

The Influence of Reverse Mixed Reform on Green Innovation Efficiency of Private Environmental Protection Enterprises

--Taking OriginWater as an Example

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Abstract

Since 2018, private environmental protection enterprises have encountered a debt crisis and their development has entered a bottleneck. Under this background, many enterprises have introduced state-owned strategic investors to promote strategic transformation. This paper takes OriginWater as an example, uses the DEA method to measure its green innovation efficiency, and analyzes the impact of reverse mixed reform on its green innovation efficiency. The study found that during the first mixed-ownership reform, OriginWater's green innovation efficiency showed a "U-shaped" change trend, and during the second and third mixed-ownership reforms, OriginWater's green innovation efficiency showed a "√-shaped" change trend. Generally speaking, the reverse mixed-ownership reform has positively promoted the improvement of green innovation efficiency. The research in this paper has certain reference significance for the reverse mixed reform of private enterprises and the practice of dual carbon goals, and at the same time provides a certain reference for optimizing the rational distribution of state-owned capital.

Keywords

Reverse mixed-ownership Reform; Environmental protection enterprises; Green innovation.

1. Introduction

Since the 18th National Congress of the Communist Party of China, my country has taken the construction of ecological civilization as an important strategy, and raised its importance in economic and social development to an unprecedented height. In 2020, the goals of "carbon neutrality" and "carbon peak" have been proposed, demonstrating China's environmental responsibility and determination to control environmental pollution. The 20th National Congress of the Communist Party of China once again emphasized that based on energy endowment, it is a systematic and profound social change to steadily and actively realize the "double carbon" goal. Private enterprises are an important force in my country's economic and social development, and the realization of the double-carbon target is inseparable from the support and efforts of private enterprises. However, due to the dual externalities of green innovation, the benefits and risks are not equal, and private enterprises, especially environmental protection private enterprises, are constrained by insufficient resources when choosing green innovation. Around 2018, due to the impact of the macro-economy and the large amount of advances and credit loans of various enterprises for rapid growth, a series of private environmental protection enterprises such as Shengyun Environmental Protection and Dunan Environmental Protection exploded intensively and became the hardest hit area for debt default. In this context, the state introduced industrial policies such as tax reduction and fee reduction.

"Mixed ownership" mainly refers to the ownership structure of "mutual integration" and "cross-shareholding" among different ownership capital structures at the micro level (Gong & Hao, 2017). After the Third Plenary Session of the 18th CPC Central Committee, the state issued documents many times to encourage private enterprises to carry out mixed ownership reform, that is, state-owned capital participates in private enterprises, which is also called "reverse mixed ownership reform" in academic circles. The entry of state-owned capital has reshaped the pattern of the environmental protection industry and has also aroused the attention of scholars. Current research focuses on financial and operational value (Zhang et al., 2023; He et al., 2022). Green innovation is an important manifestation of the company's practice of environmental concepts. Will the reverse mixed-ownership reform have an impact on it, and what changes have been made in the company's green innovation performance? This article takes OriginWater, a typical enterprise in the environmental protection industry, as a case to explore the actual impact of reverse mixed reform on the green innovation performance of environmental protection enterprises, and summarizes and analyzes its experience and paths, in order to provide reference for environmental protection private enterprises and help my country's ecological civilization construction.

2. Reasons and process analysis of OriginWater's reverse mixed-ownership reform

2.1. OriginWater Company Profile

2.1.1. Basic development history

Beijing Origin Water Purification Technology Co., Ltd. (hereinafter referred to as Origin Water) was established in 2001 and is one of the leading stocks in the private environmental protection industry. It has world-class membrane technology with intellectual property rights, which is used as a support to engage in environmental protection and water treatment business. From the perspective of main business, it is mainly engaged in municipal and water supply and drainage, water purification business and light environment solutions. From the perspective of operating regions, it has participated in water pollution control in many areas such as the Yangtze River Basin, Haihe River Basin, Taihu Lake Basin, and Chaohu Lake Basin, and participated in hundreds of national governance projects.

The development of OriginWater can be roughly divided into three stages. The first stage is from 2001 to 2015. This stage is the period of the company's start-up and development. The company relies on its independent intellectual property rights of membrane technology for sales and operation, and its business does not expand, but it develops steadily. The most important event at this stage is to achieve listing financing and grow into a star stock on the GEM. The second stage is from 2015 to 2017. During this stage, the company seized the opportunity of environmental protection policies, quickly carried out ppp cooperation projects with the government, conducted multiple rounds of strategic financing, won multiple rounds of investment projects, and achieved rapid growth in intangible assets and cash flow. The third stage is from 2018 to the present. During this stage, the company has undergone tremendous changes. Due to the rapid growth in the early stage, the company has been troubled by the debt crisis, and investment has become difficult and difficult. But at the same time, the company has introduced state-owned capital as a strategic investor, opening a new chapter in strategic development.

2.1.2. OriginWater 's situation before the official mixed-ownership reform

Considering that after China Development Bank purchased 10 % of OriginWater's shares in 2016, the shareholding ratio dropped to around 3 % after only one year of holding the shares, which lasted for a relatively short period of time and did not gain control in the end. The

company’s fundamental shareholding structure has not undergone major changes. Therefore, this section extends the research before the mixed-ownership reform to 2018, which is the year before CCCC’s shareholding.

(1) Equity status before mixed reform. Before CDB's shareholding, Originwater's shareholding structure was mainly privately held. Among the top five shareholders, the largest shareholder held 21.82% of the shares, and the remaining natural persons held 14.03% and 4.44% of the shares. In addition, Xinhua Fund and Qilu Securities each held 4.99% and 5.49% of the shares, and the shareholding structure was relatively concentrated. Before the reverse mixed reform in 2019, companies were still mainly held by individuals. Among the top five largest shareholders, the largest shareholder holds 22.77% of the shares and is the actual controller, the remaining individual shareholders hold 13.49%, 4.27 % and 3.62 % of the shares, and Xinhua Fund holds 4.73% of the shares.

(2) The status quo of green innovation before the mixed-ownership reform. OriginWater, as a leading enterprise with independent intellectual property rights, possesses unique membrane technology and takes technological innovation as the core driving force for enterprise development. Table 1 shows the status of green innovation before OriginWater’s mixed-ownership reform. It can be seen that the number of enterprise patent authorizations has increased year by year, but stagnated in 2018. This is also similar to the development cycle of enterprises. Due to the rapid investment in the past two years, the level of green patents of enterprises has also increased. Both the number of R&D personnel and R&D investment have increased rapidly, which is also inseparable from the investment and rapid growth of enterprises.

Table 1: Green Innovation Status Before Mixed-ownership Reform

index	2014	2015	2016	2017	2018
Number of green patents granted in the year	24	23	46	67	61
The number of authorized green invention patents in the year	4	8	9	3	11
Number of R&D personnel	213	322	396	416	491
Proportion of R&D personnel (%)	16.05	15.8	19.06	15.22	15.81
Total investment in R&D (10,000 yuan)	9791.	15400.	20260.	27841.	27880.
	8 9	15 6	38	15	74
Proportion of R&D investment (%)	2.84	2.95	2.28	2.02	2.42

2.2. Analysis of Reasons for OriginWater's Reverse Mixed Renovation

Ease financing constraints. The important characteristics of the environmental protection industry are high initial investment, long construction period, and slow capital recovery, which determines that its development requires a large amount of financial support. At this stage, despite the rapid development of financial technology, bank credit is still the main financing method, while private enterprises have disadvantages in obtaining resources and face the practical problem of financing difficulties. The introduction of state-owned capital can help enterprises establish and maintain good government-enterprise relations, obtain tax relief, and obtain more cash flow from banks (Dong Xiaohong et al., 2021). In addition, the entry of state-owned capital is a positive and critical signal. The capital market is more likely to believe in the strength of state-owned capital, so it can attract more funds and credit support and alleviate the impact of financing constraints on green innovation of enterprises (Li Wengui and Shao Yiping, 2016). Specifically, from the perspective of OriginWater, before 2015, the company was mainly engaged in the sales of membrane equipment, and its asset scale was small, so it

basically did not face the burden of financing constraints. However, after 2015, with the advancement of the national PPP project, Origin Water has brought development opportunities, and its business objectives have also begun to shift to engineering construction, taking the initiative in development. This radical development model soon plunged Origin Water into a heavy debt crisis, so it hopes to introduce state-owned capital to ease financing constraints.

Improve corporate governance. The shareholding structure is too single and concentrated, and the decision-making model is too simple, that is, the problem of "one share dominates", which has long been a common problem of private small and medium-sized enterprises. After the introduction of state-owned capital, the equity has been diversified, which can effectively alleviate the principal-agent problem (Qi Haodong et al., 2017). Specifically, from the perspective of OriginWater, during the mixed-ownership reform in 2016, China Development Bank directly held more than 10 % of the shares, and sent directors to participate in corporate governance. Before the mixed reform in 2018, it was mainly held by individuals, and there were 7 directors on the board of directors; after the mixed reform in 2019, the number of board members increased to 9, and 2 of them had worked in urban and rural areas in China. This is also the basic way for state-owned capital to obtain governance rights through reverse mixed reform. After the mixed-ownership reform in 2019, China Town and Country obtained 10.14 % of the shares and became the second largest shareholder. Therefore, the company's governance structure has also been greatly improved.

Realize the company's strategy and seize development opportunities. Since the 18th National Congress of the Communist Party of China, my country has paid more attention to the protection of the ecological environment, and various measures have been released one after another, which has also brought opportunities and challenges to the development of Origin Water. On the one hand, the government is actively carrying out cooperative projects with enterprises and carrying out ecological and environmental governance, which has opened up new business space for the development of private environmental protection enterprises like OriginWater; on the other hand, water pollution control and municipal projects require large investment, long payback cycles, and low gross profit margins, which pose new challenges to how companies conduct financial management.

2.3. The process of reverse mixed reform

China Urban and Rural Holdings Group (hereinafter referred to as China Urban and Rural) is a wholly-owned subsidiary of China Communications Corporation. It is mainly engaged in urban and rural water affairs, urban and rural ecological environment and other businesses.

OriginWater's mixed reform process can actually be divided into three stages. The first stage was during the large-scale entry of the "national team" in 2015 to rescue the market. China Development Bank became a shareholder of OriginWater and subscribed for more than 10 % of its shares, becoming its third largest shareholder. The second stage is 2019. In order to implement the reform of state-owned enterprises and promote the pilot work of state-owned capital investment companies; at the same time, in order to enhance its own strength and realize complementary advantages, it acquired more than 600 million shares from individual shareholders twice on May 6 and June 4, 2016, accounting for 10.12% of the company's total shares. It became the second largest shareholder of the company and sent two shareholders. The third stage is 2020 and 2021, when CCCC increased its shareholding to 21.75 % by means of private placement, becoming the de facto and nominal largest shareholder, Origin Water also officially became a company controlled by the State-owned Assets Supervision and Administration Commission, enabling the company to obtain sufficient cash flow and realize strategic transformation.

From the above analysis, we can see that OriginWater, as a leading enterprise in the water industry, has a long reverse mixed-ownership reform cycle and a relatively complicated mixed-

ownership reform process. It has adopted different methods such as equity transfer and private placement, and completed the actual mixed-ownership reform in just one and a half years.

3. Analysis of Green Innovation Performance of OriginWater's Reverse Mixed Ownership Reform

3.1. Index selection and method introduction

There are two main types of existing methods for measuring green innovation performance. One is to use the green patent data of enterprises including inventions and utility models, or the ratio of patent data to R&D investment to measure. However, patent data is more focused on the results of enterprise innovation, and innovation is also an activity with multiple inputs and multiple outputs. There are certain limitations in the ratio of patent data to R&D investment. The other type mainly uses stochastic frontier method and data envelopment analysis (DEA), relatively speaking. DEA does not need to subjectively set functions and weights, and is more effective and objective. This paper draws on the research of Lin & Zhao (2021), and uses the bcc model based on the assumption of variable returns to scale to measure the efficiency of green innovation.

OriginWater has independent intellectual property rights. According to the characteristics of its innovation process and the availability of data, referring to the research of Liu et al. (2023), R&D personnel and enterprise R&D investment are selected as alternative indicators of green innovation investment. At the same time, according to the characteristics that enterprise green innovation activities not only produce scientific and technological achievements, but also output economic benefits, the number of patents obtained by enterprises and net profit indicators are selected as innovation output variables. See Table 2 for details.

Table 2: Index selection

variable type	variable name	Variable value method and description
output variable Y_1	economic benefits	net profit
output variable Y_2	Green Innovation Benefits	The number of patents obtained by the enterprise
input variable X_1	Staff input	Number of researchers
input variable X_2	Capital investment	R&D investment data

According to the selection of the above indicators, the benchmark model constructed is as follows:

$$\min \theta = V_D, s. t. \begin{cases} \sum_{j=1}^n X_j \lambda_j + S^- \leq \theta X_0 \\ \sum_{j=1}^n Y_j \lambda_j - S^+ \leq Y_0 \\ \sum_{j=1}^n \lambda_j = 1 \\ S^- \geq 0, S^+ \geq 0, \lambda_j \geq 0, j = 1, 2, \dots, n \\ n, i = 1, 2, \dots, n \end{cases} \quad (1)$$

Among them θ is the efficiency value of the decision-making unit, X and Y respectively represent the observed value of each index, n and λ are respectively the number of each decision-making unit and the scale return, S^+ and S^- are respectively the slack improvement of each index. In this paper, the bcc model is used for calculation, the comprehensive technical efficiency (Crste) is decomposed, the result is obtained and its change is analyzed.

Analysis of changes in green innovation performance before and after OriginWater's mixed-ownership reform

Based on the use of DEAP2.1 software, this paper calculates the green innovation efficiency of OriginWater from 2014 to 2020 under the condition of variable returns to scale. The results are shown in Table 3 and Table 1. Among them, comprehensive technical efficiency (Crste) is a comprehensive measure of OriginWater's ability to utilize resources for green innovation, pure technical efficiency (Vrste) is the response to OriginWater's management and technology factors, which is mainly related to corporate governance; scale efficiency (Scale) reflects the gap between its actual scale and optimal scale, which is mainly related to corporate financial strength.

Table 3: OriginWater's Green Innovation Efficiency Index

years	Crste	Vrste	Scale	Variation in returns to scale
2014	1.000	1.000	1.000	constant
2015	0.926	0.965	0.959	decrease
2016	0.927	0.955	0.970	decrease
2017	1.000	1.000	1.000	constant
2018	0.827	0.843	0.982	increment
2019	0.665	0.677	0.983	decrease
2020	0.872	0.883	0.988	decrease
2021	1.000	1.000	1.000	constant

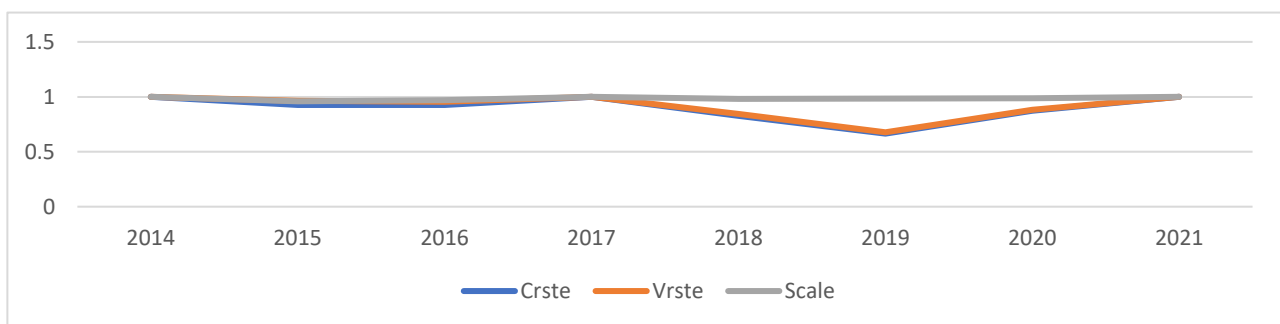


Figure 1: Changes in Green Innovation Efficiency Indicators of OriginWater

As mentioned in the previous analysis, OriginWater's mixed-ownership reform process can be roughly divided into three stages, but considering that the latter two stages are similar in time, this section will combine them for analysis and divide the sample into two stages, of which the first stage is from 2014 to 2017, and the second stage is from 2018 to 2021.

In the first stage of the mixed-ownership reform (2014-2017), OriginWater's annual comprehensive technical efficiency values were 1.000, 0.926, 0.927 and 1.000; pure technical efficiency values were 1.000, 0.965, 0.955 and 1.000; scale efficiency values were 1.000, 0.959 and 0.970 and 1.000, the comprehensive technical efficiency shows a "u-shaped" development trend. The reason for such a change is inseparable from the strategic transformation of the company and the shareholding of China Development Bank. Before 15 years, OriginWater mainly relied on its industry-leading membrane technology and product sales as the main model, and the output efficiency of innovation input was relatively high. However, at this time, the company's technological output scale was also small, and it was a small and sophisticated enterprise. However, as the company entered the ppp project business, the enterprise transformation made great strides. Coupled with the impact of the stock market crash in 2015, the enterprise faced difficulties in operation, and the efficiency of green innovation also

declined. At this time, China Development Bank, as the "national team", directly brought a wealth of capital and management experience to Origin Water, which helped Origin Water get out of the development dilemma and realize strategic transformation. Although CDB's shareholding ratio has dropped to around 3% in 2016, this is not its initiative to reduce its holdings. The abundant capital flow it brings to the company still plays a role in improving the scale efficiency of the company. Since 2015, the scale efficiency of the company has increased from 0.959 to 1.000; but at the same time, we have also noticed that with the dilution of the state-owned capital equity structure, Origin Water's pure technical efficiency has experienced twists and turns. The dilution of equity capital still has a certain impact on the efficiency of green technology innovation of enterprises, indicating that the governance effect brought by state-owned capital changes with the change of equity structure.

In the second stage of the mixed-ownership reform (2018-2021), OriginWater's annual comprehensive technical efficiency values are 0.827, 0.665, 0.872 and 1.000; pure technical efficiency values are 0.843, 0.677, 0.883 and 1.000; scale efficiency values are 0.982, 0.983, 0.988 and 1.000, the change of comprehensive technical efficiency presents a " $\sqrt{\quad}$ -shaped" development trend. In 2018, debt default "landmines" of private environmental protection enterprises broke out intensively, and OriginWater's debt crisis was also extremely severe. The asset-liability ratio reached an unprecedented 6.6%, and the current ratio and quick-freezing ratio were also below 1 for a long time, which caused the company to face serious operating problems. Green innovation requires strong resource support, so the company's green innovation efficiency declined sharply, falling to 0.665 in 2019. Therefore, in the second half of 2019, the company introduced China Urban and Rural as a strategic investor to reshape the company's development model. By 2020, China Urban and Rural completed the second round of private placement and became the actual controller of Origin Water, ushering in fundamental changes in the company's development. The entry of China's urban and rural areas has exerted strong resource efficiency and governance effects. Under the internal debt disputes and the external impact of the new crown epidemic, it has achieved the growth of green innovation efficiency, and by 2021 it has reached the forefront of technological innovation.

After the above analysis, it can be found that the participation of state-owned capital in the reverse mixed reform of private enterprises has exerted a strong resource benefit and governance effect, helping OriginWater to get out of debt difficulties, improve green innovation performance, and achieve strategic transformation.

4. Analysis conclusion

With the proposal of the dual-carbon strategy, the importance of ecological civilization construction has become more prominent, which has brought major development opportunities for environmental protection enterprises, and at the same time put forward higher requirements for the environmental protection industry. However, in 2018, private environmental protection enterprises fell into a debt crisis and encountered development bottlenecks. In this context, private enterprises are actively introducing state-owned capital, and the reverse mixed reform is advancing in depth. This paper takes OriginWater as an example, uses the DEA method to measure its green innovation efficiency, and analyzes the impact of reverse mixed reform on its green innovation efficiency. The study found that during the first mixed-ownership reform period, OriginWater's green innovation efficiency showed a "U-shaped" change trend, and during the second and third mixed-ownership reform periods, OriginWater's green innovation efficiency showed a " $\sqrt{\quad}$ -shaped" change trend. Generally speaking, the reverse mixed-ownership reform has positively promoted the improvement of green innovation efficiency. The research in this paper has certain reference significance for the reverse mixed reform of private enterprises and the practice of dual carbon goals, and at the

same time provides a certain reference for optimizing the rational distribution of state-owned capital.

The inspiration of this article is as follows. First, state-owned capital is an important strategic investor, which has played an important role in improving the green innovation performance of environmental protection enterprises and is conducive to the realization of dual carbon goals. Therefore, it is of certain positive significance to optimize the rational distribution of state-owned capital and actively promote the reverse mixed reform of environmental protection enterprises and other industries facing certain development bottlenecks. Second, corporate governance is crucial to improving the efficiency of corporate green innovation. The important mechanism for the reverse mixed reform to play a role is to enter the board of directors of private enterprises through equity arrangements and play a role in daily operations and key strategic decisions. It can be seen that the improvement of the governance structure is of great significance to enterprises.

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