Exploration of Mixed Ownership of New Energy State-owned Enterprises Based on Stackelberg

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Abstract. Aiming at the dynamic game between the government, social capital and employees in the process of mixed ownership reform of state-owned new energy enterprises. From the perspective of the government, author considers the incentive effect of the reasonable shareholding structure on the social capital side and the employee side, and establishes the Stackelberg complete information dynamic game model with the expected return of the three parties as the decision goal. Solving by the inverse induction method, the ratio of each party under equilibrium is obtained. Then, the reform is the energy-saving wind power in the case of the simulation reform. The research results show that the established Stackelberg model can well divide the new energy ownership structure of state-owned enterprises, complete the reform of mixed ownership, and optimize the three-way income.

Introduction

State-owned enterprises are the pillars of China's national economy. However, state-owned enterprises have many problems such as industry monopoly, low creativity and low efficiency [1]. In recent years, traditional energy sources have been continuously reduced. The new energy industry has become a hot topic in today's society. Domestic and foreign scholars have conducted in-depth research on the relationship between the shareholding structure of listed companies and corporate performance, but there are still very few studies on the shareholding structure and corporate performance of new energy listed companies. Based on the ownership structure determined by the equity concentration system and the nature, the company's organizational structure, ownership structure and benefit distribution model can be determined. It is directly related to the enterprise’s control level, therefore the relationship between equity and company performance. [2].

The research on the relationship between ownership structure and corporate performance has always been a heated topic for Chinese and foreign scholars. However, neither abroad nor domestic research has given a unified conclusion on the relationship between the two. Therefore, it is of great practical significance to study the relationship between the equity structures of new energy listed companies and company performance. The research object of this paper is positioned as a new energy listed company, and focuses on the relationship between the equity structure of new energy listed companies and company performance, and conducts key research and empirical analysis.

There is a clear correlation between the change of shareholding structure and the enterprise benefit in the process of mixed ownership reform. Yan Qingyou and Yang Le have established a “mixed double-headed Cournot monopoly model” to explore whether and how mixed-ownership companies will transfer their non-violent technological innovation licenses [3]. British professors Romano Pagliari and Anne Graham conducted a comprehensive assessment about the impact of the competitive nature of ownership changes between the two airports in 2016-2017 [4]. Also at the European Bank for Reconstruction and Development, Çağatay Bircan examines the ownership structure, productivity of multinational subsidiaries and their impact on domestic industries [5]. Tulay Ilhan-Nas et al., who studied the effects of mixed ownership in the overseas investment of family businesses in developing countries, discussed how this affects the equity system when companies
invest abroad [6]. Corrado Benassi et al. studied the benefits of producing low-quality goods to maximize the competitive price equilibrium between different private companies that to maximize the profitability of high-quality goods [7].

Stackelberg Model

The Stackelberg game belongs to the complete information dynamic game model. The game process is: In the first phase, the superior decision maker determines and announces his own decision; in the second phase, the lower decision maker observes the superior decision maker. After making the decision, according to the best response of the party, make the corresponding decision; the end of the game, the income of both parties is determined. Both sides of the game understand each other's income function, so the superior decision-makers can know the optimal response of the lower-level decision-makers in advance, and then consider them into their own decisions [8].

This paper considers the degree of attraction of social capital parties and the incentive effect on employees, assuming that the government's decision-making variables are the equity structure of new energy state-owned enterprises. The game process is as follows: In the first phase, the government determines and announces the adjustment plan for the shareholding structure of the new energy state-owned enterprises. In the second phase, the social capital side considers and accepts the adjustment of the shareholding structure, customizes the most favorable efforts for the parties according to relevant strategies. In the third period, the share of the government and social capital shares is stable, and the decision-making level allocates employee stocks according to the strategic development direction of the enterprise and the final income of the enterprise as an indicator. At last, the game ends and the three parties' income is determined.

| parameter | Interpretation | parameter | Interpretation |
|-----------|---------------|-----------|---------------|
| $\alpha$  | The level of effort of the social capital side $\alpha \geq 0$ | $\mu$ | Sensitivity to variable costs during project engineering |
| $\beta$   | Employee effort $\beta \geq 0$ | $i$ | interest rate |
| $T_r$     | Business profit cycle $T_r \geq 0$ | $f_a$ | Social effort coefficient |
| $T_f$     | The enterprise profit experience cycle can be obtained through forecasting and statistics. $T_f \geq 0$ | $f_B$ | Employee effort factor versus profit impact factor |
| $T_m$     | Reform franchise period $T_m \geq 0$ | $\pi$ | Benchmark profit $\pi \geq 0$ |
| $\eta$    | Effort factor on corporate profit cycle impact factor $\eta \geq 0$ | $r$ | Enterprise franchise period unit profit |
| $C_f$     | Energy development cost $C_f \geq 0$ | $R$ | Total amount after equity adjustment Social capital share ratio (decision variable), $0 \leq k \leq 1$ |
| $C_i$     | Fixed cost $C_i \geq 0$ | $k$ | Social capital investment ratio, $0 \leq \gamma \leq 1$ |
| $C_v$     | Variable costs $C_v \geq 0$ | $\gamma$ | Social capital investment ratio, $0 \leq \gamma \leq 1$ |
| $C_o$     | Capital cost $C_o \geq 0$ | $m$ | Employee shareholding ratio (decision variable), $0 \leq m \leq 1$ |
| $\lambda_a$ | Sensitivity of variable costs to the level of social capital effort | $\theta$ | Employee sensitivity to salary sensitivity |
| $\lambda_B$ | Sensitivity of variable costs to employee effort | $\delta$ | Employee fatigue index |

Suppose the enterprise profit cycle is $T_t$, and its expression is:

$$T_t = T_f - \eta \alpha - \eta \beta$$

(1)

It can be seen from the above formula model that the harder the social capital party and the employee side in the enterprise operation, the greater the effort, the shorter the enterprise profit cycle and the actual situation.
Assume that the energy development cost of the new energy enterprise is $C_t$, and the development cost includes the fixed cost $C_f$ and the variable cost $C_v$, as:

$$C_t = C_f + C_v$$  \hfill (2)

Among them, the fixed cost $C_f$ is a fixed value, which can be obtained through pre-measurement. According to the literature [9], the variable cost $C_v$ is expressed as:

$$C_v = \frac{1}{2} \lambda_\alpha \alpha^2 + \frac{1}{2} \lambda_\beta \beta^2 + \mu T_t$$  \hfill (3)

In which $1/2 \lambda_\alpha \alpha^2$ is a general expression in principal-agent theory; $\lambda_\alpha$ and $\lambda_\beta$ represent the sensitivity of social capital and employee effort to variable costs, respectively; $\mu$ is the impact of corporate profit cycle on variable costs. It can be seen that the social capital side and the employee side have the only degree of effort, which makes the variable cost the lowest and is in line with the actual situation.

In the actual business operation process, when the equity reform is carried out, a franchise period will be determined, and the time is $T_m$, assuming $T_m$ is a fixed value. Combined with the actual situation, the introduction of state-owned enterprises and social capital cannot need to lend money from financial institutions for a long time, so in order to simplify the model, the capital occupation cost $C_o$ is the cost capital statement. Interest is calculated:

$$C_o = R(1 - \gamma)(T_m + T_s)i$$  \hfill (4)

The income of the energy enterprise $NI$ is the difference between the operating income of the franchise period and the capital investment and capital occupation cost. Assuming that the enterprise franchisee unit average profit is $r$, and $r$ is related to the effort degree coefficient, that as:

$$r = \pi + \alpha f_\alpha + \beta f_\beta$$  \hfill (5)

There is a benchmark profit $\pi$, and the greater the degree of effort of the social capital party and the employee side, the greater the actual average profit $r$, the actual load situation.

The new energy enterprise expects the income function expression as:

$$NI = T_m(\pi + \alpha f_\alpha + \beta f_\beta) - C_o$$  \hfill (6)

In the process of mixed ownership reform, the social capital side has a double-layered role even if it is a shareholder (principal). The social capital side income is like the sum of the profit (ie, related income) of the affiliated enterprise of the new energy enterprise and the division of labor (ie, the operating period income). The expected return function of the social capital side is:

$$NI_{sc} = R - C_c + kNI - Rk\gamma$$  \hfill (7)

The government's income is the difference between the operating period dividend and the amount of capital investment after the reform of the shareholding structure. The income function can be expressed as:

$$NI_{sc} = (1 - k - m)NI - R(1 - k - m)$$  \hfill (8)

The employee's income is the project dividend and occupational salary. Since the employee does not need to invest the cost capital, but the employee's effort is not infinite. In this case, it is necessary to add a fatigue index $\delta$ to limit the level of employee’s effort. The employee side income function can be expressed as:

$$NI_{sm} = mNI + \theta \beta - Rm\alpha - \delta \beta$$  \hfill (9)

In summary, we can get the Stackelberg game model:

$$\max_{\omega_{sc}} NI_{sc} = \max_{\omega_{sc}} [(1 - k - m)NI - R(1 - k - m)]$$  \hfill (10)

$$\max_{\omega_{sc}} NI_{sc} = \max_{\omega_{sc}} (R - C_c + kNI - Rk\gamma)$$  \hfill (11)

$$\max_{\omega_{sc}} NI_{sm} = \max_{\omega_{sc}} (mNI - \theta \beta - Rm\alpha - \delta \beta)$$  \hfill (12)
New Energy Enterprise Mixed Ownership Reform Model Solving

**Model Assume:** there is no direct correlation between the level of social capital effort and the level of employee effort.

The Stackelberg model is usually solved by inverse induction: firstly, the degree of effort \( \alpha^* \) of the social capital side and the degree of employee effort \( \beta^* \) are given for a given stock ratio \( k \) and \( m \). The social capital side and the employee side respond according to the given stock ratio and choose the optimal effort level. Therefore, the optimal effort level is a function of the stock ratio, called the optimal response function, which is recorded as \( \alpha^*(k) \) and \( \beta^*(k) \). Secondly, the two optimal response functions are brought into the government's income function, and the most common equity ratios \( k^*, m^* \) are solved by optimization. Finally, the most shareholding ratio is brought into the optimal response function, and the optimal effort degree \( \alpha^*(k^*) \) of the social capital side and the employee's optimal effort degree \( \beta^*(k^*) \) are calculated.

**Lemma 1** In the game model, the optimal response function of the social capital side to the equity ratio determined by the government:

\[
\alpha^*(k) = \frac{R + R(1-\gamma)(T_f - \eta \beta) i - \pi T_m - \beta T_m f_B}{\lambda_a(T_m f_B + R(1-\gamma)\eta i)}
\]  

(13)

**Lemma 2** In the game model, the employee's optimal response function for the equity ratio determined by the government

\[
\beta^*(m) = \frac{R(1-\gamma)(T_m + T_f - \pi \alpha f_B) i + R \gamma - T_m (\pi + \alpha f_B)}{\lambda_B(T_m f_B + R(1-\gamma)\eta i + \theta - \delta)}
\]  

(14)

**Theorem 1** The subgame Nash equilibrium of the game model is solved by

\[
\begin{align*}
70 - 150 N + 1470 N & \rightarrow - R + R(1-\gamma)(T_f - \eta \beta) i - \pi T_m - \beta T_m f_B \\
& \left(\lambda_a(T_m f_B + R(1-\gamma)\eta i)\right)
\end{align*}
\]  

(15)

(16)

With \( N, M, O \) as:

\[
\begin{align*}
N &= \left(\frac{R(1-\gamma)(T_f - \eta \beta) i - \pi T_m}{\lambda_a(T_m f_B + R(1-\gamma)\eta i)} + \alpha \right. \\
&\left. + (1 - \gamma)\right) \left(\frac{R(1-\gamma)(T_f - \eta \beta) i}{\lambda_B(T_m f_B + R(1-\gamma)\eta i)} \right) \\
M &= T_m \left(\pi + \frac{\alpha}{\lambda_a(T_m f_B + R(1-\gamma)\eta i)} + \lambda_B(T_m f_B + R(1-\gamma)\eta i + \theta - \delta) \right) \\
O &= T_m \left(\pi + \frac{\alpha}{\lambda_a(T_m f_B + R(1-\gamma)\eta i)} + \lambda_B(T_m f_B + R(1-\gamma)\eta i + \theta - \delta) \right)
\end{align*}
\]  

(17)

(18)

(19)

It can be seen from the model that \( R(\gamma-1)[1+(T_m+T_f)i] \) is a negative financial cost and \( T_m \pi \) is the benchmark profit of the franchise period. From the empirical point of view, the franchise benchmark profit can inevitably cover the financial cost, so there is \( R(1-\gamma)[1+(T_m+T_f)i]+T_m \pi > 0 \). Then the expected return function of the government is:

\[
NI_{SG} = (1 - k - m)(M + Nk + Om) - R(1 - \gamma)(1 - k - m)
\]  

(20)

In the process of solving the optimal solution of the government's expected return function, we need to find the full derivative of \( k \) and \( m \). According to the literature [10], we can get the maximum incentive degree of equity split when \( k\): \( m=14 \), so let \( k\) = 14 \( m \), find the total derivative for NISM:

\[
m = \frac{O - 15 M + 210 N}{300}
\]  

(21)

\[
k = \frac{70 - 150 M + 1470 N}{150}
\]  

(22)
Bring them into the optimal response function to get:

\[ a^*(k) = \frac{R + R^{70 - 150M + 1470N}}{150} \frac{(1 - y)(T_m - 2\beta) + \pi T_m - \beta_T u_1}{\lambda (T_m + R(1 - y)\pi)} \]

\[ \beta^*(n) = \frac{(0.15M + 210N)}{300} \frac{(1 - y)(T_m + T_r - na)k + RT - T_m(n + aE)}{\lambda (T_m + R(1 - y)\pi + \theta - \delta)} \]

New Energy Enterprise Mixed Ownership Model

The establishment of the Stackelberg model has great guiding significance for the reform of state-owned new energy enterprises. The following is an analysis of the current situation of China’s new energy industry, and the simulation application of the Stackelberg model for one of the wind power enterprises, the energy-saving wind power.

Analysis of the Status Quo of the Ownership Structure

According to the table of the literature [2] page 17-19, we can measure the current situation of the concentration of equity in China’s new energy listed companies. It can be found that among the 70 new energy companies in the statistics, there are 10 of the largest shareholder holding more than 50%. There are 46 between 20% and 50%. Among them, the top five shareholders of the three companies have a shareholding ratio of more than 60%, which is a high concentration of equity. Based on China’s national conditions, the highly concentrated equity basically belong to state-owned shares. According to the Stackelberg model, the shareholding ratio of the largest shareholder has a great impact on the ratio of social capital stocks to k and the share of employees.

![Figure 1. Effect of Stock Ratio k on Government Revenue.](image1)

![Figure 2. Effect of Share Ratio k on Social Capital Side.](image2)

It can be seen that for the social capital side, the increase in the proportion of equity will increase the overall income of the project. At the same time, with the extension of the franchise period, the marginal effect of the stock's impact on the social capital side's income will gradually increase. As can be seen from Fig. 1, when the proportion of state-owned shares is too high, the overall corporate income begins to decline, with the government’s earnings most damaged.

New Energy Companies Mix All Value Reform Models

This paper fully combines the actual situation and characteristics of new energy listed companies, and takes the energy-saving wind power as the simulation object, establishes the Stackelberg model, and analyzes how the energy-saving wind power reforms the mixed ownership system. According to the information obtained by the website, China Energy-saving Wind Power is the A-share wind power enterprise of the main board of the Shanghai Stock Exchange, with a total market value of 11.469 billion.
The top three shareholders of China Energy Conservation have concentrated 63.16% of the shares, and all of them are state-owned shares. The highly concentrated state-owned shares have a negative correlation with the development of enterprises. Therefore, China Energy-saving Wind Power has begun preparations for mixed ownership reform this year. According to the Stackelberg model analysis, reforms are carried out. The reform process is shown in Fig. 3:

![Stackelberg Reform Flow Chart](image)

**Figure 3. Stackelberg Reform Flow Chart.**

In the process of finding the best advantage, use MatLab to calculate the correlation curve between the ratio of social capital stocks and the proportion of employee stocks to earnings, as shown in Fig. 4 to Fig. 7.
According to the calculation of MatLab, the optimal subgame Nash equilibrium result is $k=43.4\%$ $m=3.1\%$. According to the Stackelberg game model, the optimal scheme for the reform of the energy-saving wind power hybrid ownership system is to introduce social capital of 4.974 billion and 43.4% of the diluted shares. Social capital, which in turn constitutes a new management team, divides employee shareholding according to the Stackelberg model, and completes the reform of corporate mixed ownership.

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