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Research Article

The Government Incentive Regulation Model and Pricing Mechanism in Power Transmission and Distribution Market

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The power transmission and distribution (T&D) market's natural monopoly and individual information have been the impediment to improving the energy efficiency in the whole T&D market. In order to improve the whole social welfare, T&D market should be controlled by government. An incentive regulation model with the target of maximizing social welfare has been studied. A list of contracts with transferring payment and quantity of T&D are given to motivate the corporation to reveal the true technical parameter and input the optimal investment. The corporate revenue, optimal investment, and effort are proved to depend on its own technical parameter. The part of incentive regulation model ends with the optimal pricing mechanism of T&D market. At the end of this paper, we give a numerical example to explain our research and confirm its function graphically.

1. Introduction

Power transmission and distribution (T&D) corporations play an important role in energy efficiency improving, mainly due to the natural monopoly and their individual information [1]. Power transmission pricing mechanism receives more and more attention in recent years, since power transmission is a very special service [2]. It is related to not only the future of the transmission grid but also the reformation of power pricing [3]. But the power transmission grid is naturally monopolistic. In this situation, government has to regulate the power transmission market to prevent inefficiency and protect social welfare. To formulate reasonable T&D, pricing mechanism is the key to the power reformation in China [4, 5]. The problems in power transmission and distribution market are seriously blocking the power reform in China [4]. So it is of great significance to research the regulation and pricing mechanism in T&D market and obtain some sensible conclusions.

The former researches in regulation of T&D market mainly focus on the cost regulation [6–8]. Joskow [9] concludes the researches about T&D regulation mechanism published in the economic journal; most of these researches formulate regulation mechanism based on the corporate cost, effort, and the asymmetric information in quality. Kristiansen [10] shows three kinds of T&D pricing mechanisms based on incentive regulation model: the Wangensteen model, the optimal power flow model, and the Hogan model; nevertheless, only Hogan model is the incentive regulation model in economics.

Both theory and practice have shown that the current regulation prices of T&D market cannot properly address several vital problems such as asymmetric information and low efficiency [11, 12]. Vogelsang [13] focuses on two-part tariffs where the variable part would reflect congestion charges (and ancillary services), while the fixed part would reflect capacity costs. Vogelsang [14] shows that performance-based regulation (PBR) is influenced by the Bayesian and non-Bayesian incentive mechanisms. Further, he points out that Bayesian incentives are impractical, and, from their properties, they can be combined with practical non-Bayesian mechanisms for application to transmission pricing. Hogan et al. [2] point out that certain investments in transmission upgrades cause negative network effects on other transmission links, so that capacity is multidimensional. So they study the problems with a new model (HRV model) which combines the merchant (long-run financial rights to transmission) and regulatory (incentive regulation hypothesis) approaches in a setting with price-taking electricity generators and loads. In the model, there are two types of price index weights: chained Laspeyres weights and idealized weights. Laspeyres weights have shown good economic properties under well-behaved, stable cost, and demand conditions, while idealized weights correspond to perfectly predicted quantities and possess strong efficiency properties. Hogan et al. [15] prove the HRV model practicable. Rosellón and Weigt [16] obtain the result suggesting that a new incentive mechanism, based on HRV regulatory approach, is generally suited as an incentive tool for network extensions.

The T&D market price usually abnormally soars and fluctuates mainly due to the dissatisfaction with the requirement of the corporate incentive compatibility [17–21]. So, Joskow [22] suggests incentive regulation theory and addresses that incentive regulation theory implies that the adverse selection and moral hazard problems resulting from the regulators' information disadvantages are best handled by offering firms a menu of cost contingent incentive contracts. Wang et al. [23] study a model, with which government can reveal enterprise's cost successfully and make out consumer types effectively. Cai and Ye [24] research government incentive regulation model under asymmetric information and obtain the optimal price of power transmission and distribution. Osorio and Sauma [1] study two models of the principal agent bilevel type in T&D market, and they point that, under the traditional regulatory frameworks, T&D corporations have disincentive to promote energy efficiency.

In summary, to analyze how to reduce the effect of asymmetric information and incent the corporation to invest and improve the efficiency by researching the incentive regulation model is useful and urgent. In this paper, we consider regulation and pricing mechanism based on government incentive regulation model [25] and obtain the optimal price of power with economic mechanism design theory [26, 27]. The major contributions of this paper are as follows:

(1) Based on government incentive regulation model, we research government regulation and pricing mechanism in T&D market. As the regulator, government focusing on the social welfare offers a menu of contracts about the regulation policy and the pricing mechanism to T&D corporations.

(2) It encourages corporation to not only reveal the accurate technical parameter but also make optimal investment. In this paper, we consider the technical parameter as the private information of corporation, and investment lets the efficiency be higher (reducing the technical parameter). So government obtains this private information and encourages corporation to invest by some helpful policy.

2. Premise of the Model

2.1. Assumptions. In this paper, we consider 6 assumptions between government and the T&D corporation.

Assumption 1. The corporation and government have different targets. The corporation is eager for more profit; however, government as the regulator must maximize the social welfare. Government pays transferring payment to observe accurate technical parameter β of the corporation, meanwhile encouraging the corporation to invest and improve efficiency.

Assumption 2. We designate $Mpq/((1-G)NA)$ as the utility to the consumers if the quantity of power transmission and distribution is q, based on Social Welfare and Comprehensive Evaluation of Electric Power Universal Service [28] and Social Welfare Function Construction of Electric Power Universal Service Based on Expected Utility Theory and Prospect Theory [29].

Assumption 3. Neglect the loss in the process of power transmission and distribution, and we assume p and q follow the following function:

$$p = a - bq. \tag{1}$$

Assumption 4. Consider moral hazard and adverse selection in motivation. The corporation keeps the technical parameter β as its private information, and it can improve efficiency by increasing investment $I(e)$ (the cost of effort); as the result, the unit cost can be reduced by e.

The output cost of the corporation can be shown as below [25, 30]:

$$C = (\beta - e)\, q, \tag{2}$$

where $\beta \in [\underline{\beta}, \overline{\beta}]$ and high β means inefficient technical level. $F(\beta)$ means the absolutely continuous distribution function and its density is $f(\beta)$. While $\beta \in [\underline{\beta}, \overline{\beta}]$, $f(\beta) > 0$ and the monotone hazard rate $d[F(\beta)/f(\beta)]/d\beta \geq 0$, for most distributions, such as uniform distribution, normal distribution, logarithmic distribution, exponential distribution, and Laplace distribution, satisfy the condition.

Here we designate e as the moral hazard parameter, and it is related to the type of the corporation; it is represented in $e = e(\beta)$. $I(e)$ is the cost of effort the corporation made or it can be seen as the investment for improving the efficiency, and it is constrained by $I' > 0$, $I'' > 0$, $I''' \geq 0$, and $I(\beta) = +\infty$.

Assumption 5. The output cost of the corporation C, the cost of effort $I(e)$, and the quantity of transmission and distribution q are visible to government.

Assumption 6. The corporation has its accurate information of technical parameter, while government just knows it belongs to $[\underline{\beta}, \overline{\beta}]$. When the corporation announces the technical parameter $\widehat{\beta}$, it selects one from a series of contracts $\{T(\beta), q(\beta)\}$ given by government.

2.2. The Sequence of Government and the Corporation. The game sequence is shown in Figure 1:

(1) The corporation obtains its accurate information of technical parameter β according to its experience and historical data.

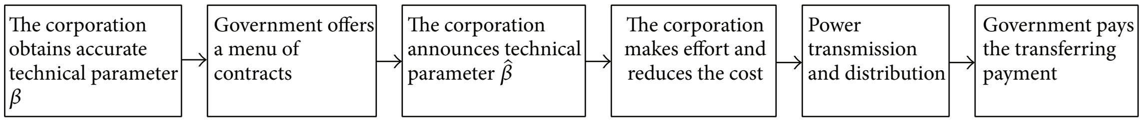

Figure 1: The game sequence between government and the corporation.

(2) Based on all information it can get, government formulates a series of contracts $\{T(\beta), q(\beta)\}$ with the target of maximizing the social welfare.

(3) The corporation announces the technical parameter $\hat{\beta}$ after researching the contracts and selects one.

(4) The two participants, government and the corporations, sign up the contract.

(5) The corporation invests $I(e)$ and reduces the unit cost to the level $c = \beta - e$.

(6) Government pays the transferring payment $T(\hat{\beta})$. The contract ends.

3. The Model and Pricing Mechanism

In this model, we consider the target of government, the expected profit of the corporation, the incentive constraints, and the participant constraints.

3.1. The Target of Government and the Corporation. Government aims at the social welfare, including both the utility of consumers and the utility of the corporation. The utility of consumers is the difference between total utility and the cost they pay, as it is shown below:

$$\frac{Mp(q)q}{(1-G)NA} - (1+\lambda)T, \tag{3}$$

where T is the transferring payment from government and $\lambda > 0$ is the shadow cost of public funds.

The utility of the corporation is formed by three terms: the transferring payment (T), the output cost (C), and the cost of effort (I):

$$U = T - C - I. \tag{4}$$

We can directly obtain the social welfare function from (3) and (4):

$$J_0 = \left[\frac{Mp(q)q}{(1-G)NA} - (1+\lambda)T\right] + (T - C - I). \tag{5}$$

Further, the final incentive target of government can be written as

$$S_0 = \int_{\underline{\beta}}^{\overline{\beta}} \left\{\left[\frac{Mp(q)q}{(1-G)NA} - (1+\lambda)T\right] + (T - C - I)\right\} dF(\beta). \tag{6}$$

It is the total social welfare from various types of corporations.

3.2. The Incentive Constraints to the Corporation. Government and the corporation sign up the contract based on the technical parameter $\hat{\beta}$ announced by the corporation. Then, the utility of the corporation can be expressed by the accurate technical parameter β and the announced technical parameter $\hat{\beta}$:

$$U(\hat{\beta}, \beta) = T(\hat{\beta}) - I(\beta - C(\hat{\beta})) - C(\hat{\beta}). \tag{7}$$

Thus, we obtain the incentive constraints when each of $\beta_1, \beta_2 \in [\underline{\beta}, \overline{\beta}]$, as they are shown below:

$$\begin{aligned} &T(\beta_1) - I(\beta_1 - C(\beta_1)) - C(\beta_1) \\ &\quad \geq T(\beta_2) - I(\beta_1 - C(\beta_2)) - C(\beta_2), \\ &T(\beta_2) - I(\beta_2 - C(\beta_2)) - C(\beta_2) \\ &\quad \geq T(\beta_1) - I(\beta_2 - C(\beta_1)) - C(\beta_1). \end{aligned} \tag{8}$$

3.3. The Participant Constraints to the Corporation. In order to achieve the target, government should not let the utility of the corporation be less than its lowest profit (normalized to 0 here) to keep the corporation working:

$$U(\hat{\beta}, \beta) \geq 0. \tag{9}$$

3.4. Model Based on Government Incentive Regulation. According to all the analyses above, the problem can be formulated as follows:

$$\begin{aligned} \{P_1\} \quad S = \max_{\{T(\cdot), q(\cdot)\}} &\int_{\underline{\beta}}^{\overline{\beta}} \left\{\left[\frac{Mp(q)q}{(1-G)NA} - (1+\lambda)T\right] + (T - C - I)\right\} dF(\beta) \\ \text{s.t.} \quad &(8) \ (9). \end{aligned} \tag{10}$$

Let us consider the problem. From (8), we get

$$\int_{\beta_1}^{\beta_2}\int_{C(\beta_1)}^{C(\beta_2)} I''(x-y)\,dx\,dy \geq 0. \quad (11)$$

Because $I'' > 0$ (Assumption 4), (11) indicates that $C(\beta)$ is the nondecreasing function of β; in other words, $\dot{C}(\beta) \geq 0$.

For the best profit, the corporation may give simulated technical parameter β, so we take the envelope theorem into (7) to maximize the utility of the corporation; we get

$$\dot{U}(\beta) = -I'(\beta - C(\beta)) \leq 0. \quad (12)$$

In addition, the more utility the corporation obtains, the more payment the government will pay. Therefore, government lets $U(\overline{\beta}) = 0$, and we can get $U(\beta)$ from (12):

$$U(\beta) = \int_{\beta}^{\overline{\beta}} I'\left(e\left(\widetilde{\beta}\right)\right) d\widetilde{\beta}. \quad (13)$$

Equation (13) shows the information rent obtained by the corporation with lower technical parameter or high effective technical level. Accordingly, the information rent government paid willingly is

$$\begin{aligned}\int_{\underline{\beta}}^{\overline{\beta}} U(\beta)\,dF(\beta) &= \int_{\underline{\beta}}^{\overline{\beta}}\int_{\beta}^{\overline{\beta}} I'\left(e\left(\widetilde{\beta}\right)\right) d\widetilde{\beta}\,dF(\beta) \\ &= \int_{\underline{\beta}}^{\overline{\beta}} \frac{F(\beta)}{f(\beta)} I'(e(\beta))\,dF(\beta).\end{aligned} \quad (14)$$

Thus, the target of government equation (10) can be rewritten as

$$\begin{aligned}S = \max_{\{C(\cdot),q(\cdot),U(\cdot),I(\cdot)\}} \int_{\underline{\beta}}^{\overline{\beta}} \Bigg[& \frac{Mp(q)q}{N(1-G)A} - (1+\lambda)C \\ & - (1+\lambda)I - \lambda U \Bigg] dF(\beta).\end{aligned} \quad (15)$$

By replacing (4) and (14) into (15), we can reformulate the problem as

$$S = \max_{\{e(\cdot),q(\cdot)\}} \int_{\underline{\beta}}^{\overline{\beta}} \left[\frac{M(a - bq(\beta))q(\beta)}{N(1-G)A} - (1+\lambda)\cdot(\beta - e(\beta))q(\beta) - (1+\lambda)I(e(\beta)) - \lambda\frac{F(\beta)}{f(\beta)}I'(e(\beta)) \right] dF(\beta) \quad (16)$$

$$\text{s.t.} \quad \dot{e}(\beta) \leq 1. \quad (17)$$

Equation (17) is equivalent to $\dot{C}(\beta) \geq 0$.

We designate J as the integral part of (16); thus,

$$\frac{\partial^2 J}{\partial q^2} = -2b\frac{M}{N(1-G)A} \leq 0. \quad (18)$$

So we can obtain the optimal q from $\partial J/\partial q = 0$, as it is shown below:

$$q^* = \frac{a}{2b} - \frac{(1+\lambda)(\beta - e(\beta))(1-G)NA}{2bM}. \quad (19)$$

In addition, since $I''' \geq 0$ (Assumption 4), J is concave. Neglect the constraint equation (17); we obtain the following formula by rewriting $\partial J/\partial e = 0$:

$$I'(e(\beta)) = q(\beta) - \frac{\lambda}{1+\lambda}\cdot\frac{F(\beta)}{f(\beta)}\cdot I''(e(\beta)). \quad (20)$$

Furthermore, find the derivative of β from (20); we get

$$\dot{e}(\beta) = -\frac{(NA/(2bM))\cdot(1+\lambda)(1-G) + (\lambda/(1+\lambda))\cdot I''(e(\beta))\cdot d(F(\beta)/f(\beta))/d\beta}{I''(e(\beta)) + (\lambda/(1+\lambda))[F(\beta)/f(\beta)]I'''(e(\beta))}. \quad (21)$$

It is obvious that $\dot{e}(\beta) < 0$, so that it does not contradict (17).

From (20), we get $e^*(\beta)$. And the optimal information rent and the transferring payment follow the following formulations:

$$\begin{aligned}U^*(\beta) &= \int_{\beta}^{\overline{\beta}} I'\left(e\left(\widetilde{\beta}\right)\right) d\widetilde{\beta}, \\ T^*(\beta) &= U^*(\beta) + I(e^*(\beta)) + C^*(\beta),\end{aligned} \quad (22)$$

where $C^*(\beta) = \beta - e^*(\beta)$ is strictly increasing function. From this, it is noted that $C^*(\cdot)$ can be replaced by its inverse function $\beta = \beta^*(C)$. Thus, the optimal transferring payment from government can be expressed as

$$\begin{aligned}T^*(C) = & \int_{\beta}^{\overline{\beta}} I'\left(e^*\left(\widetilde{\beta}(C)\right)\right) d\widetilde{\beta} + I(e^*(\beta^*(C))) \\ & + [\beta^*(C) - e^*(\beta^*(C))]\cdot\Bigg[\frac{a}{2b}\end{aligned}$$

$$-\frac{(1+\lambda)\left(\beta^*(C)-e^*\left(\beta^*(C)\right)\right)(1-G)NA}{2bM}\Bigg], \tag{23}$$

where the output cost C is visible for the regulator, government.

4. Results Analyses

Proposition 1. *Government regulates the corporation with these contracts $\{T^*(C), q^*\}$, which can make the corporation not only show its accurate technical parameter β but also make more effort $e(\beta)$. The contracts $\{T^*(C), q^*\}$ are represented in*

$$T^*(C)=\int_{\underline{\beta}}^{\overline{\beta}} I'\left(e^*\left(\widetilde{\beta}(C)\right)\right)d\widetilde{\beta}+I\left(e^*\left(\beta^*(C)\right)\right) + \left[\beta^*(C)-e^*\left(\beta^*(C)\right)\right]\cdot q^*, \tag{24}$$

$$q^*=\frac{a}{2b}-\frac{(1+\lambda)\left(\beta-e(\beta)\right)(1-G)NA}{2bM}. \tag{25}$$

Equation (24) shows that the transferring payment from government consists of three parts: the compensation for output cost $[\beta^*(C)-e^*(\beta^*(C))]\cdot q^*$, the compensation for the investment $I(e^*(\beta^*(C)))$, and the information rent $\int_{\underline{\beta}}^{\overline{\beta}} I'(e^*(\widetilde{\beta}(C)))d\widetilde{\beta}$. In the model based on government incentive regulation, the quantity of power transmission and distribution q^* is different when the technical parameter β and the effort $e(\beta)$ change. In addition, there is no distortion of the quantity of power transmission and distribution q^*.

Proposition 2. *The corporation receives different information rent $U^*(\beta)$ due to its technical parameter, and $U^*(\beta)=\int_{\underline{\beta}}^{\overline{\beta}} I'(e(\widetilde{\beta}))d\widetilde{\beta}$.*

Information rent means the rest of the transferring payment and the cost. From $U^*(\beta)$, we conclude that the information rent is directly related to the technical parameter and the marginal cost for effort to improve efficiency.

Proposition 3. *The optimal investment for improving efficiency is represented in*

$$I'\left(e(\beta)\right)=q(\beta)-\frac{\lambda}{1+\lambda}\cdot\frac{F(\beta)}{f(\beta)}\cdot I''\left(e(\beta)\right). \tag{26}$$

Under the optimal regulation mechanism, the T&D corporations should put optimal effort to improve the efficiency. And the optimal effort can be seen as the optimal investment. From Proposition 3, the optimal investment is influenced by the technical parameter (different corporation has different optimal investment level), the distribution of the technical parameter, and the shadow cost.

Proposition 4. *In the model based on government incentive regulation, the price of power transmission and distribution is shown below:*

$$p^*=\frac{a}{2}+\frac{(1+\lambda)\left(\beta-e(\beta)\right)(1-G)NA}{2M}. \tag{27}$$

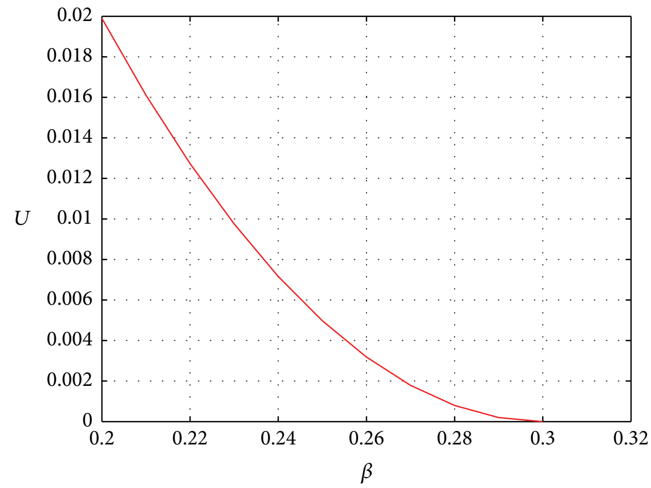

FIGURE 2: Diagram of the corporate information rent.

From Proposition 4, we confirm that Gini coefficient, coefficient of social welfare, shadow cost of public funds, and quantity of people in certain area and their average income including demand play important roles in the price of power transmission and distribution.

5. Numerical Example

We make a numerical example to explain our model lively. Consider β has a uniform distribution over $[0.2, 0.3]$ and its distribution function is $F(\beta) = 10\beta - 1$; meanwhile, we designate $I(e) = e^2$, $\lambda = 0.08$, and $G = 0.47$ [31]; the software Matlab 7.1 is used to simulate the case.

5.1. Main Results. Figure 2 shows that the information rent U increases with the technical parameter β. Especially when $\beta = 0.3$, U turns to be 0. In order to reveal the accurate technical parameter of the corporation and encourage it to make an effort, government must pay some information rent to the corporation with low technical parameter (high technical level). The T&D corporation cares more about the information rent, which can be seen as the net profit. The information rent goes down when the technical parameter increases in Figure 2, in agreement with Proposition 2 without any surprise.

The most important decision content of the regulation mechanism between the government and the T&D cooperation is the transferring payment and the quantity (in Proposition 1). Figures 3 and 4 show the changing tendency of the transferring payment over β and the advantage in technical parameter $\overline{\beta}-\beta$. Figure 4 shows if $\overline{\beta}-\beta \in [0, 0.02]$, the transferring payment changes in the same direction with $\overline{\beta}-\beta$; while $\overline{\beta}-\beta \in [0.02, 0.10]$, they change in the opposite direction. That is because the compensation for output cost is more than the compensation for cost of effort when $\beta \in [0.20, 0.28]$. So government tends to the corporation with low technical parameter (high technical level) more.

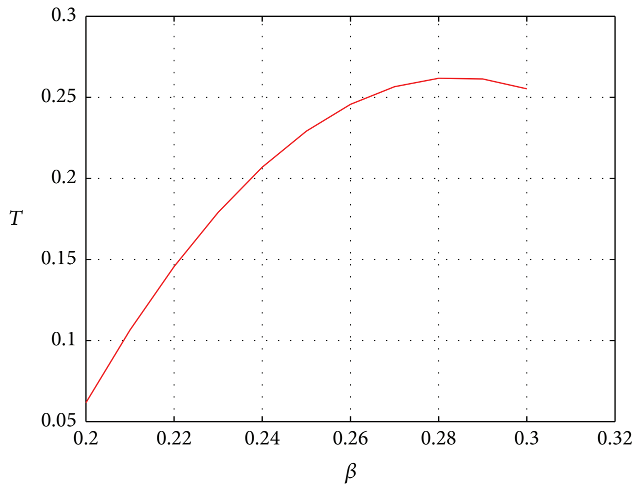

Figure 3: Diagram of the transferring payment in β.

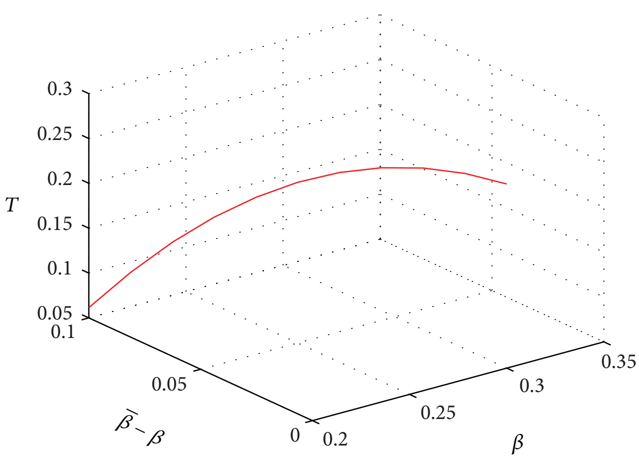

Figure 4: Diagram of the transferring payment in β and $\overline{\beta} - \beta$.

Furthermore, we designate $\beta = 0.25$, $a = 1.2$, $b = 0.3$, $M = 4450$, $A = 7383$, and $N = 2.42$ [32] and simulate the social welfare J (15). As Figure 5 shows, for certain technical parameter β, government, aiming at maximizing the social welfare, must pay reasonable transferring payment to encourage the corporation to make optimal effort and reach optimal quantity.

5.2. Sensitivity Analyses. We perform several sensitivity analyses. The results of the sensitivity analyses regarding the transferring payment, the social welfare, and the optimal effort of the T&D corporation are discussed below.

The sensitivity analyses for social welfare versus a, which can be seen as the market scale, are performed by replacing by −50%, −25%, +25%, and +50% one by one and keeping the remaining parameters, as shown in Table 1. The social welfare significantly changes with the market scale. And when the market scale goes up (+50%, +25%), the social welfare changes much more than when it goes down (−50%, −25%), for example, 0.6391 versus 0.3572 when $\beta = 0.22$, or 0.51 versus 0.2281 when $\beta = 0.26$.

Table 1: Sensitivity analyses for social welfare versus a.

Technical parameter	*Basement* and changes of a	Social welfare
	+50%	+0.6391
	+25%	+0.2843
$\beta = 0.22$	*1.2*	*0.4060*
	−25%	−0.2139
	−50%	−0.3572
	+50%	+0.5746
	+25%	+0.2521
$\beta = 0.24$	*1.2*	*0.3006*
	−25%	−0.1815
	−50%	−0.2926
	+50%	+0.5100
	+25%	+0.2197
$\beta = 0.26$	*1.2*	*0.1997*
	−25%	−0.1493
	−50%	−0.2281
	+50%	+0.4454
	+25%	+0.1875
$\beta = 0.28$	*1.2*	*0.1031*
	−25%	−0.1170
	−50%	−0.1635

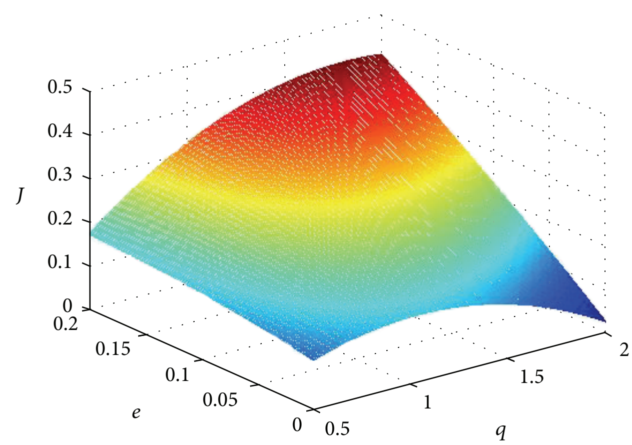

Figure 5: Diagram of social welfare in corporate effort and quantity.

Figure 6 shows the diagram for the optimal effort versus shadow cost with uncertainty, when the T&D corporate technical parameter $\beta = 0.25$. And it is obvious that as the shadow cost λ increases (or in other words, the public funding becoming expensive), the T&D corporation should put larger optimal effort (e^* becomes larger). And the optimal effort increases by the shadow cost linearly in Figure 6. But the shadow cost influences the second-order derivative of the efficiency investment ($I''(e)$) directly and then impacts the optimal effort indirectly, which can be seen in Proposition 3. And the linear influence for the optimal effort versus shadow cost is explained by the quadratic relationship between the efficiency investment I and the effort e.

The optimal effort of the T&D corporation decreases by the electricity coefficient of social welfare M (shown in

Table 2: Sensitivity analyses for social welfare versus M.

Technical parameter	*Basement* and changes of M	Optimal effort	Price	Social welfare
	+50%	−0.5100	+0.0158	+0.1922
	+25%	−0.0306	+0.0142	+0.0880
0.22	*4450*	*0.1591*	*0.6699*	*0.4060*
	−25%	+0.0511	−0.0549	−0.0558
	−50%	+0.1533	−0.2821	−0.0179
	+50%	−0.0383	−0.0168	+0.2108
	+25%	−0.0323	−0.0066	+0.0993
0.24	*4450*	*0.1194*	*0.7386*	*0.3006*
	−25%	+0.0383	−0.0124	−0.0764
	−50%	+0.1149	−0.1254	−0.0955
	+50%	−0.0256	−0.0495	+0.2266
	+25%	−0.0154	−0.0273	+0.1086
0.26	*4450*	*0.0796*	*0.8073*	*0.1997*
	−25%	+0.0255	+0.0300	−0.0922
	−50%	+0.0766	+0.0313	−0.1496
	+50%	−0.0128	−0.0822	+0.2398
	+25%	−0.0077	−0.0481	+0.1162
0.28	*4450*	*0.0398*	*0.8760*	*0.1031*
	−25%	+0.0128	+0.0725	−0.1032
	−50%	+0.0383	+0.1880	−0.1801

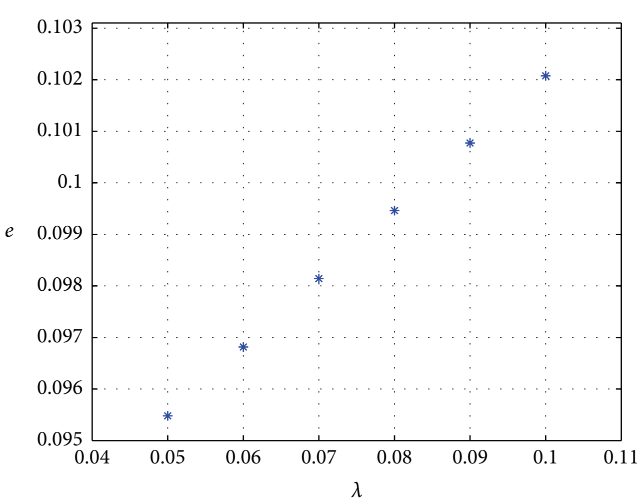

Figure 6: Diagram for the optimal effort versus shadow cost with uncertainty.

Table 2). When M goes up 50% or 25%, the optimal effort changes more than when M goes down 50% or 25%. The optimal price of T&D market varies differently by M, according to the technical parameter. When $\beta = 0.22$, the price increases by M's increase; when $\beta = 0.24$, the price decreases whatever M goes up or down; when $\beta = 0.26$ or $\beta = 0.28$, the price decreases by M's increase. Interestingly, the social welfare also varies differently by M. When $\beta = 0.22$, the social welfare always increases whatever M increases or decreases; when

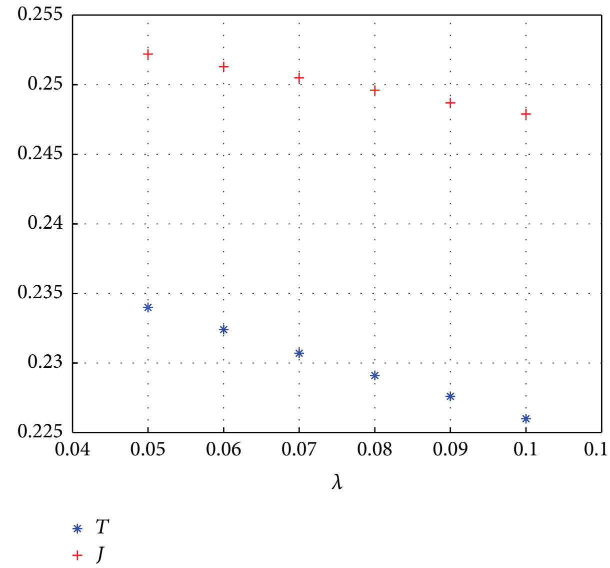

Figure 7: Diagram for transferring payment and social welfare versus shadow cost with uncertainty.

$\beta = 0.24$, $\beta = 0.26$, and $\beta = 0.28$, the social welfare has the same trend with M.

Nevertheless, when the technical parameter $\beta = 0.25$, both the transferring payment and the social welfare decrease by the shadow cost, as shown in Figure 7. And the transferring payment goes a little sharper than the social welfare. That is to say, the loss of the T&D corporation due to the shadow cost increasing (the transferring payment goes down) will not be compensated from the social welfare partly. The drop of the social welfare is shared by the public and the T&D corporation.

More interestingly, the transferring payment and the social welfare decrease also by the average income, as shown in Figure 8. The social welfare goes much sharper than the transferring payment. Even the social welfare becomes smaller than the transferring payment, when the average income is bigger than 2.7. The public may pay more for the electricity usage, when they are rich enough (average income big enough). So the loss of the T&D corporation due to the average income increasing will be compensated from the public mostly.

6. Conclusions

Power transmission and distribution is naturally monopolistic due to the nondivision and scale economy of the power network. Government regulates the power corporation to protect social welfare from monopolistic price. Reasonable pricing mechanism is more important to the reformation in Chinese power market. In this paper, we use this efficient tool, government incentive regulation model, to research the problems resulting from the regulators' information disadvantages. And the conclusions we obtain are shown below:

(1) This model is proved efficient to reveal the corporate private information and encourage it to invest to

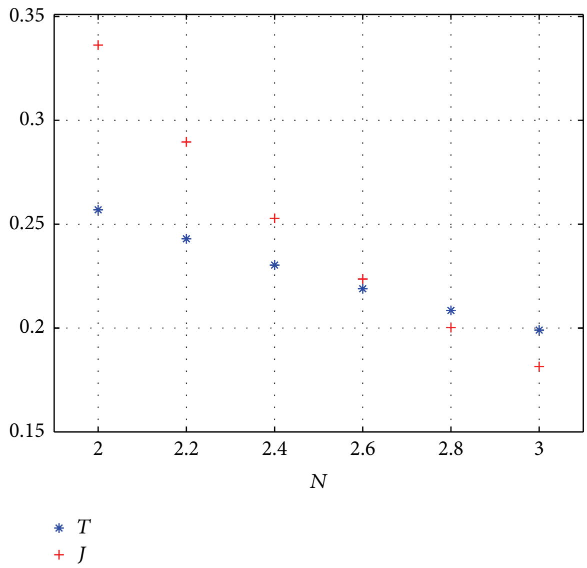

FIGURE 8: Diagram for transferring payment and social welfare versus average income with uncertainty.

improve the power transmission and distribution efficiency. Government achieves its purpose by a menu of contracts to regulate the corporation.

(2) Government makes the compensation policy which includes the compensation for output cost, the compensation for the effort, and the information rent. In addition, the information rent is relevant to corporate technical parameter.

(3) We find the optimal price of power transmission and distribution. Many factors are related to the price including demand, such as the average income of people, the quantity of people, the Gini coefficient, the shadow cost of public funds, and the coefficient of social welfare.

It is important to note that this paper is modeled based on the Chinese P&D market, so the conclusions are given with the basis of Chinese situation. Of course, the government incentive regulation model is also suitable for other P&D markets regulated by government, for example, California [1], UK [8], and Iberian [17]. And the conclusions also make sense in other P&D markets. Above all, in this paper, we only consider the government's regulation in T&D market, but there is also the market power effect during the T&D pricing. So next we will add the market effect in our model.

Parameters

q: Quantity of power transmission and distribution
β: Technical parameter (high β means inefficient technical level)
e: Effort made by the corporation
I: Investment of the corporation (the cost of effort)
U: Utility of the corporation
C: Output cost of the corporation
T: Transferring payment from government
p: Price of power transmission and distribution
A: Quantity of people in a certain area
N: Average income of people in a certain area
G: Gini coefficient
λ: Shadow cost of public funds
M: Coefficient of social welfare.

Competing Interests

The authors declare that they have no competing interests.

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