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Review Article

A Review on the Externalities of Enterprise Green Food Production from the Perspective of Game Theory

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Abstract: This study introduces the externalities of green food production and related theories. Production games between enterprises in the market proved that without government regulation, enterprises would abandon the green manufacturing strategy due to the high costs but low profits associated with it resulting, a decrease in social welfare. Through the evolutionary game between enterprises and the government, the importance of government's role in internalizing the externalities associated with the food manufacturing is magnified. Therefore, the coordination between the government, enterprises and consumers is needed to internalize the environmental externalities in the manufacturing industries such as the food manufacturing sector to insure the realization of a green growth path in the near future.

Keywords: Evolutionary game, game theory, government, green food production

INTRODUCTION

In recent years, food safety issues have started to attract attention. At present, the concept and realization of green food still in the early stages of development (Wang, 2001). With respect to the total amount of food, its scale of development, production and the total area of development is still small, so the old pattern is changing but has not come to an end and the new one is yet to take shape.

Green food producers are unable or unwilling to invest the significant time and money necessary to developing green food industry and higher cost to consumers to buy green food caused by high of production cost and search cost, most important of all, consumers can't ensure the green food which they buy in the market is truly green. So what cause it, We think one important factor is the high cost of the ecological environment of green food production, as it requires good ecological environment and restricts or prohibits the use of pesticides, fertilizers, hormones, antibiotics, genetically modified technology in the production process, so it increase the production cost and while the processing, storage packaging require absolute safety and environmental protection (Cuperus *et al*., 1999), in addition the cost of the ecological environment is very difficult to cash through the market, which seriously affected the enthusiasm of green food producers and restricted the development of green food.

Based on the above contents, from the perspective of game theory, we did analysis by constructing a game between the green food production enterprises and traditional food production enterprises and evolution game between the food producers and the government in the market, we conclude that food production enterprises and government strategy selection, taking into account the externalities of green food, the government should take actions to encourage green food production enterprises.

EXTERNALITY AND CORPORATE GREEN PRODUCTION

The term "externality" was first proposed by Pigou (1960). He specifies that the external economies occurs if a vendor need not pay for the loss caused to other manufacturers. Then the marginal private costs are less than marginal social costs. When it happens, such losses can't be addressed by market mechanisms, the so-called market failure and the government's macro-regulatory functions should be strengthened (Pigou, 1960). Nevertheless, Coase thinks Pigou's concept is wrong, as he believes that the rational subject will consider spillover costs and benefits so that resources are best utilized. In fact, there is no social cost which Pigou (1960) found and the externalities could be shifted into the issue of property rights by means of negotiation, consultation and other means to maximize the benefits (Ronald, 1991). Chinese scholar Zhang thinks the problem of externalities is to save defined property rights exogenous transaction costs and unclear property rights endogenous transaction costs savings, the essence of which is the problem of transaction costs (Zhang and Yong, 2000). Samuelson defines externality

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as the situation where production or consumption of other groups forced recruitment of non-compensation costs or given without compensation income (Paul, 2009), which means additional costs or benefits occur through the production or consumption of some subjects caused by others. Therefore, externalities can be divided into two categories: external positive effect, which means that some acts intentionally or unintentionally bring external benefits to other subjects, which is a benefit spillover; on the contrary it will lead to a cost spillover caused losses to other subjects, that is, external negative effects.

The concept of externality is just a tool to explain the market failure which discusses the significance of the internalization of the external or correct market failures, but scholars have divergent views to problem about means to correct market failure (Song *et al*., 2008).

Green food production refers to production activities not only to maximize the benefits and minimize the cost of target, but also include food safety, energy conservation and pollution reduction targets through scientific management and advanced technology to achieve business goals change from extensive to intensive. Thus it could ensure food safety and health, reduce the generation of pollutants and optimize coordinated economic and social benefits, which contains a very deep meaning.

Production: In order to ensure food safety and environment protection, companies are required to adhere to clean production among the whole process of production. The whole life cycle of product designing, process planning, material selecting, equipment manufacturing, packaging, transporting and scrap recycling should adhere to the coordination of economic benefits and social benefits (Wu, 2003).

Environment and resource optimization: The purpose of green food production lies in the food safety and environment protection to the maximum under the circumstance of considerable economic profits. With the development of the world economy, countries no longer only focus on short-term growth of the national economy, but pay more attention to the protection of the long-term economic development of the economic environment. Montreal Protocol on Substances that Deplete the Ozone Layer, Convention on Biological Diversity, Protocol on Biosafety and other international conventions require states to green produce, protect the environment and undertake social responsibility.

Benefits: Green food production is a kind where harmonious unity is to be achieved among enterprises' economic benefits, consumers' demands and ecological civilization. And enterprises are supposed to meet the consumption demands of consumers, based on which their own economic interests could be achieved in accordance with the requirement of ecological civilization construction.

Therefore, externalities can be obviously traced in green food production activities. The green food production brings resource conservation and environmental protection, the externalities of which spillovers to other sectors of society.

PRODUCTION GAME BETWEEN ENTERPRISES

Since food enterprises in the market exist to be profitable, benefits maximization or costs minimization are requested accordingly. And production should be reasonably arranged to achieve organizational goals, based on market supply and demand and the competitive position of the enterprise.

Suppose there are I "rational" companies offering the same food on the market, N represents their collection, $N = \{s_1, s_2, ..., s_{i-1}, s_i\}$, Q indicates I enterprise output, thus, $Q = \sum_{i=1}^{I} q_i$, q_i means the output of a single enterprise. The price is determined by the market supply and demand. And there is a negative correlation between price and sales. Suppose P is the market-clearing price, then $P = P(Q) = a - bQ$, $(a > 0, b > 0)$, c_i represents the food production cost, now in the market, m enterprises adopt green food production, its production costs are c_{mi}, n is the number of enterprises i_n which don't adopt green food production, the production cost of c_{ni} and $m+n = 1$. Therefore, the objective function of each food enterprise can be expressed as:

$$U(q_1, q_2, ..., q_{i-1}, q_i) = (a - b\sum_{j=1}^{I} q_i)q_i - c_i q_i \tag{1}$$

To maximize their own interests in the fierce competition, enterprises are motivated to develop their best competitive strategy, which forms Nash equilibrium (Zhang, 2012):

$$U(q_1', q_2', ..., q_s' ... q_{i-1}', q_i') \geq U(q_1', q_2' ..., q_s ... q_{i-1}', q_i') \tag{2}$$

q_i' means the optimal strategy of the company i towards other (i-1) enterprises. In order to obtain, $\{q_1', q_2' ..., q_s' ... q_{i-1}', q_i'\}$ or maximize the objective function:

$$\begin{cases} MaxU_i(q_1', q_2' ..., q_s' ... q_{i-1}', q_i') \\ q_i \geq 0, i \in N \end{cases} \tag{3}$$

Take the derivative of formula (1), let it equal to zero:

$$a - b \sum_{j \in N \setminus \{i\}} q_j' - 2bq_i - c_i = 0 \tag{4}$$

And take the second derivative of formula (1):

$$U^{(2)}(q_{1,}q_{2,}\cdots,q_{i-1,}q_i) = -2b < 0 \quad (5)$$

So the solution of formula (2) $q_i' = \frac{a - c_i - b\sum_{j\in N\setminus\{i\}} q_j'}{2b}$ is the optimal solution for the i food enterprise and each manufacturer determines their output at the same time, so the total output in the market is indicated by Q^*.

Repeat the solving process for I times and it can be inferred that:

$$Q^* = \frac{Ia - \sum_{i=1}^{I} c_i}{bI+1}, q_i' = \frac{a - c_i + b(\sum_{i=1}^{I} c_i - Ic_i)}{b(bI+1)}$$

Then the output of green food manufacturing enterprises:

$$q_i' = \frac{a - c_{mi} + b(\sum_{i=1}^{I} c_i - Ic_{mi})}{b(bI+1)}$$

The output of non-green food manufacturing enterprises:

$$q_i' = \frac{a - c_{ni} + b(\sum_{i=1}^{I} c_i - Ic_{ni})}{b(bI+1)}$$

and $P = a - bQ^*$, therefore:

$$P = \frac{a + b\sum_{i=1}^{I} c_i}{bI+1} \quad (6)$$

So the profits of each enterprise can be expressed as:

$$U_i = \frac{a + b\sum_{i=1}^{I} c_i}{bI+1}\frac{a - c_i + b(\sum_{i=1}^{I} c_i - Ic_i)}{b(bI+1)} - c_i\frac{a - c_i + b(\sum_{i=1}^{I} c_i - Ic_i)}{b(bI+1)} \quad (7)$$

So:

$$U_{mi} = \frac{a + b\sum_{i=1}^{I} c_i}{bI+1}\frac{a - c_{mi} + b(\sum_{i=1}^{I} c_i - Ic_{mi})}{b(bI+1)} - c_{mi}\frac{a - c_{mi} + b(\sum_{i=1}^{I} c_i - Ic_{mi})}{b(bI+1)} \quad (8)$$

$$U_{ni} = \frac{a + b\sum_{i=1}^{I} c_i}{bI+1}\frac{a - c_{ni} + b(\sum_{i=1}^{I} c_i - Ic_{ni})}{b(bI+1)} - c_{ni}\frac{a - c_{ni} + b(\sum_{i=1}^{I} c_i - Ic_{ni})}{b(bI+1)} \quad (9)$$

Simplify Eq. (8) and (9) and obtain:

$$U_{mi} = \frac{(a - c_{mi} + b\sum_{i=1}^{I} c_i - Ibc_{mi})^2}{b(bI+1)^2} \quad (10)$$

$$U_{ni} = \frac{(a - c_{ni} + b\sum_{i=1}^{I} c_i - Ibc_{ni})^2}{b(bI+1)^2} \quad (11)$$

It follows that the size of U_{mi} or U_{ni} depends on the size of the c_{mi} and c_{ni}. Although green food enterprises could optimize resource utilization and production management, its costs would be increased considering its design, production, packaging, transport and sales under the current technology condition. Meanwhile, expenditure on pollution minimization and control would be increased. It follows that $c_{mi} > c_{ni}$, so $U_{mi} < U_{ni}$.

As rational enterprises are the premise of the assumption and there is no government management, green food production is expensive than non-green production under the current condition (Ye *et al*., 2006). Consequently, profits would shrink relatively, forcing non-green production enterprises to continually produce in traditional way. And the high cost of green food production will lead to lower profits that green food manufacturer would consider giving up green food production. Thus, the number of green food enterprises in the market would gradually decrease, resulting in Nash equilibrium: $q_i' = \frac{a - c_{ni}}{b(i+1)}$. Meanwhile, pursuit of economic benefit maximization would force companies to give up green food production.

Therefore, negative externalities like resources waste and environmental damage are not limited caused by traditional production enterprises, while positive externalities of green food production enterprises are not protected which results in reduction of social welfare. Thus, in the field of food safety and environmental protection, government must play a key role in solving the externalities instead of the market itself.

EVOLUTIONARY GAME BETWEEN FOOD ENTERPRISE AND GOVERNMENT

The production game between food enterprises is without the presence of government management. Since companies seek to maximize economic benefits, then no green food production enterprises will exist in the market. However, public management is one of the responsibilities of government and the government will implement green food management to intervene in the enterprise's market behavior. As a result, game between government and food enterprises will affect the green food production of enterprises.

The model assumes that: when food enterprises adopt green food production, social benefit U_1 is created as production costs are increased W_1 and also the ensure food safety and protect the environment. Thus, as government revenue, the social benefit is created valued W_2, which brings reputation to the enterprises. Meanwhile, the government will take

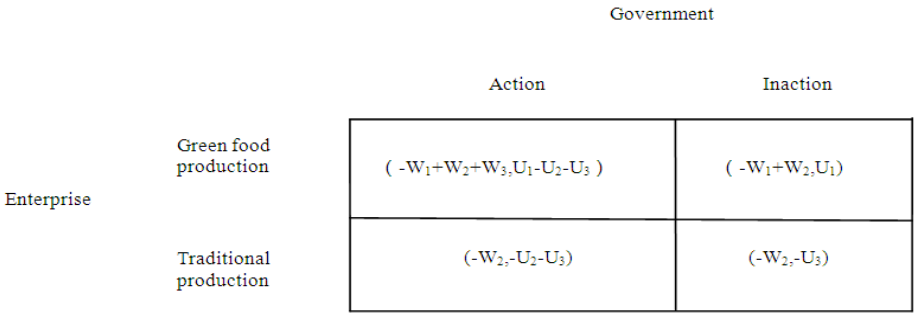

Fig. 1: The government and enterprises game matrix

appropriate incentives to give green food enterprises W_3 subsidies and the supervision cost towards government is U_2. When enterprises don't take green food production, not only leads to resource waste and environmental damage, the government needs to put U_3 to develop new energy resources and pollution and bring the negative impact of W_2 (Fig. 1).

Assume that the ratio of enterprises adopt green production is α, the proportion of non-green production is (1-α), the probability of government action under the condition of supervision is β and the probability of government inaction is (1-β).

Then the payoff of green food enterprises are as follows:

$$R_1 = \beta(-W_1 + W_2 + W_3) + (1-\beta)(-W_1 + W_2) \quad (12)$$

And the payoff of non-green food enterprises are as follows:

$$R_2 = \beta(-W_2) + (1-\beta)(-W_2) \quad (13)$$

The average expected revenue of enterprises:

$$\overline{R} = \alpha R_1 + (1-\alpha)R_2 \quad (14)$$

And the replicated dynamic equation could be inferred based on (12), (13) and (14):

$$F(R) = \frac{d\alpha}{dt} = \alpha(R_1 - \overline{R}) = \alpha(1-\alpha)(\beta W_3 + 2W_2 - W_1) \quad (15)$$

The replicated dynamic Eq. (13) has three stable states:

$$\alpha^* = 0, \alpha^* = 1, \beta^* = \frac{W_1 - 2W_2}{W_3}$$

Evolutionary stable strategy is that if the majority of a group chooses the strategy, then small mutation groups can't intrude into this group (Jorgen, 2006). If there is an evolutionary stable strategy, it is required:

- $U(S^*, S^*) \geq U(S', S^*)$
- If $U(S^*, S^*) = U(S', S^*)$, so $U(S^*, S') > U(S', S')$

That is to say, under the pressure of natural selection, the enterprise should either select evolutionary stable strategy, or phase out from the market.

According to the stability principle of differential equations (Shi *et al*., 2005). the stability strategy β^* occurs when $F'(\beta^*) < 0$. Therefore, when the formula $\beta^* = \frac{W_1 - 2W_2}{W_3}(W_1 - 2W_2 > 0, W_3 > W_1 - 2W_2)$ is true, the equality $F(R) = 0$ follows. When the proportion of green food production enterprises reaches β^* any attitude taken by the government towards the strategic choices of food enterprises would be stable. When $\beta > \beta^*$, $F'(0) > 0$ and $F'(1) < 0$. It proves that $\alpha^* = 1$ is the evolutionary stable strategy, namely, enterprises will achieve the pareto optimality gradually in the interaction with the government eventually. When $\beta < \beta^*$, $F'(0) < 0$, $F'(1) > 0$, $\alpha^* = 0$ is the evolutionary stable strategy, namely, when the ratio of food enterprises adopting green food production is less than β^*, the government would abandon encouragement policies considering the benefits and cost factors and take a strategy of inaction.

Using the same analytical method it can be obtained:

When $\alpha^* = \frac{U_2}{U_3}(U_3 > U_2 > 0)$ is true, the conclusion $F(R) = 0$ could be drawn. When the probability of taking appropriate measures by the government reaches α^*, the strategic choices of enterprises about green food production are stable. When $\alpha > \alpha^*$, $F'(0) > 0$ and $F'(1) < 0$. It proves $\beta^* = 1$ is evolutionary stable strategy, that is to say, the government and the enterprise can achieve pareto optimality. When $\alpha < \alpha^*$, $F'(0) < 0$ and $F'(1) > 0$, this time $\beta^* = 0$ is the evolutionary stable strategy. Namely, when the probability of taking appropriate measures by government is less than α^* and the subsidies are not attractive enough, enterprises will give up green production.

As shown in above Fig. 2, it remains to be proven the dynamic process would tend to which equilibrium. Hirshleifer and Martinez-Coll (1988) proposed that if the trajectory of evolution

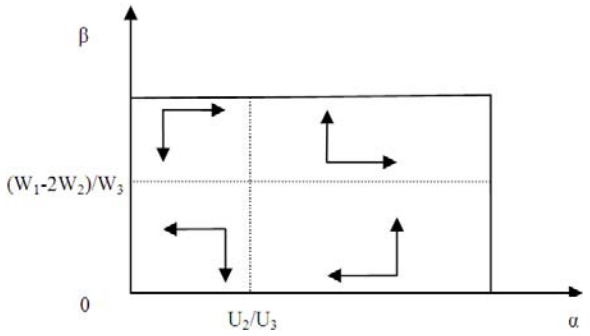

Fig. 2: Relations and stability of the government and enterprises replicator dynamics

set out within the territory of a dynamic system small enough tends to the balance point, then the equilibrium point is locally asymptotically stable (Shi *et al*., 2005). The evolutionary stable strategy and Jakobian matrix proposed by Friedman (1991) based on the replication dynamic are to be used to analysis five equilibrium points of (0, 0), (0, 1), (1, 0), (1, 1), $\left(\frac{U_2}{U_3}, \frac{W_1-2W_2}{W_3}\right)$ (Hirshleifer and Martinez-Coll, 1988).

If $F_1(\alpha,\beta)=\frac{d\alpha}{dt}$, $F_2(\alpha,\beta)=\frac{d\beta}{dt}$, Jakobian matrix is:

$$J=\begin{bmatrix}\frac{\partial F_1(\alpha,\beta)}{\partial\alpha} & \frac{\partial F_1(\alpha,\beta)}{\partial\beta}\\ \frac{\partial F_2(\alpha,\beta)}{\partial\alpha} & \frac{\partial F_2(\alpha,\beta)}{\partial\beta}\end{bmatrix}$$
$$=\begin{bmatrix}(1-2\alpha)(\beta W_3+2W_2-W_1) & \beta W_3(\beta-\beta^2)\\ U_3(\alpha-\alpha^2) & (1-2\beta)(\alpha U_3-U_2)\end{bmatrix}$$

So:

$$Tr(J)=(1-2\alpha)(\beta W_3+2W_2-W_1)+(1-2\beta)(\alpha U_3-U_2) \quad (16)$$

$$Jet\,(J)=(1-2\alpha)\,(\beta W_3+2W_2-W_1)\,(1-2\beta)\,(\alpha U_3-U_2)-\beta W_3U_3(\beta-\beta^2)(\alpha-\alpha^2) \quad (17)$$

When $Tr(J)<0$ and $Jet(J)>0$, the equilibrium belongs to the evolutionary is stable strategy (Friedman, 1991). Thus it can be seen (0, 0) and (1, 1) are evolutionary stable strategies. It means two scenarios would happen in the evolution of replicator dynamics: food enterprises don't take green food production under the premise of government taking no actions; the other is that food enterprises adopt green food production under the basis of government actions. It also suggests that whether the government takes protection measures of the positive externalities of green food production or limits the negative externalities of traditional production is directly related to the food enterprises' selection of production strategies.

CONCLUSION

The fact has been found in the game involving food production enterprises: under the condition of existing technology, adopting green food production would increase the cost of enterprise while the traditional production mode of food enterprise's production costs are relatively low, coupled with consumer's weak consciousness with environmental protection as well as weak the green consumption lead to green food production enterprises in market competition at a disadvantage. Facing such a market situation, green food production enterprises will inevitably give up green food production and then they may go back to traditional production, which will easily lead to endanger the health of consumers, aggravate the environmental pollution and leads to waste of resources which will consequently reduce the social welfare.

It is found from evolutionary game among food enterprise and government that government greatly influences the food enterprise's green manufacturing strategy choice. If you want to guarantee maximum external positive effect, effect and achieve pareto optimality, the government should take active measures to encourage enterprise's green food production and food enterprises should response actively and practice green food production to ensure that enterprise's external positive effect are protected and maximized, somaximized, so that the social welfare will be enhanced.

Based on the above conclusions, since the market is not perfect, our country legal system has not been perfected and the consumers "search cost" for green products should be considered, so the difficulty of the various subjects to solve the externality is increased and changing the disadvantage of green food production of enterprise cannot be relied on market completely. At this moment, the main players in the market try their best to protect the green food production enterprise of positive externality, limit the negative externality of traditional production enterprises and change the position in market competition so as to buffer the pressure of resources, environment and the "green barriers" in international trading, especially in the era of economic crisis.

Food enterprises strengthen technical innovation and optimization of production management. Because the production cost of green food production limits its positive externalities seriously in market competition. So the enterprises should strengthen technological innovation, reduce the cost in the design, manufacture, packaging, transport, storage and other production as far as possible. We don't only focus on short-term interests, but also believe that green food production is a choice of the society in the long run. Enterprise adheres to be the coordinated unification of economic interests and environmental interests and should bring the externality production of green food into full play.

Develop and implement relevant laws, regulations and industry standards. Strengthen the protection of green food production gradually, formulate the related environmental protection laws, take ISO14000 international standard on the food production enterprise implementation step by step, take "green food production", "green food products" and other signs to protect green food products, eliminate the member of junk food and environmental pollution enterprise gradually, encourage green food production enterprises, ensure the positive externalities of green manufacturing enterprise and limit the negative externality of high-polluting enterprises.

Government insists on green procurement. Green procurement of government can make enterprise green production to achieve economies of scale, incentive the invention and innovation of enterprises green production technology and enhance the market competitiveness of green food production enterprise (Tang, 2007). All of these can turn the disadvantage through the green food production enterprises in the market competition which also can encourage and support green food production of the enterprises.

The government implements some incentive and punitive measures for the production. Government gives price and fiscal subsidies for green food production and green procurement. It also means that it is the enterprise positive externalities of green food production to the government. This is also consistent with Coase's theory of property rights meanwhile; the government takes punitive measures to the behaviors of serious environmental pollution waste of resource and to limit its negative externalities.

Propaganda, guide and encourage green consumption. Because consumers tend to choose cheap goods in the homogenous consumer goods and choose green consumption will increase intangible search costs, consumers have green consumption risk in market system, leading to decrease consumer demand for green food products, affect the incentive to produce and market competitiveness (Ma and Zhan, 2014). Through spreading the idea of green consumption and living, we can set up supply chain of green consumption and green consumption.

Therefore, both the enterprise, government and consumers should be take care of the long-term development of economy, take the corresponding measures and means to protect the green food production enterprise and the positive externalities, which is conducive to coordinated development of economy and environment in our country, it is also good for putting our economy onto the path of green growth in the very near future.

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