normann (2014) used Gounod model to imitate generation-side electricity market monopolized by oligarchs, under the condition of complete information and incomplete information. Their research also imitated Nash equilibrium solution caused by manufacturers' game. By calculation examples they analyzed the effect the market information has on the state of Nash equilibrium. Finally, Gounod model is proved to be more adaptive to explain the real competitive situation in electricity generation market than Bertrand model. However, some existing research based on Gounod model obviously had some deficiencies. For example, their research was limited to the equilibrium solution after the game process. In other words, they discussed manufacturers' game process under the conditions of information symmetry and asymmetry rather than giving a lucubration to their strategic behavior. According to the relevant economics principles about imperfect competition and the above mentioned literature, it can be inferred that some power generation manufacturers can maximize their profits by game. At that time, there will be imperfect competition equilibrium in the market. The power price will be higher than that of perfect competition market. But now, different manufacturers have different market power. Mighty market power can make market entry barriers and information asymmetry in competition. While the asymmetric information will lead to manufacturers' noncompetitive strategic behaviors. All these micro market behaviors will bring difficulties to market supervision and affect the normal operation of the market.

The quantitative research on enterprises' micro behaviors belongs to the theoretical category of the NEIO (New Empirical Industrial Organization). SCP analysis framework is the basic pattern of early empirical industrial organization analysis. Researches by Bain (1941; 1949; 1951; 1993) had explained the analytic method and theoretical basis in detail. Like Bain's analytic pattern, the research by Weiss (1974) emphasized statistical relation between industrial profits and industrial concentration. But it does not build any model on individual enterprise, let alone a quantitative conclusion to the strategic behaviors of enterprises. In the early research of industrial organization, the price synergy among enterprises is an unreachable field. It can neither give an empirical measurement and judgment to collusion, nor provide effective guide and forewarning for enterprises.

Research by Porter (1983) had laid a foundation for the exploration of this field. The core contents of this research is to supervise the cost characteristics and demand shift to measure competition behaviors among enterprises and provides reasonable probability. After that, Bresnahan (1987) applied and expanded Porter's way of supervising collusion to different commodities through building a system. In the system commodity features can be observed. And the model design is simpler, which also provides a platform for this research to study generation-side power market. The exploration method proposed by Porter and Zona (1993; 1999) distinguished collusion by measuring the differences of determinants of price. All the methods above can be significant theoretical basis for researching collusion of generation-side power market in power industry and valid evidences for management. These methods can also pave the way for forewarning the collusion among manufacturers of generation-side electricity market in power industry.

3. Basic Model

Researches by Roy, Hanssens and Raju (1994) and by Sudhir (2011) believed that the fluctuation observed cannot totally attribute to collusion between manufacturers because changes in price and output are affected by many factors. In addition, during the process of dynamic game, it is rather difficult for manufacturers to identify collusion and competition through relevant data about price and output. Research by Green and Porter (1984) pointed out that enterprises taking part in Cartel in the market have to catch market information at any time so that they can find other participants' behaviors, some of which need support and others need to be restrained. In this case, if the five power generation companies price their own net bidding without knowing other companies' power output, then all power generation companies can be regarded as homogeneity, that is to say, they are in the same price market. If market demand curve includes random factor, then the appearance of ultra-low cost in market is a sign of demand promotion or collusion deviation.

There is always a reservation price in Cartel alliance (Green & Porter, 1984). Supposing that the price in market is below the bottom line, participants will make immediate reaction to maintain *Cartel*. Otherwise, it will break. The appearance of low-cost is certainly caused by the *betrayal* of some enterprise. Enterprises, considering secretly expanding their output level over collusion level, must weigh the profits gained in a short period, the risk increase when market price is lower than trigger price and the possible low-profit risk. Green and Porter (1984) also point out that price war occurring in the market should happen after the unanticipated recession in demand rather than after *the real cheat* of participating enterprises. Therefore, it is necessary to define game behaviors in non-cooperation market. As the cooperation period getting longer, output descends to full cooperation level and marginal revenue of cheat increases, which will result in the increasing *betrayers*. Hence, *Cartel* has to be maintained through raising trigger price. In this research, two rhetoric questions are proposed: *1) whether price bidding of generation side can lead electricity generation manufacturers to raise the price; 2) whether price fluctuation is related to non-cooperative competition behaviors*.

Employing simultaneous equations of switching regressions model proposed by Porter (1983) to estimate parameters of demands and cost function. Concrete model is set as follows,

$$\log Q_t = \alpha_0 + \alpha_1 \log p_t + \alpha_2 L_t + U_{1t} \tag{1}$$

In this model, aggregate demand is marked as logarithmic linear function of price. p_t is market price at time t. L_t is dummy variable. U_{1t} is independent normally distributed variable, $N(0, \sigma_1^2)$.

α_1 is price elasticity and we assumed it to be negative. α_2 is also negative and displays the recession in electricity demand.

Due to the different and asymmetric of corporate cost function in generation-side market, the cost function is set to be,

$$C_i\left(q_{it}\right) = a_i q_{it}^{\delta} + F_i, i = 1, 2, \ldots N \tag{2}$$

In this function, δ is the flexibility variable cost to output. Porter's model (1983) had set it as a fixed value and if equilibrium exists, then the value will greater than 1. a_i are specific variable parameters and reveal different features among enterprises. F_i are fixed costs and are small enough to guarantee anticipated discount profits to be positive.

Due to the homogeneity of products in all power generation enterprises, the same price in market equilibrium and different behaviors of enterprises, their actions can be set as,

$$P_t\left(1+\theta_{it} / \alpha_1\right) = MC_i\left(q_{it}\right), i = 1, 2 \ldots \mathrm{N} \tag{3}$$

In (3), *MC* refers to marginal cost. Formula (3) can offer another perspective on the strength of enterprise market forces, providing the foundation for the empirical results at the rest of this paper. Based on the change of *MC*, three cases can be set as follows. *Case 1*: Enterprises choose non-cooperative price at any time bucket. Then as expected by the theory of Bertrand, its price is equal to marginal cost, that is $\theta_{it} = 0$. *Case 2*: Enterprises implement interest-coalition and maximize the common interests, that is $\theta_{it} = 1$. *Case 3*: Enterprises produce at the level of Gounod (5 enterprises), that is, θ_{it} equals to market share and also equals to $S_{it} = q_{it}/Q_{it}$. According to date type collected by Porter (1983), using aggregated data calculation and weighting individual supply equation by using market share during t time bucket, supply relationship should be,

$$p_t\left(1+\theta_t / \alpha_1\right) = \sum_i S_{it} MC_i\left(q_{it}\right) \tag{4}$$

In (4), $\theta_t = \sum_i S_{it}\theta_{it}$, simultaneous market and cost function can be inferred,

$$S_{it} = \frac{\alpha_i^{1/(1-\delta)}}{\sum_j \alpha_j^{1/(1-\delta)}} \equiv S_i \tag{5}$$

Porter's model (1983) inferred that market share of each enterprise will not change along with time and industrial behaviors, whereas the bigger the change of the a_i variable cost parameters is, the smaller the market share of enterprises will be. Supply relationship can be further deduced as:

$$p_t\left(1+\theta_t / \alpha_1\right) = DQ_t^{\delta-1} \tag{6}$$

In (6), $D = \delta\left(\sum_i a_i^{1/1-\delta}\right)^{1-\delta}$, it can be concluded that D is influenced only by parameters of cost function. The value of θ is corresponded to Bertrand, Gounod and full cooperation. Suppose *I* is an indicator variable. When it is in cooperation, it should be 1; and when it is in disintegration (non-cooperation), it should be 0. Therefore, the supply relationship can be deduced as follows,

$$\log p_t = \beta_0 + \beta_1 \log Q_t + \beta_2 S_t + \beta_3 I_t + U_{2t} \tag{7}$$

in which, β_0 = log*D*, β_1 = δ – 1, suppose δ is greater than 0, then β_1 should be positive. The research by Porter (1983) pointed out that the best implementation mechanism will exchange short-term interest for the stability of Cartel in the future. Therefore, in this case, the value of β_3 will be estimated solely rather than be restricted. Because the price in cooperation period will be relatively high, the value of β_3 should be positive. Suppose it conforms to Bernoulli distribution:

$$I_t = \begin{cases} 1, & p = \lambda \\ 0, & p = 1-\lambda \end{cases} \tag{8}$$

According to this, switching and regression problems about simultaneous equation are produced. *Switching* is only reflected in the constant term of supply equation and β_0 has the same implication with β_3. Parameters of demand and supply function as well as handover probability λ can be estimated using the method proposed by Kiefer (1980). The technology is called E-M clustering (Expectation-Maximization Clustering). Porter (1983) points out that when applying E-M clustering to this kind of model, function (2) and (3) can be merged into

$$By_t = \Gamma X_t + \Delta I_t + U_t \tag{9}$$

In (9),

$$y_t = \begin{pmatrix} \log Q_t \\ \log p_t \end{pmatrix}, X_t = \begin{pmatrix} 1 \\ L_t \\ S_t \end{pmatrix}, U_t = \begin{pmatrix} U_{1t} \\ U_{2t} \end{pmatrix} \tag{10}$$

$$B = \begin{pmatrix} 1 & -\alpha_1 \\ -\beta_1 & 1 \end{pmatrix}, \Delta = \begin{pmatrix} 0 \\ \beta_3 \end{pmatrix}, \Gamma = \begin{pmatrix} \alpha_0 & \alpha_2 & 0 \\ \beta_0 & 0 & \beta_2 \end{pmatrix} \tag{11}$$

U_t ~ $N(0,\Sigma)$ meets independent identically distributed, $\Sigma = \begin{pmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{pmatrix}$ in the given situation, the probability density function of y_t is

$$h\left(y_t \mid I_t\right) = \left(2\pi\right)^{-1} \left\|\Sigma\right\|^{-1/2} \left\|B\right\| \exp\{-1/2\left(By_t - \Gamma X_t - \Delta I_t\right)\Sigma^{-1}\left(By_t - \Gamma X_t - \Delta I_t\right)\} \tag{12}$$

If there are T observed value, maximal likelihood function should exist:

$$L\left(I_1,\ldots,I_t\right)=\prod_{t=1}^{T}h\left(y_t \mid I_t\right) \tag{13}$$

If sequence $\{I_t\}$ is known, the estimate value of B, Γ, Δ and Σ can be obtained through maximal likelihood function. When the sequence meets Bernoulli distribution, the probability density function of y_t can be written as:

$$f\left(y_t\right)=\left(2\pi\right)^{-1}\left\|\Sigma\right\|^{-1/2}\left\|B\right\|\begin{bmatrix}\lambda\exp\{-1/2\left(By_t-\Gamma X_t-\Delta I_t\right)\Sigma^{-1}\left(By_t-\Gamma X_t-\Delta I_t\right)\} \\ +\left(1-\lambda\right)\exp\{-1/2\left(By_t-\Gamma X_t\right)\Sigma^{-1}\left(By_t-\Gamma X_t\right)\}\end{bmatrix} \tag{14}$$

Likelihood function can be written as:

$$L=\prod_{t=1}^{T}f\left(y_t\right) \tag{15}$$

Given an initial estimate $\{\omega_1^0, \ldots, \omega_T^0\}$, then ω_1^0 refers to the estimate of $Pr\{I_t = 1\}$. Get the initial estimate of λ through $\lambda^0 = \sum_t\omega_t^0/T$, and the initial estimate of B, Γ, Δ, Σ can be obtained by maximizing $L(\omega_1^0, \ldots, \omega_T^0)$. Using $\Omega^0 = (\Delta^0, \Sigma^0, B^0, I^0)$ to signify above estimates. Research by Kiefer (1980) employed Bayes algorithm to update sequence ω_t^0:

$$\omega_1^0=\Pr\{I_t=1 \mid y_t,X_t,\Omega^0,\lambda^0\}=\frac{\lambda^0 h\left(yt \mid X_t,\Omega^0,I_t=1\right)}{\lambda^0 h\left(yt \mid X_t,\Omega^0,I_t=1\right)+\left(1-\lambda^0\right)\left(yt \mid X_t,\Omega^0,I_t=0\right)} \tag{16}$$

If new sequence $\{\omega_1^0, \ldots, \omega_T^0\}$ exists, the new estimate Ω^1 of (B, Γ, Δ, Σ)can also be obtained by maximizing $L(\omega_1^0, \ldots, \omega_T^0)$. The new estimate of λ is $\lambda^1 = \sum_t\omega_t^1/T$, and iterative program can continue until the result converged, i.e., the two consecutive correlation of iteration exceeds 0.999. At this moment, the estimate values of λ and Ω are maximal likelihood estimates. Therefore, $L=\prod_{t=1}^{T}f\left(y_t\right)$ is maximized.

Research by Lee and Porter (1984) pointed out that if the maximal likelihood estimate of ω_t exceeds 0.5, it can be proved that t is in collusion period. At this moment, new sequence $\widehat{I}_t=\left(\widehat{\omega}_1,\ldots,\widehat{\omega}_T\right)$ produces. If $\widehat{I}_t$ equals to 1, then $\widehat{\omega}_T$ will be greater than 0.5; if $\widehat{I}_t$ equals to 0, then $\widehat{\omega}_T$ will be in other cases. Keifer (1980) did not make any definition to estimation process. If conforming to the price strategy triggered by *bottom price* proposed by Green and Porter (1984), then the new sequence will follow Markov derivation process. Such restrictions will bring difficulties to estimation process. We employ the estimation method proposed by Keifer to define PN and maximum likelihood method focus coefficient. The maximum likelihood estimate of Keifer is in accordance with the estimated result of Logistic model. In order to understand the specified function form, evaluate the sensibility of the plan and estimate the model using the linearity setting $y_t = \begin{pmatrix} \log Q_t \\ \log p_t \end{pmatrix}$ in Equation (9), Porter(1983) points out that it will not have significant difference in terms of empirical results.

4. Variable Design and Data Collection

The data collection ranged from January 1st, 2005 to January 1st, 2007 and included daily settlement data because price bidding pilot period is from 2005 to 2006. The data came from five power generation groups in Jilin province, Liaoning province, the Inner Mongolia Autonomous Region and Heilongjiang province. Five power generation groups are China Huadian Corporation, China Huaneng Group, China Guodian Corporation, China Datang Corporation, China Power Investment Corporation. The data set includes everyday power generation data of subordinate power generation companies and relevant settlement statistics of dispatching center. The data are obtained through system integration of State Electricity Regulatory Commission and dispatching center of State Grid Corporation of China.

According to the actual situation in this case, there are 17 power stations taking parting in pilot from January 1st 2005 to March 1st, 2006, 6 new power stations from May 1st 2005 to December 31st, 2005, and 4 new power stations from January 1st, 2006 to December 31st, 2006. The collected data mainly include daily generating volume of thermal power of five power generation groups, total power generating volume, unit price of thermal power and some necessary information. And then we design variables as in Table 1.

MR	Daily settlement price index of thermal power of five power generation groups.
TSU	Actual daily generating volume of thermal power of five power generation groups.
LGR	Dummy variable: LGR=1, if State Grid adjusted transmission-distribution price; LGR=0, otherwise.
PO	Dummy variable: PO=1, if price fluctuation among groups is observed; PO=0, if not.
PN	Dummy variable: PN=1, if price fluctuation among groups is estimated by Keifer model; PN=0, if not.
DM1	Dummy variable: DM1=1, if there is new power plant of China Guodian Corporation join the pilot from 2005.5.1 to 2005.12.31; DM1=0, if not.
DM2	Dummy variable: DM1=1, if there is new power plant of China Huaneng Group join the pilot from 2006.1.1 to 2006.12.31; DM2=0, if not.

Note: Samples data-collection period: from 2005.1.1 to 2007.1.1. Collection scope: five power generation groups in Jilin, Liaoning, the Inner Mongolia Autonomous Region and Heilongjiang.

Table 1. Variable setting

MR: Samples-collection contains only thermal power units and there is no subsidy for thermal power price. Therefore, subsidy policy is not involved and price index can be more accurate and coincide better with logarithmic model.

$$MR = \frac{\text{actual generating volume of thermal power}}{\text{total power generating volume}} * \text{unit price of thermal power} \qquad (17)$$

TSU: Actual daily generating volume of thermal power of five power generation groups. The situation that not all units are full generated is ignored. The thermal power units in the five groups are nearly the same and raw materials only differ in coal types, such as Shenhua Coal, Zhunge'er Coal. In this research, the products are assumed homogeneous. Based on this hypothesis, we will leave out the characteristic function of multilevel demand structure proposed by Houseman.

LGR: During the data-collection process, through the comparison between transmission-distribution price and the real generating capacity of the five groups and their subordinate power generation enterprises, we find that during the pilot process, transmission-distribution price of grid companies keeps changing. It is obviously the fluctuation of transmission-distribution price will affect the final electricity price. Therefore, dummy variable LGR is necessary for this model.

PO: The change of the electric power dispatching can be estimated through the dispatching and monitoring system of State Grid. Based on it, it is feasible to work out the real-time price fluctuation and to judge whether there is price war among the five groups.

PN: This dummy variable is based on Keifer's method (1980). According to the definition of $\widehat{I}_t$, PN reveals whether the five groups are in collusion. In addition, it will also reflect degree of collusion (MacAvoy, 1965; Ulen, 1978).

DM1 and DM2: Newly increased pilot power plants may shock the existing markets and may cause subtle changes in market structure. Their influence on the implement of the policy is worthy of concern and research. These two dummy variables can be combined with Formula (3) to analyze the influence the intensity of market power has on the collusion degree.

Verification on the effect of *price biding* policy on collusion behaviors is another major issues of this research. Although there is no variables represent policy index, the result from detecting collusion during the sample period still has an explanation meaning to this question. In order to make the measurement results more accurate, we established data screening. The statistical description of variables are displayed in Table 2.

Variables	Mean	Standard error	Minimum	Maximum
MR	0.2335	0.06344	0.162	0.357
TSU	788901	35246	89034	1087653
LGR	0.5641	0.4973	0	1
PO	0.6778	0.4213	0	1

Table 2. descriptive statistics of the variables

5. Data Analysis and Results

Porter (1983) has given U_{1t} a relatively strict assumption. Two-stage-oriented least square method and the maximal likelihood method are employed respectively in regression. Green and Porter (1984) has proved that the estimated results of two-stage-oriented least square method are the same as those of three-stage-oriented least square method. The maximal likelihood method is based on Keifer's discussion (1980) on Logistic regression method. Following it, we carried out regression analysis and discussed the results. However, it is necessary to points out that the application of FIML (Full Information Maximum Likelihood) by Melo, Graham and Noland (2009) and Miranda (2003) will have a better explanation for simultaneous equations. Miranda's application of FIML also includes Keifer's iterative process. The difference is that Miranda has taken the endogenous influence of dummy variable L into account. Therefore, after the regression by Porter's empirical method, we employed FIML method to verify the reliability of the conclusion and robustness of the model.

	Two-stage-oriented least square method (PO)		Maximal likelihood method (PN)	
Variables	Demand function	Supply function	Demand function	Supply function
MR	-4.372*** (0.173)		-3.245*** (0.144)	
LGR	-0.571** (0.135)		0.447** (0.127)	
TSU		0.433** (0.131)		0.167** (0.061)
PO/PN		0.377*** (0.053)		0.669*** (0.037)
DM1		0.267** (0.071)		0.522*** (0.034)
DM2		0.384*** (0.043)		0.613*** (0.052)
Goodness of Fit Adjusted Goodness of Fit	0.429 0.512	0.491 0.535	0.319 0.387	0.772 0.793

Notes: Certified by Stata11.0 measurement regression. The results of regression equation show that there are standard deviation of regression in parentheses. ***, ** and * indicate the significance level of 1%, 5%, 10% respectively.

Table 3. *Collusion* estimation results

As mentioned above, two-stage least square method is adopted to regression Equation (9). 2SLS of a single equation, 3SLS of simultaneous equations and iterative 3SLS can be deemed as approximately consistent when the presumption is strict. And the measurement results are showed on the left side of Table 3. On the right side of the table it lists the regression results by the iterative maximum likelihood estimation method utilized by Keifer (1980). We also considered the estimation method by GMM and found that MLE and GMM are the same when their expectation matrix is 0.

Regression coefficients are listed in the left column when two-stage least square is applied to Equation (9), which enables PO to offer a precise classification of structural environment and proves that there exists price competition in power generation group. Important variables are all different from zero obviously. It is a pity that the PO model matches poorly, while PN model fits well. Combining the data from Table 3 and 4, comprehensive analyses are as follows:

Price			
	LGR		
PN	0 1	0 0.1476 0.2227	1 0.1624 0.2331
Quantity			
	LGR		
PN	0 1	0 733556 458872	1 543755 212769
Revenue			
	LGR		
PN	0 1	0 37756 43768	1 13466 16345

Notes: The unit of revenue is 10,000 Yuan RMB and it's the average value settled every day.

Table 4. *Collusion* estimation: Details on price, quantity and revenue

(1) In the process of estimating the demand function, the two methods both show that users' demands will be reflected on the demand function under the case that the overall power rate has changed. According to the data, the power rate improves distinctly and users' demands decrease. Setting the parameters on the basis of the model, the absolute value of price elasticity will be less than 1. Therefore, the marginal revenue of the power plants which participate in the bidding for electric network will be negative and their benefits are likely to go down. Meanwhile, in the pilot of price bidding for power grid, the rise in grid purchase price will decrease the spreads space of Grid Company, which plays the role of middlemen, and will surely harm its power-selling behavior.

(2) The data of the supply function manifest that the sensitivity of a model can be raised by Keifer's method (1980) and the network price would be raised to a certain extent when grid company changes the transmission-distribution prices. At this time, the price would be higher if the power plants collude with each other. This can be explained by the hypothesis that *there exists inertia in a Cartel* (Porter, 1983): given that the power plants have formed *a recessive Cartel* through market information without the influence of the bidding policy for electric network, the expected power price is no doubt a low price beyond the bottom line. By this time, other participants would adopt the strategy of raising the on-grid price in the market to guarantee the continuity of Cartel.

(3) From the PN coefficient, 0.669 which is higher than 0.5, in Table 3 and 4, there is no reason to doubt the existence of *recessive collusion*. Combined with the relationship between price and output pointed by Porter (1983) that the expected supply price is the increasing function of power output. It can be seen as the evidence of diseconomies of scale if the supposed cost function is used. There will be no positive effects and the duration time of Cartel may be stimulated if the transmission-distribution price is raised in pilot enterprises in which price bidding policy is carried out.

(4) According to the definition for parameter β_3 in the model deduction, measurement estimates show that in the sample period, it is concluded by PO that there exists price competition strategies among the five power generation groups while that is not influenced by the policy of *price biding*. However, Keifer's calculation (1980) points out that the PN coefficient of the top5 power generation groups are all higher than 0.5. The collusion is more serious in the period when implementing price bidding policy. It can be known from the power price and fluctuation of revenue in Table 4 that the number 16345 reflects the game between power companies and power grid. Collusion may cause a 27.4% increase of network price, according to the statistics, and decrease 23.2% of electricity quantity. While the revenue of power generation groups increase about 13.7%. These are the benefits of these groups rather than that of the pilot power plants that participate in the bidding. Taking relevant data from Tongliao Power Plant affiliated from Power Investment Company in Inner Mongolia Autonomous Region, it can be seen that the plant's revenue decreased by 7.8% compared with those in last period during the work on pilot program. It is because the network price ceiling is set lower than Cartel price. And the decrease of productivity caused by collusion leads to the declining of revenue. According to the analysis of the power price formula, the elevation of on-grid price squeezes and reduces the profit margins of the grid company. It has seriously affected the enthusiasm of their participating in transmission-distribution services which lead to inactive reaction to the policies. The result reveals that collusion among power plants will have a negative effect on the implementation of the policy. These passive effect will act on all

participants of pilot work directly. Therefore, the market's equalization fund deficit should also be settled when carrying out price bidding policy. That is to say, the balance between supply and demand should be ensured and bearing market risk is the basis of the policy's continuous operation. According to the case, during the pilot process in Northeastern power market, the whole-year bidding electricity quantity was 100 billion KWH in 2005. Such high volume means that 1 billion margin will be produced as soon as 1 cent in power price fluctuates. The market risks brought by large sums of money are not able to be undertaken by any market participant. Implementing price bidding policy and carrying out the grading mechanism of capacity price should be done at the same time. This is to guarantee fairness and justice in the process of bidding. As for this case, under the bidding mode many power plants are still those built with funds which repay capital with interest and they bid unequally with those funded by the nation. Segmenting and adding up the comprehensive strength of the power plants participating in the bidding are the foundation of dividing the bidding levels.

(5) Regional market power will lead to vicious competition. The sampled data shows that from May 1st, 2005 to December 31st, 2005, six new added subordinate plants of China Guodian Corporation made the PN coefficient value higher than 0.5. From the materials and considering that all the six plants are located in Dalian jurisdiction, there is a clear escalating trend of power price in this region during the period and other power plants raised their price responsively. Thus it can be concluded that if there is a Cartel, other single power plant or small Cartel would in turn adopt the adhesion bidding strategies. In addition, the zoom of power price will also strangle some small private power plants, and cause more vicious competition in the market.

(6) Different from Porter's method (1983), FIML is a continuous process of estimation which is similar to three-stage least squares. Their hypothesis for the indicator variable are different. Porter supposes that indicator variant I conforms to the Bernoulli distribution while FIML calculation demands the indicator variant to be submitted to Poisson distribution. FIML calculation will be taken as the inspection method to examine whether our empirical results are stable and correct. And accordingly, it is shown that all indexes are significant: DM1 is 0.813 under the significant level of 1%; DM2 is 1.030 under that of 10%; and PO is 0.721 under that of 1%. The estimation of PO is proved to be robust through significance examination. On the basis of our model deduction results, $\left(\widehat{B}_1, \widehat{\Sigma}_1\right)$ is the unbiased estimation of $\left(B, \Sigma\right)$ supposing that L_1 is the maximum in maximum likelihood estimation by Keifer's method (1980). What's more, when $\Delta = 0$, L_0 is the maximum in the estimation, the difference between two maxima can be displayed as $L_1 - L_0 = \left(\log\left\|\widehat{B}_1\right\| - 1/2\log\left|\widehat{\Sigma}_1\right|\right) - \left(\log\left\|\widehat{B}_0\right\| - 1/2\log\left|\widehat{\Sigma}_0\right|\right)$.

(7) Based on the original hypothesis, the intrinsic model is not specifically limited. Computing $2T(L_1 - L_0)$ with the assistance of the sample data, it can be found that the original assumption is significantly different from the result. And also we can learn that the section in which prices are fluctuating between PO and PN may due to the non-cooperative competition which is clearly existed. Table 4 shows us that non-cooperative competition will reduce the on-grid price, which would play an active part in the whole industry. Till now, it can be concluded that there are non-cooperative competition and collusion when price bidding is carried out in the whole market.

6. Conclusions

6.1. The Control and Optimization of Power Market

Through analyzing the practical situation of the *price bidding* project in the northeast regional pilot, it is inferred that collusion among exists among power enterprises in the market. And the policy did aggravate the collusion. Moreover, non-cooperative competition and collusion are conducted alternatively in the power market. If there is no Cartel and the market is relatively stable, the competition among various enterprises will form lower power price. This will benefit the development of the whole industry. When forming Cartel, high network price will be set and then be conflict with the interests of Grid Company. The conflicts are mainly reflected on the fluctuation space of power price. Power plants squeeze the profit margin by raising network price, then the grid company as a middleman will further enhance the obtained profits of transmission-distribution price. It will leave the accompanying negative influence to consumers and be harmful to the development of the industry. The collusion action in the power-generating process not only affects power price but also reduces market entrants with the continuous impact of market forces formed by long-term Cartel. The concentration of market resources in Cartel will lead to inefficient competition in power market and bring negative impact to consumers.

Moreover, as for the negative influence caused by collusion among power manufacturers, the circumvention aims to maintain virtuous competition in market, avoid postponing the implementation of market-oriented policies, and ease the contradiction among enterprises in the power-generating and distributing sections. Finally the target is to control and reduce power price. For example, more firms can be introduced into the power market to break the structure which is monopolized by oligarchs. Green and Porter (1984) have shown that more market participants will efficiently decrease the negative influence brought by the collusion. But this method cannot get rid of collusion thoroughly since it can be seen everywhere. More market participants would efficiently weaken the strength of collusion groups and undermine the effects on market price. In addition, more participants would carve up the market shares owned by the original large enterprises and also the market composition would be more harmonious.

It’s noteworthy that flagrant collusion does not appear in the power-generating process like the JEC case. It is committed through market information or information issued by relevant institutions (the balance among relevant personages in enterprises are also taken into account). As the duration time of Cartel is influenced by information transmission, the government can control the information about price fluctuation in market to make open and transparent of market information while liberalizing market access. Also it can build a real-time bidding system. A strong Cartel is able to handle market price and this kind of ability is often selfish (Cournot, Bacon & Fisher, 1960). Thus, the government should keep an eye on the abnormal price fluctuation and avoid the continuity of collusion before it appears.

This research analyzes the problems in pursuing the market-oriented policy of price bidding and discusses the negative influence brought by collusion in China’s power supply market. It is necessary to proactively implement the policy in light of successful cases in advanced countries. Based on our empirical study, relevant units should control network price and the power output by using the concept of balanced index. That means they shall observe the fluctuation in the ratio of each power plant’s on-grid price and electricity quantity under relatively stable conditions of competition. What’s more, the control of output ought to be accompanied by the awareness of reduction caused by non-market demand fluctuation. Grid companies’ profits from the *excess transmission-distribution price* must be avoided. And the transmission-distribution price should be limited to avoid the conflicts among enterprises in the generation-distribution process and create good conditions for carrying out the policy. With regard to the monopoly market structure formed by the five power generation groups, we consider that it can be divided to increase the number of group companies which will avoid the growth of its forces.

6.2. Strategic Management of Collusion Among Enterprises

It is found that the participants in the market are enterprises with different functions when observing the empirical case carefully. And because of the appearance of collusion, there are both beneficiaries and the harmed among other relevant enterprises. For instance, the grid company is influenced by collusion although it did not take part in the regular market activities. The influence of collusion on the benefited and harmed enterprises can be summarized as follows:

Empirical research reveals that collusion can bring benefits to power groups themselves. As a way of enterprise collaboration, collusion can produce synergy for the participating enterprises, however, at the cost of hurting other market entities. It brings little active influence on the whole power market and is much likely to harm other market entities. If taking collusion cooperation as the basis, more enterprises need to be networked to expand the synergistic effect and to promote the revenue of the whole power market. Meanwhile, the market information should be public inside the group so as to ensure that the information resources can be shared and the price signals be captured in the power plant subordinated by the group. And enterprises could achieve synergistic effect to promote their revenue because collusion may be restricted by relevant laws and market conditions.

This research shows that collusion harmed the benefits of other market entities outside the cartel. Further, when enterprises collaborating with one another for extra profits, the others' benefits may be damaged and they may be forced to adjust prices or output or form new alliances to keep profitable. As the competition is no longer one-to-one for most enterprises, it has become a challenge to keep efficient cooperation and virtuous competition. It is going to be further studied. Directors, especially those market supervisors must look on the value activities from a systematic perspective, advocate efficient cooperation and regulate behaviors which apparently harm market efficiency.

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