Distribution strategy of energy supply chain based on corporate social responsibility

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Abstract: From corporate social responsibilities influence on the consumer’s preferences, applying the basic idea of game theory, the study on tactics of profit distribution of the one-period game between manufacturer and vendor in energy supply chain, then the repetitive game results of the two partners are discussed. The results show that alliance pricing is the unique nash equilibrium of the one-period game between manufacturer and vendor, and the profit of both manufacturer and vendor will increase after cooperation in the range of agreed value of the profit distribution factor. It’s optimal for manufacturer and vendor to insist on alliance pricing for their long-term benefits in energy supply chain.

1. Introduction
With the development of China’s domestic consumption conception and the global concern over energy, the energy management calls for more advanced methods and ideas. The implementation of supply chain management requires us to structure a model which takes the energy base as the supplier, the energy processing plant as the manufacturer, the energy distribution station as the vendor and the end-user as the consumer. Currently, the rampant phenomena of over consumption, extreme pollution and poor efficiency in the uncertain environment is the common occurrence in the various links of the whole energy supply chain which is characterized by multi-phases, multi-channels and multi-members participants. One of the important approaches to minimize the dissipation and the wastage of energy logistics is to optimize supply channels and strengthen supply chain management.

Supply chain management highlights the win-win idea which is featured by combining competition and cooperation. The enterprises on the supply chain can obtain more profit through cooperation; while they share the profit through competition. First, the energy base, the energy processing plant and the energy distributor establish a strategic partnership to realize the integration and the optimized utilization of the resources, improve resource quality and reduce the production and transaction cost, so as to attain excess earnings from cooperation and then share the achievement through an effective distribution strategy. As the interest of the energy base, the energy processing plant and the energy distributor is independent of each other, the root cause driving them to join the energy supply chain is to acquire more benefits. The absence of reasonable profit distribution strategy will reduce their zest to cooperate and negatively impact the operating efficiency and stability of the energy supply chain. Therefore, to conduct profit distribution strategy research for the energy supply chain is the key to the construction and the management of the energy supply chain.

At the same time, Corporation Social Responsibility (CSR) has been talked about a lot recently. More and more companies intend to improve their company image by contributing more in CSR
aspect. CSR activities imply a harmonious development considering environment, consumer, charity groups, ethnic groups, employee welfare and community. Sethi introduced a sort of CSR activity which is the social responsibility including social obligations and more volunteering social responsibility[1]. Carol developed the framework of CSR, including economy, law and ethic responsibility[2,3]. In other literature reviews, the definition of CSR is involved with environment, human rights, fraternity, safety and etc[4–9]. It is reasonable that energy supply chain, compared with other types of supply chain, should take CSR more into consideration especially environmental responsibilities.

2. Literature review

Foreign scholars have already conducted some researches on CSR of supply chain. Che -Fu Hsueh and Mei -Shiang Chang researched on the web-shaped supply chain constituted by manufacturer, distributor and retailer. The conclusion shows that the optimized solution for the supply chain network usually cannot be realized or to be stable. In order to make the optimized solution of the system be in a stable status, they proposed a competitive strategy, which is coordination among manufacturers for CSR [10]. In the environment of CSR, Jose M. Cruz studied the dynamic supply chain network[11]. Francesco Ciliberti and Pierpaolo Pontrandolfo proposed the concept of LSR (Logistics Social Responsibility). He mainly researched on the contents of LSR practice based on the analysis of Italian companies[12]. D. Eric Boyd, Robert E. Spekman and John W. Kamauff and some others believe that the purchaser in supply chain should ensure the social responsibility being carried out by suppliers in terms of employment, environment and others. This paper believes that an intense surveillance may not enforce the CSR of suppliers, but may cause damage to the relationship between purchaser and supplier[13]. Esben Rahbek Pedersen and Mette Andersen studied the safe measurements which can be applied to ensure CSR in global supply chain and how to manage the behavioral rules between purchaser and supplier[14]. Currently, there are few researches conducted on the CSR in supply chain domestically and there is no literature published which studies CSR in a supply chain coordination and pricing perspective[15]. Carter and Jennings have explored the influence of environment purchase on company performance. Results show that environment purchase is significantly related to the company net income. Carter`s study also shows that CSR has direct and positive influence on the supply chain performance[16].

At present, main studies on the profit distribution of supply chain can be classified into the following categories: What is frequently employed in the profit distribution of supply chain is the income-sharing contract, under which the downstream enterprises can share income with the upstream enterprises proportionally. It is the profit redistribution in the supply chain in practice. By introducing income-sharing contract, the leading enterprises can gain access to more profits from modifying the income sharing proportion, creating flexibility for leading enterprises to formulate profit distribution system. Pasternack[17] studied the applicable conditions of income-sharing contract from the perspective of a vendor. Dana and Spier’s[18] finding indicated that income sharing was of great value in vertical integration industry as it can coordinate three kinds of supply chain, namely random or variable demand quantity; the downstream inventory must be determined before the demand is met; the inter-competition among downstream enterprises. Cachon and Lariviere[19] made an extensive research into the income-sharing strategies and then argued that income sharing can coordinate the supply chain involving an individual distributor or a couple of competing distributors. Their research also found that income sharing was better than repurchase in coordination.

This paper researches on the realization of optimized solution of energy supply chain by establishing a game model based on the issue of sharing social responsibility between energy processing plant and the energy distributor.

3. Profit distribution model of energy supply chain

Consumer`preference means the social responsibilities of a product for consumers. Here it mainly refers to environment responsibilities which bring preference in profit and decide the size of consumer
surplus. Consumers will choose products according to the size of consumer surplus. For convenience of analysis, the following assumption is made: the products at consumers’ disposal are consisted of two kinds which are good and bad for consumer environment responsibility correspondent to the relatively good and bad products for environment responsibility shoudered by the upper stream energy processing plant; the two energy processing plants produce identical products while products only vary in terms of carrying out product environment social responsibility; consumer’s preferences will depend on the carrying out product environment social responsibility of the products; consumer preference consumer’s preferences will be expressed in higher value of products. Every consumer will have specific needs in certain kinds of products while the products produced by an energy processing plant which carries out more environment social responsibility will bring higher environment value for consumers.

Consider an energy supply chain energy that is composed of processing plant ed manufacturers - vendors - consumers. \( e, i \) represent two cases that manufacturers perform social responsibility better and worse, \( \alpha \) is indicator variables of consumer to buy two products, \( \beta \) is consumer’s preferences, \( \beta^* \) is critical point of consumers to buy two products when products are sold at alliance pricing, \( \beta^r \) is critical point of consumers to buy two products when products are sold at retail price. \( \beta^r \) is upper bound of consumer’s preferences, \( u \) is product’s utility, \( v \) is product’s value, \( v(\beta) \) is consumer’s surplus. \( R \) is consumer`s profit owing to corporate social responsibility, \( R_e, R_i \) is consumer’s profit owing to corporate social responsibility of \( e \) and \( i \) products separately, \( p \) is the consumer retail price sold by vendors, \( p_m \) is the wholesale price of products sold by manufacturers to vendors, \( c \) is cost of production, \( \theta \) is profit distribution factor, \( \eta \) is manufacturer’s profits discount rate when products are sold at retail price, \( \tau \) vendor’s profits discount rate when products are sold at retail price, \( \Pi_m \) is manufacturer’s profits, \( \Pi_r \) is vendor’s profit, \( \Pi_c \) is the whole profit of supply chain, \( H(\beta) \) is the distribution function of consumer’s preferences, \( \lambda \) is the proportion of high social value that consumers think, \( \lambda' \) is the proportion of high social value that consumers think when manufacturer’s profits are equal from two products.

3.1. One-period game

If the value of the products provided by energy processing plants to consumers is indicated by \( v = u + \beta R \), then consumer’s surplus function is

\[
v(\beta) = u + \beta R - p
\]

(1)

If \( v(\beta) > 0 \), consumers will buy products, then

\[
v(\alpha, \beta) = \alpha v_e(\beta) + (1 - \alpha) v_i(\beta), \alpha \in \{0, 1\}
\]

(2)

Therefore,

\[
\beta^* = \frac{(p_e - p_i)}{(R_e - R_i)}
\]

(3)

If the whole consumer group is regarded as 1 for identical product, consumer’s preferences function is

\[
H(\beta) = 1 - \lambda + \lambda' \frac{\beta}{\beta^r}, \beta \in [0, \beta^r]
\]

(4)
\[
\begin{align*}
\Pi_{me} &= \int_0^\beta (p_{me} - c_e) dH(\beta) \\
\Pi_{mi} &= \int_0^\beta (p_{mi} - c_i) dH(\beta) \\
\Pi_{re} &= \int_0^\beta (p_m - p_{me}) dH(\beta) \\
\Pi_{ri} &= \int_0^\beta (p_{p_m} - p_{ri}) dH(\beta) \\
\Pi_{e} &= \int_0^\beta (p_e - c_e) dH(\beta) = \left(\frac{\lambda}{\beta'}\right)(\beta' - \beta^*) \\
\Pi_{i} &= \int_0^\beta (p_i - c_i) dH(\beta) = \left(\frac{\lambda}{\beta'}\right)\beta^*
\end{align*}
\]

Due to \( p_{me} > c_e \) and \( p_{mi} > c_i \), then \( p_e^* \neq p_{re}^* \) and \( p_i^* \neq p_{ri}^* \). The whole supply chain’s profit can’t ensure maximization. Selling at \( p_{re}^* \) and \( p_{ri}^* \), vendor’s profit will reduce selling at \( p_e^* \) and \( p_i^* \) and will refuse. It’s critical to determine profit distribution factor \( \theta \) which can be determined according to strength of manufacturer and vendor or negotiations and the range of which need to be determined prior.

For manufacturer, \( \partial \Pi_{me} \left(p^*\right) \geq \eta \Pi_{me} \left(p^*_e\right) \) and \( \partial \Pi_{mi} \left(p^*\right) \geq \eta \Pi_{mi} \left(p^*_i\right) \); for vendor, \( (1-\theta) \Pi_{re} \left(p^*\right) \geq \tau \Pi_{re} \left(p^*_e\right) \) and \( (1-\theta) \Pi_{ri} \left(p^*\right) \geq \tau \Pi_{ri} \left(p^*_i\right) \), therefore, when

\[
\begin{align*}
\eta \int_0^\beta (p_{me} - c_e) dH(\beta) &= \tau \int_0^\beta (p_{me} - c_e) dH(\beta) \\
\int_0^\beta (p_{re} - p_{me}) dH(\beta) &= \int_0^\beta (p_{re} - p_{me}) dH(\beta) \\
\end{align*}
\]

profit of two product’s manufacturer and vendor will be greater than before, thus, joint sales of \( e \) and \( i \) products can be formed likely in the range of \( \theta_e \) and \( \theta_i \) negotiated by manufacturer and vendor.

\[
\begin{align*}
\frac{\partial \Pi_{e}}{\partial p_e} = 0 \text{ and } \frac{\partial \Pi_{i}}{\partial p_i} = 0 \text{ solved simultaneously, Equilibrium price in the case that two products are sold jointly can be obtained}
\end{align*}
\]

then

\[
\begin{align*}
\Pi_{me} &= \int_0^\beta (p_{me} - c_e) dH(\beta) \\
\Pi_{mi} &= \int_0^\beta (p_{mi} - c_i) dH(\beta) \\
\Pi_{re} &= \int_0^\beta (p_m - p_{me}) dH(\beta) \\
\Pi_{ri} &= \int_0^\beta (p_{p_m} - p_{ri}) dH(\beta) \\
\Pi_{e} &= \int_0^\beta (p_e - c_e) dH(\beta) = \left(\frac{\lambda}{\beta'}\right)(\beta' - \beta^*) \\
\Pi_{i} &= \int_0^\beta (p_i - c_i) dH(\beta) = \left(\frac{\lambda}{\beta'}\right)\beta^*
\end{align*}
\]
\[ p^*_e = \frac{1}{3} \left[ 2c_e + c_i + 2\beta' (R_e - R_i) \right] \]
\[ p^*_i = \frac{1}{3} \left[ c_e + 2c_i + \beta' (R_e - R_i) \right] \]

(10)

\[ \frac{\partial \Pi_{re}}{\partial p_e} = 0 \text{ and } \frac{\partial \Pi_{ri}}{\partial p_i} = 0 \] solved simultaneously, vendor’s Optimal price \( p^*_e \) and \( p^*_i \) can be obtained.

\[ p^*_e = \frac{1}{3} \left[ 2p_{me} + p_{mi} + 2\beta' (R_e - R_i) \right] \]
\[ p^*_i = \frac{1}{3} \left[ p_{me} + 2p_{mi} + \beta' (R_e - R_i) \right] \]

(11)

Compare formulas (10) and (11), \( p^*_e \geq p_e \) and \( p^*_i \geq p_i \) is knowable. And plug formulas (10) into (3), \( \beta_{ri}^* \) can be obtained

\[ \beta_{ri}^* = \frac{1}{3} \left[ \beta + \frac{c_e - c_i}{R_e - R_i} \right] \]

(12)

Plug formulas (10) and (12) into formulas (1), \( \Pi_{ce}^* \) and \( \Pi_{ci}^* \) can be obtained

\[ \Pi_c \left( p_e^* \right) = \frac{\lambda \left( c_e - c_i + 2\beta' (R_e - R_i) \right)^2}{9 \beta' (R_e - R_i)} \]
\[ \Pi_c \left( p_i^* \right) = \frac{1 - \lambda}{3} \left( c_e - c_i + \beta' (R_e - R_i) \right) + \frac{\lambda (c_e - c_i + \beta' (R_e - R_i))^2}{9 \beta' (R_e - R_i)} \]

(13)

Plug formulas (11) into formulas (3), \( \beta_r^* \) can be obtained

\[ \beta_r^* = \frac{1}{3} \left[ \beta + \frac{p_{me} - p_{mi}}{R_e - R_i} \right] \]

(14)

Plug formulas (14) into (5), formulas (11) and (14) into (6), \( \Pi_{me}^* \), \( \Pi_{ci}^* \), \( \Pi_{re}^* \) and \( \Pi_{ri}^* \) can be obtained.

Plug \( \Pi_{ce}^* \), \( \Pi_{me}^* \), \( \Pi_{mi}^* \) into formulas (8), and plug \( \Pi_{ci}^* \), \( \Pi_{ri}^* \), and \( \Pi_{ri}^* \) into formulas (9), then the range of profit distribution factor is shown as

\[ \theta_e = \left\{ \frac{3n_e \left( p_{me} - c_e \right) \left( 2\beta' R_e - 2\beta' R_i + p_{me} + p_{mi} \right)}{\left( c_e - c_i + 2\beta' (R_e - R_i) \right)^2}, 1 - \frac{\left( p_{mi} - p_{me} + 2\beta' \left( R_e - R_i \right) \right)^2}{\left( c_e - c_i + 2\beta' (R_e - R_i) \right)^2} \right\} \]
\[ \theta_i = \left\{ \frac{3n_i \lambda \left( p_{mi} - c_i \right) \left( \beta' R_e - \beta' R_i + p_{me} - p_{mi} \right)}{3 \beta' \left( 1 - \lambda \right) \left( R_e - R_i \right) \left( c_e - c_i + \beta' (R_e - R_i) \right) + \lambda \left( c_e - c_i + \beta' (R_e - R_i) \right)^2}, 1 - \frac{3 \tau_i \beta' \left( 1 - \lambda \right) \left( R_e - R_i \right) \left( p_{me} p_{mi} + \beta' (R_e - R_i) \right) + \lambda \tau_i \left( p_{me} p_{mi} + \beta' (R_e - R_i) \right)^2}{3 \beta' \left( 1 - \lambda \right) \left( R_e - R_i \right) \left( c_e - c_i + \beta' (R_e - R_i) \right) + \lambda \left( c_e - c_i + \beta' (R_e - R_i) \right)^2} \right\} \]

(15)

(16)
Therefore, the expect profit of both manufacturer and vendor will increase after cooperation in the range of agreed value of the profit distribution factor.

Conclusion 1: The profit distribution of overall supply chain priced by both manufacturer and vendor can achieve a win-win situation. When the $\theta$ value is within negotiated between manufacturer and vendor, the profit of products priced by overall supply chain will be higher than the profit of products priced by a single party. Therefore, the sole Nash Equilibrium result of repeated game between manufacturer and vendor in energy supply chain of two kinds will be (cooperation, cooperation).

3.2. The repetitive game

In order to prove the stability of energy supply chain, it is necessary to discuss the repeated game between associated partners. To make the results of repeated game to be (cooperation, cooperation), the strategies with constraints according to the strength of both parties are needed.

As the acquired profit before the united profit distribution is more than the profit after alliance, vendors will probably give up cooperation during the second stage. If vendors can predict such result before trade, they would not choose to cooperate during the first stage. At this time, the Nash Equilibrium results between manufacturers and vendors are (noncooperation, noncooperation). Therefore, the rules without constraints will not facilitate long term cooperation for both parties. The following will be emphasized on the equilibrium results of repeated game.

In energy supply chain, vendors have relatively more power because they can apply “trigger strategy” as the core companies in a supply chain. $n$ is used to represent the number of stage of repeated game between manufacturer and vendor. We assume the profit distribution factor in the $k$ stage is $\theta^k_j=e_i$. If manufacturer choose to quit cooperation during number $n$ stage, considering the time value of finances, the discount rate for manufacturer during each stage will be $l_m$ and the discount rate factor will be $e_m^n=\frac{1}{1+l_m}$. While defining the value for $\theta^k$, retailers will demand $\min_{k-1}\{\theta^k\}$ in order to get higher profits. At this time, the extra profit for manufacturer will be little and cooperation or not will not greatly influence the profit for manufacturer. In case of betrayal of the manufacturer, vendors can impose constraining measurements on manufacturers. The measurement can indicate that if the profit of manufacturer decreases by $D$, meaning that manufacturer decides not to cooperate during number $n+1$ stage, the total present value of earning will be

$$\Pi_{mj} = \sum_{k=1}^{\infty} \left(1-\min\{\theta^k\}\right)\Pi_c(p^*_j)\mu^k + \sum_{k=1}^{\infty} \left[\Pi_{mj}(p^*_j)-D\right]\mu^k_{nj}=e_i$$

If manufacturer decides to continue cooperation after $n$ stages, then it will be

$$\bar{\Pi}_{mj} = \sum_{k=1}^{\infty} \left(1-\min\{\theta^k\}\right)\Pi_c(p^*_j)\mu^k_{nj}=e_i$$

$$D \geq 0 \Rightarrow \bar{\Pi}_{mj} > \Pi_{mj}$$ will be constant truth. A rational manufacturer will not easily give up united cooperation. Therefore, repeated game will only result in united cooperation. In a positive perspective, vendors can apply an opposing strategy, repaying union by cooperation and properly increase $\theta^k$ to motivate manufacturer for further stages of union. Similarly, in an energy supply chain, more powerful manufacturers are usually the core companies in a supply chain while the result of repeated game will be vendors choosing cooperation union.

Therefore, Pareto optimum equilibrium result in each period is (cooperation, cooperation) in energy supply chain.
Conclusion 2: It’s optimal for manufacturer and vendor of $e$ and $i$ two products to insist on alliance pricing for their long-term benefits in energy supply chain.

4. Numerical experiments

It is assumed that a certain energy supply chain is composed of energy processing plant and energy distribution station. The two parties will price according to the overall supply chain, in order to influence the purchase cut-off point value $\beta_i^*$ of consumers and therefore both their profit will be increased. Without considering advertising, taxation and other factors, consumers are very sensitive to product price.

If $c_e=45, c_i=40, p_{me}=55, p_{mi}=55, R_e=30, R_i=0, \beta'=0.9$, equilibrium price of joint sales two products are $p_e^*=67.222, p_i^*=53.628$ and optimal price of vendors are $p_{re}^*=75.621$. Then the range of $\theta_e$ and $\theta_i$ are discussed. If $\lambda=0.8, \eta_e=0.8, p_{ri}^*=60.314, \eta_i=0.6, \tau_e=0.5, \tau_i=0.15$, then $\theta_e \in (0.342,0.573)$ and $\theta_i \in (0.385,0.562)$. Supposing $\theta_e=0.4$ and $\theta_i=0.4$, then $\Pi_{me}^e=\theta_e \Pi_{ce}^e(p^*)=4.034$, $\Pi_{re}^e=(1-\theta_e) \Pi_{ce}^e(p^*)=6.050$, $\Pi_{mi}^i=\theta_i \Pi_{ci}^i(p^*)=2.530$ and $\Pi_{ri}^i=(1-\theta_i) \Pi_{ci}^i(p^*)=3.794, \eta_e \Pi_{me}^e(p^*)=3.515, \tau_e \Pi_{re}^e(p^*)=4.521, \eta_i \Pi_{mi}^i(p^*)=1.002$ and $\tau_i \Pi_{ri}^i(p^*)=1.135$. Therefore, $\Pi_{me}^e \geq \eta_e \Pi_{me}^e(p^*)$, $\Pi_{mi}^i \geq \eta_i \Pi_{mi}^i(p^*)$, $\Pi_{re}^e \geq \tau_e \Pi_{re}^e(p^*)$ and $\Pi_{ri}^i \geq \tau_i \Pi_{ri}^i(p^*)$.

5. Conclusions

This paper has established a profit distribution game model based on the issue of CSR in a energy supply chain. In a one-period game model, the influence of consumer environment preference on market price is considered while the profit distribution factor value range of overall supply chain is also confirmed. The cooperation between manufacturer and vendor depends on the comparison of profit in repeated game model. The results show that the best solution between manufacturer and vendor in a energy supply chain is to cooperate. The results of this paper can provide important theoretical guidance when energy supply chain decides on profit distribution, considering the influence of environment responsibility on consumers. Besides, this paper is based on the assumption that the two level energy supply chain is composed of a energy processing plant and a energy distribution station. In real practice of supply chain operation, there may be several energy processing plants and energy distribution stations in a energy supply chain. Studying the coordination and profit distribution issue under such circumstance is one of the directions of future research.

Acknowledgement

Natural Science Foundation of Guangdong Province(2015A030313681); Philosophy and Social Sciences Co-construction Projects for 12th Five-Year plan of Guangdong Province (GD15XGL04)

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