Research on the Theoretical Model of CSR Realization in Energy Industry based on Evolutionary Game Theory

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Abstract. Corporate social responsibility (CSR) is a hot topic in recent years. From the perspective of game theory, this paper analyses the game process of the CSR realization in energy industry. From the perspective of the non-cooperative game and cooperative game theory, this paper constructs the theoretical model of CSR realization in energy industry based on evolutionary game theory. Through the research, this paper finds that cooperation is the premise of CSR to achieve sustainability and stability. Through cooperative pricing, the cost of CSR could be minimized.

1. Introduction

Energy security is an overall and strategic issue related to the economic and social development of a country. It is crucial to the prosperity and development of a country, the improvement of people’s lives, and the long-term stability of society. At the same time, energy is also an important resource and factor of national economy and people’s livelihood. The sustainability and stability of energy is about people’s life, market stability and economic development. Due to the serious pollution in the energy industry, we should be objective and fair in the disclosure of social responsibility information to all stakeholders.

With the development of China’s economy and the improvement of people’s living standards, people from all sectors of society have higher and higher requirements for the quality of life. On October 18, 2017, General Secretary Xi Jinping pointed out in the report at the opening of the 19th National Congress of the Communist Party of China that the principal contradiction is “the contradiction between unbalanced and inadequate development and the people’s ever-growing need for a better life”. Thus, the enterprise should not only pay attention to its profit and financial performance but also bear and perform the corresponding CSR. Although “at present, the system construction, implementation, and management mode of corporate social responsibility (CSR) in China are not perfect” [1], CSR is indeed a hot spot in the research of economic and social science.

The research results of Fu ting and Wang Xin (2019) show that “the community of CSR is the continuation and extension of the traditional CSR governance theory, and the effectiveness of CSR governance depends on the agreement and rationality of the operational objectives and mechanisms of the governance community formed by the governance subjects [2]”. Zhao Xinhua (2019) confirmed that “the concern of stakeholders makes corporate governance and CSR practice tend to the same development direction [3].”
In all, from the perspective of game theory, this paper studies the CSR realization mechanism in energy industry in China and constructs the theoretical model of CSR realization based on evolutionary game theory in China.

2. Research value
CSR covers a wide range of aspects, from environmental protection, ecological restoration, underground space and water resources protection, consumer interests, employee rights, interests, etc. It is difficult to achieve all of these by a single enterprise, so all social enterprises should cooperate to solve from the perspective of a cooperative game. According to the stakeholder theory, the relationship among enterprises has a major impact on the performance of CSR, so it is of practical value to analyse the performance of CSR from the perspective of transaction volume and relevant relationships among enterprises. It is of theoretical value to study CSR based on evolutionary game theory, which can enrich the research of game theory and CSR. At the same time, energy industry is about the national economy and people’s livelihood, and energy price fluctuation is also about thousands of households. The analysis and study of CSR in energy industry from the perspective of government guided pricing has reference value for better government pricing.

3. Research hypothesis
Through empirical research, Li Xuan et al. (2013) find that “bilateral contract transaction of products is a necessary condition for upstream manufacturers to implement CSR behaviour [4]”, and “high-enough efficiency of manufacturer’s CSR behaviour is a sufficient condition for node enterprises (manufacturers and retailers) to improve CSR performance and economic performance of supply chain through bilateral contract transaction of intermediate products”. The choice of trading objects is smooth, and the choice of these trading objects will affect the performance of CSR. Based on this, this paper establishes the first research hypothesis:

**H0: the relationship and transaction among enterprises have a positive impact on the performance of CSR**

Based on game theory, Ma Yueru et al. (2019) find that “with the improvement of the bargaining power of downstream enterprises, the input of supply chain CSR will decrease [5]”. Jiang Huihua (2019) proposes “the cooperation management mode of core enterprises and their stakeholders to manage the CSR of supply chain [6]”. The relationship among enterprises in the supply chain and the bargaining power of each enterprise affect not only the fulfilment of their CSR but also the fulfilment of other’s CSR in the supply chain. Therefore, the second research hypothesis is made:

**H1: the bargaining power of enterprises and the relationship among enterprises have a positive impact on the performance of CSR**

According to the research results of Shang Haiyan et al. (2018), “government price intervention can effectively reduce the impact of price factors [7]”. At the same time, Zheng Jianing (2014) also concludes that “while giving more autonomy to the market, we still need to pay attention to the role of government guidance and supervision [8]”. In a market economy, the price of a product cannot be determined completely by the market, but it needs the government-guided pricing or government-supervised pricing mechanism. Based on this, this paper puts forward the third hypothesis:

**H2: the price of products needs the guidance or supervision of the government**

4. Theoretical Game Model
Based on the above research hypotheses and theories, this paper studies CSR along the mainline of “energy-supplying enterprise” and “energy-consuming enterprise”. Several supposes are made, such as the product demand in the Chinese market is random; the energy-supplying enterprises are all producing according to the idea of “self-production and self-sale”; the product suppliers can directly face the product consumers in the market; the energy-supplying enterprises and the energy-consuming enterprises can meet their own needs for all kinds of equipment and other spare parts. All market risks
between the product supplier and the product consumer are neutral, and the price, demand, and other market information are completely open, and there is no extreme market supply situation such as product shortage or excessive product surplus. By fully studying game theory and other models, this paper establishes the CSR model of the whole supply chain system as follows:

$$CSR_i = \sum W_i CSR_j$$

$$0 < i < 1, \text{ and } \sum i = 1$$

$w_i$: the CSR of the whole supply chain system

$W_i$: the weights of energy-supplying enterprise and energy-consuming enterprise

$Y_i$: the CSR of energy-supplying enterprise (1) and the CSR of energy-consuming enterprise (2)

According to the equilibrium theory in the economic principle, based on the traditional demand-price formula, we can get a new demand-price formula of the product with CSR as follows:

$$D = \alpha + \beta CSR_i - \mu P$$

$D$: the demand for the product in the market

$P$: the price of the product in the market

$CSR_i$: the CSR of the whole supply chain system

$\alpha$: the other factors of demand in the market

$\beta$ and $\mu$: coefficients

To simplify the game process and calculation related, this paper does not consider the R&D cost, processing cost and sales cost of the energy-supplying enterprise, and does not consider the purchase cost, transportation cost, and storage cost of the energy-consuming enterprise too. According to the cost function, this paper obtains the cost function of energy-supplying enterprise and energy-consuming enterprise based on CSR cost:

$$C_i = w_i CSR_i$$

$$i = 1, 2$$

$C_i$: cost increased by CSR

$w_i$: conversion rate of CSR and related costs

$CSR_i$: the CSR of energy-supplying enterprise (1) and the CSR of energy-consuming enterprise (2)

In the same way, according to the accounting profit formula “profit=income-cost”, without considering other cost factors, this paper expresses the profit formulas of energy-supplying enterprise, energy-consuming enterprise and whole market as follows:

$$PT_1 = P_1 D - C_1 = P_1 D - w_1 CSR_1$$

$$PT_2 = P_2 D - P_1 D - C_2 = P_2 D - P_1 D - w_2 CSR_2$$

$$PT = PT_1 + PT_2 = (P_2 - P_1) (\alpha + \beta CSR_i - \mu P) - (CSR_i + CSR_2)$$

$PT_1$: profit of energy-supplying enterprise

$PT_2$: profit of energy-consuming enterprise

$PT$: profit of the whole market

In many cases, the administrative penalty is calculated on the multiple transaction prices. Therefore, this paper assumes that the government will punish the enterprise for failing to perform its CSR or overestimating the cost of its products, which will increase the cost of the enterprise as follows:

$$C_n = n P_i$$

$C_n$: cost increased by administrative penalty

$n$: multiple of the transaction price

$P_i$: the price of the product
5. Research on the gaming process

5.1 Realization mechanism of CSR under non-cooperative game

In the case of the non-cooperative game, because energy-supplying enterprise and energy-consuming enterprises do not cooperate and care about their costs and profits, they can only bear their CSR. At this time, energy-supplying enterprise and energy-consuming enterprises perform as two independent subjects: energy-supplying enterprise or energy-consuming enterprise only bears its own CSR.

In the first stage, energy-supplying enterprise will anticipate the demand of energy-consuming enterprise to determine the optimal product supply price $P_1$, and then realize the maximum profit under CSR.

$$PT_1 = P_1(\alpha + \beta CSR_1 - \mu P_1) - w_1 CSR_1$$

To get the derivation of $PT_1$:

$$\frac{\partial PT_1}{\partial P_1} = \alpha + \beta CSR_1 - w_1 P_1 = 0$$

And then:

$$P_1 = \frac{\alpha + \beta CSR_1}{w_1}$$

In the second stage, energy-consuming enterprise will use the economic order quantity (EOQ) model to determine the best order quantity and price according to its short-term and long-term product demand to maximize its profit under CSR.

$$PT_2 = (P_2 - P_1)(\alpha + \beta CSR_2 - \mu P_2) - w_2 CSR_2$$

To get the derivation of $PT_2$:

$$\frac{\partial PT_2}{\partial P_2} = \alpha + \beta CSR_2 - w_2 (P_2 - P_1) = 0$$

And then:

$$P_2 = \frac{\alpha + \beta CSR_2}{w_2} + P_1$$

In the third stage, based on the supply chain, energy-supplying enterprise or energy-consuming enterprise considers its profit maximization without cooperation to bear CSR. In the case of their respective social responsibilities, the sum of profits will be maximized as follows:

$$PT = PT_1 + PT_2 = (P_1 - P_2)(\alpha + \beta CSR_1 - \mu P_1) - w_1 CSR_1$$

To get the derivations of $P_1$ and $P_2$:

$$P = \frac{\alpha + \beta (2CSR_1 + CSR_2)}{\mu + \mu}$$

5.2 Realization mechanism of CSR under cooperative game

In the case of the cooperative gaming process, energy-supplying enterprise and energy-consuming enterprise do not only consider their profits. Based on the maximization of the overall profits, they should bear their CSR. Therefore, they will perform their social responsibilities based on price negotiation, joint pricing, or negotiated pricing. The overall profit will be calculated by the unified negotiation pricing $P$.

$$PT = P(\alpha + \beta \sum w_i CSR_i - cP) - (w_1 CSR_1 + w_2 CSR_2)$$

To get the derivations of $P$:

$$\frac{\partial PT}{\partial P} = \alpha + \beta \sum w_i CSR_i - cP = 0$$

And then:

$$P = \frac{\alpha + \beta \sum w_i CSR_i}{\mu + \mu}$$
5.3 Realization mechanism of CSR under cooperation game and price guidance or supervision of the government

Under the price guidance or supervision of the government, to avoid punishment, but also to perform CSR at less cost, enterprises generally choose to cooperate.

\[ PT = P(\alpha + \beta \sum w_iCSR_i - cP) - nP - (w_1CSR_1 + w_2CSR_2) \]

To get the derivations of \( p \):

\[ \frac{\partial PT}{\partial P} = \alpha + \beta \sum w_iCSR_i - cP - n = 0 \]

And then:

\[ p = \frac{\alpha}{\mu} + \frac{\beta}{\mu} \sum w_iCSR_i - \frac{n}{\mu} \]

In order to better verify and simulate the realization mechanism of CSR in the energy industry under the game theory, this paper uses MATLAB r2019b for numerical simulation. The settings of parameters related are shown in Table 1.

| Parameter | Value | Parameter | Value |
|-----------|-------|-----------|-------|
| a         | 70    | K_1       | 0.7   |
| b         | 3     | K_2       | 0.3   |
| c         | 2.5   |           |       |

6. Conclusion and discussion

This paper studies the realization mechanism of CSR in energy industry from the perspective of game theory. Considering the different results of CSR under the two different game modes of the cooperative game and non-cooperative game, this paper constructs the evolutionary-game-theoretical model of CSR in energy industry. Through theoretical research, we get the following enlightenment: (1) energy is about the national economy and the people’s livelihood, and the price of energy is important. Therefore, the price of energy cannot be completely market-oriented, and should be properly controlled by the government; (2) the interdependence among enterprises has a significant impact on their CSR, and strengthening the cooperation among enterprises is essential to improve the CSR of the whole supply chain; (3) the transaction volume and frequency among enterprises have a great impact on their mutual dependence; (4) the bargaining power of enterprise is the key to restrict the number of transactions between enterprises. From the perspective of game theory, if enterprises want to fulfill their CSR, cooperation, and the government “guide price” are the keys to establish a sustainable and stable mechanism of CSR.

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