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Research Article

The Government Subsidy Strategy Choice for Firm's R&D: Input Subsidy or Product Subsidy?

Zhiying Liu and Qinqin Li

School of Management, University of Science and Technology of China, Hefei 230026, China

Correspondence should be addressed to Qinqin Li; lqqzzu@mail.ustc.edu.cn

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To encourage enterprises to conduct technology innovation, the government needs to formulate appropriate subsidies policy. This paper compares two R&D subsidy policies in a supplier-manufacturer supply chain, in which the manufacturer conducts R&D activity for quality improvement. By means of game theory, we investigate the optimal decisions of the players under the two R&D subsidy policies, that is, input subsidy policy and product subsidy policy. Finally, we compare the profits and welfare to explore the better R&D subsidy policy and provide decision support for government to formulate subsidy policy. The results show that under input subsidy policy the optimal production output, quality improvement, profits, government subsidies, and social welfare are all lower than those of product subsidy policy. Therefore, the government should use product subsidy strategy to encourage enterprise R&D activities.

1. Introduction

In the international market, international competition is becoming increasingly fierce. With this trend, the enterprises are confronted with constantly fluctuating environments. They have to maintain continual technological innovation to improve quality of products, reduce the costs of produce, and develop new products, in an effort to increase international competitive edge. The quality of products is a key component in achieving a competitive advantage, while quality management practices are significantly correlated with players' strategies that in turn influence tangible business results and customer satisfaction levels [1].

However, R&D activity to improve quality of products is a risky and uncertain undertaking and thus must be financed out of financial resources or venture capital. Furthermore, R&D activity has spillover effect. Consequently, the level of private innovation activities will be below the social optimum. Countries all over the world are aware of these problems and of the importance of technological change and innovations for the future growth [2]. As a response, public instruments have been implemented to overcome this dilemma and to stimulate corporate innovation activities, such as tax incentive schemes and subsidies. Those instruments operate in a different way to induce innovation activities.

The effectiveness of subsides in stimulating more R&D has been the topic of several scholarly papers [3–7]. Spencer and Brander [8] presented a theory of government intervention which provides an explanation for industrial strategy policy such as R&D or export subsidies in imperfectly competitive international markets. Fan and Wolfstetter [9] reconsidered the explanation of R&D subsidies by Spencer and Brander [8] and others. They enriched their model by allowing firms to pool R&D investments and licensed the innovation of the RJV. Hinloopen [10] compared the effect on private R&D investments of allowing firms to cooperate in R&D with that of providing R&D subsidies and found that in general the latter policy is more effective than the former in promoting R&D activity. Haaland and Kind [11, 12] compared cooperative and noncooperative R&D subsidy policies and focused on product differentiation and trade costs. Gretz et al. [13] considered the optimal research and development subsidy regime in a two-firm two-country model. Shin and Kim [6] analyzed the effect of government subsidy policies on creating an incentive for domestic firms to improve their product quality before exporting to an outside market. Gretz et al. [4] investigated government subsidy games for private

sector research and development in a two-country two-firm intraindustry trade model and compared two funding structures: cost sharing and reward for performance.

On the basis of R&D subsidies, different instruments operate in a different way to induce innovation activities. In this paper, the focus has been made on two different types of subsidies, namely, subsidies for unit product and subsidies for R&D expense. The former is a type of subsidy to reward the achievement of R&D; the latter is to reduce R&D costs in proportion to R&D investment. Thus, the question that may arise is what impact the two different types of subsidies have upon the quantity, R&D, and profits? Which type of subsidies is more effective for the government to induce R&D?

This paper is organized as follows: the problem is described in Section 2. The equilibrium quantity and quality improvement are obtained under two different types of subsidies in Section 3. We discuss and compare the results in Section 4. We will finally draw some conclusions and implications for further research in Section 5.

2. Description of the Problem

Assumption is made that there is a supplier that supplies an intermediate input to a manufacturer. We investigate the optimal subsidy strategy taken by the government while the manufacturer determines to conduct R&D on its own. The manufacturer uses one unit of this input to produce one unit of final product. Suppose the demand for the final product is linear: $p_m = a - q_m$. For a stable supply of the intermediate product, the manufacturer has developed a long-term cooperative partnership with the supplier. Thus, the supplier will provide the intermediate product in a fixed price. Let w be the price of the intermediate product. The marginal cost of the manufacturer is c_m, and the marginal cost of the supplier is c_s. Therefore, the corresponding profit of the manufacturer is $q_m(p_m - c_m - w)$, and the profit of the supplier is $q_m(w - c_s)$. We get the equilibrium price of the intermediate product by backward induction when the manufacturer has no R&D activities. The equilibrium price is $w = (a - c_m + c_s)/2$, which is permanent even if the manufacturer undertakes R&D activities.

Assumption is made that the manufacturer conducts R&D to improve the products' quality, which will not increase marginal costs of the manufacturer. Let θ be the quality improvement as a result of R&D undertaken by the manufacturer. For simplicity, assume that the R&D cost is given by $I\theta^2$, which assures that the profit function is concave on θ [14]. Similar to the prior literature [14], we assume that the demand function of the manufacturer is $p_m = a - q_m + r\theta$. Here, the quality improvement stimulates the final market demand to increase by $r\theta$.

We will analyze two different subsidy strategies of the government. One subsidy strategy called R&D input subsidy is that the government will provide a proportion of the total R&D cost for the manufacturer. $s{\cdot}I\theta^2$ is the proportion undertaken by the government while $(1-s)\cdot I\theta^2$ is the proportion undertaken by the manufacturer. Another subsidy strategy called product subsidy is that the government will provide unit product of the manufacturer with unit subsidy. e is the per unit subsidy for the new product. This paper constructs a three-game model on the R&D input subsidy and the product subsidy. In the first stage, the government determines the optimal rate of subsidy to maximize social welfare. In the second stage, the manufacturer determines the optimal R&D level. In the third stage, the manufacturer determines the optimal quantity of the final product competing in Cournot fashion. Then we will solve the optimal equilibrium of the three-game model via backward induction.

3. Model Analysis

3.1. R&D Input Subsidy Strategy. For R&D input subsidy strategy, the government will share a proportion of the total R&D cost for the manufacturer. Therefore, the profit of the manufacturer and the profit of the supplier are as follows:

$$\pi_m = q_m\left(a - q_m + r\theta - w - c_m\right) - (1-s)\, I\theta^2 \tag{1}$$

$$\pi_s = q_m\left(w - c_s\right). \tag{2}$$

In order to determine the equilibrium by backward induction, we first solve the manufacturer's optimal quantity. Solving the first order condition of (1), we find that the optimal quantity is

$$q_m^1 = \frac{a - w - c_m + r\theta}{2}. \tag{3}$$

Using (3), we can derive the manufacturer's profit shown in

$$\pi_m^1 = \left(\frac{a - w - c_m + r\theta}{2}\right)^2 - (1-s)\, I\theta^2. \tag{4}$$

Solving the first order condition of (4) with respect to θ, we find that the optimal quality is

$$\theta_1 = \frac{r\left(a - w - c_m\right)}{4I\,(1-s) - r^2}. \tag{5}$$

For the sake of simplicity, the wholesale price is the same as that of the case of no R&D; that is, $w = (a - c_m + c_s)/2$, which will have no influence on our results.

Inserting $w = (a - c_m + c_s)/2$ into (3) and (4), we obtain

$$\begin{aligned} q_m^1 &= \frac{I\,(1-s)\left(a - c_m - c_s\right)}{4I\,(1-s) - r^2}, \\ \theta_1 &= \frac{r\left(a - c_m - c_s\right)}{2\left[4I\,(1-s) - r^2\right]}. \end{aligned} \tag{6}$$

In the first stage, the government determines the optimal rate of subsidy to maximize social welfare. The social welfare is as follows:

$$W = \frac{1}{2}q_m^2 + \pi_s + \pi_m - s\cdot I\theta^2. \tag{7}$$

Solving the first order condition of (7), we find that the optimal rate of subsidy is

$$s = \frac{6I - r^2}{10I}. \tag{8}$$

Therefore, the optimal decisions are

$$\begin{aligned} q_m^1 &= \frac{\left(4I + r^2\right)\left(a - c_m - c_s\right)}{2\left(8I - 3r^2\right)} \\ \theta_1 &= \frac{5r\left(a - c_m - c_s\right)}{2\left(8I - 3r^2\right)} \\ \pi_s^1 &= \frac{\left(4I + r^2\right)\left(a - c_m - c_s\right)^2}{4\left(8I - 3r^2\right)} \\ \pi_m^1 &= \frac{\left(4I + r^2\right)\left(a - c_m - c_s\right)^2}{8\left(8I - 3r^2\right)} \\ W_1 &= \frac{\left(4I + r^2\right)\left(a - c_m - c_s\right)^2}{8\left(8I - 3r^2\right)}. \end{aligned} \tag{9}$$

3.2. R&D Product Subsidy strategy. For R&D product subsidy strategy, the government will provide unit subsidy for unit product of the manufacturer. e is the per unit subsidy for the new product. Therefore, the profit of the supplier and the profit of the manufacturer are as follows:

$$\pi_m = q_m\left(a - q_m + r\theta - w - c_m + e\right) - I\theta^2, \tag{10}$$

$$\pi_s = q_m\left(w - c_s\right). \tag{11}$$

In order to determine the equilibrium by backward induction, we first solve the manufacturer's optimal quantity. Solving the first order condition of (10), we find that the optimal quantity is

$$q_m^2 = \frac{a - w - c_m + r\theta + e}{2}. \tag{12}$$

Using (12), we can derive the manufacturer's profit shown in

$$\pi_m^2 = \left(\frac{a - w - c_m + r\theta + e}{2}\right)^2 - I\theta^2. \tag{13}$$

Solving the first order condition of (13) with respect to θ, we find that the optimal quality is

$$\theta_2 = \frac{r\left(a - w - c_m + e\right)}{4I - r^2}. \tag{14}$$

Inserting $w = (a - c_m + c_s)/2$ into (12) and (14), we obtain

$$\begin{aligned} q_m^2 &= \frac{I\left(a - c_m - c_s + 2e\right)}{4I - r^2}, \\ \theta_2 &= \frac{r\left(a - c_m - c_s + 2e\right)}{2\left(4I - r^2\right)}. \end{aligned} \tag{15}$$

In the first stage, the government determines the optimal subsidy for unit product to maximize social welfare. The social welfare is as follows:

$$W = \frac{1}{2}q_m^2 + \pi_s + \pi_m - eq_m. \tag{16}$$

Solving the first order condition of (16), we find that the optimal unit subsidy is

$$e = \frac{\left(6I - r^2\right)\left(a - c_m - c_s\right)}{2\left(2I - r^2\right)}. \tag{17}$$

Therefore, the optimal decisions are

$$\begin{aligned} q_m^2 &= \frac{2I\left(a - c_m - c_s\right)}{2I - r^2}, \\ \theta_2 &= \frac{r\left(a - c_m - c_s\right)}{2I - r^2}, \\ \pi_s^2 &= \frac{I\left(a - c_m - c_s\right)^2}{2I - r^2}, \\ \pi_m^2 &= \frac{I\left(4I - r^2\right)\left(a - c_m - c_s\right)^2}{\left(2I - r^2\right)^2}, \\ W_2 &= \frac{I\left(a - c_m - c_s\right)^2}{2I - r^2}. \end{aligned} \tag{18}$$

From the equations above, we know that $2I > r^2$, which assures that the quantity is positive.

4. Comparison of Two Subsidy Strategies

In order to distinguish between R&D input subsidy strategy and R&D product subsidy strategy, we, respectively, compare the quantity, quality improvement, profit, subsidies, and social welfare of two subsidy strategies. The comparison results are shown in Table 1.

4.1. Comparison of Results for Enterprises

(1) *Comparison of Quantity Is as Follows.*

$$\begin{aligned} q_m^1 - q_m^2 &= \frac{\left(4I + r^2\right)\left(a - c_m - c_s\right)}{2\left(8I - 3r^2\right)} - \frac{2I\left(a - c_m - c_s\right)}{2I - r^2} \\ &= \frac{-\left(4I - r^2\right)\left(6I - r^2\right)\left(a - c_m - c_s\right)}{\left(16I - 6r^2\right)\left(2I - r^2\right)} < 0. \end{aligned} \tag{19}$$

Proposition 1. *The manufacturer's quantity under input subsidy strategy is lower than that under product subsidy strategy.*

Table 1: Comparison of results under two subsidy strategies.

	Input subsidy	Product subsidy
Quantity	$\frac{(4I+r^2)(a-c_m-c_s)}{2(8I-3r^2)}$	$\frac{2I(a-c_m-c_s)}{2I-r^2}$
Quality improvement	$\frac{5r(a-c_m-c_s)}{2(8I-3r^2)}$	$\frac{r(a-c_m-c_s)}{2I-r^2}$
Subsidies	$\frac{5r^2(6I-r^2)}{8}\cdot\left(\frac{a-c_m-c_s}{8I-3r^2}\right)^2$	$I(6I-r^2)\cdot\left(\frac{a-c_m-c_s}{2I-r^2}\right)^2$
Profit of the supplier	$\frac{(4I+r^2)(a-c_m-c_s)^2}{4(8I-3r^2)}$	$\frac{I(a-c_m-c_s)^2}{2I-r^2}$
Profit of the manufacturer	$\frac{(4I+r^2)(a-c_m-c_s)^2}{8(8I-3r^2)}$	$\frac{I(4I-r^2)(a-c_m-c_s)^2}{(2I-r^2)^2}$
Social welfare	$\frac{(14I+r^2)(a-c_m-c_s)^2}{8(8I-3r^2)}$	$\frac{I(a-c_m-c_s)^2}{2I-r^2}$

(2) *Comparison of Quality Improvement Is as Follows.*

$$\begin{aligned}\theta_1-\theta_2&=\frac{5r(a-c_m-c_s)}{2(8I-3r^2)}-\frac{r(a-c_m-c_s)}{2I-r^2}\\&=\frac{r(r^2-6I)(a-c_m-c_s)}{2(8I-3r^2)(2I-r^2)}<0.\end{aligned}\tag{20}$$

Proposition 2. *The quality improvement of manufacturer under input subsidy strategy is lower than that under product subsidy strategy.*

(3) *Comparison of Profit Is as Follows.*

$$\begin{aligned}\pi_s^1-\pi_s^2&=\frac{(4I+r^2)(a-c_m-c_s)^2}{4(8I-3r^2)}-\frac{I(a-c_m-c_s)^2}{2I-r^2}\\&=\frac{-(4I-r^2)(6I-r^2)(a-c_m-c_s)^2}{4(8I-3r^2)(2I-r^2)}<0.\end{aligned}\tag{21}$$

Proposition 3. *The supplier's profit under input subsidy strategy is lower than that under product subsidy strategy:*

$$\begin{aligned}&\pi_m^1-\pi_m^2\\&=\frac{(4I+r^2)(a-c_m-c_s)^2}{8(8I-3r^2)}-\frac{I(4I-r^2)(a-c_m-c_s)^2}{(2I-r^2)^2}\\&=\frac{\left[I(r^2-2I)(120I-14r^2)+r^4(r^2-10I)\right](a-c_m-c_s)^2}{8(8I-3r^2)^2}\\&<0.\end{aligned}\tag{22}$$

Proposition 4. *The manufacturer's profit under input subsidy strategy is lower than that under product subsidy strategy.*

4.2. Comparison of Results for Government

(1) *Comparison of Subsidies Is as Follows.*

$$\begin{aligned}&s\cdot I\theta^2-eq\\&=\frac{5r^2(6I-r^2)}{8}\cdot\left(\frac{a-c_m-c_s}{8I-3r^2}\right)^2\\&\quad-I(6I-r^2)\cdot\left(\frac{a-c_m-c_s}{2I-r^2}\right)^2\\&=\left(\left[I(r^2-2I)(256I-74r^2)+r^4(5r^2-18I)\right]\right.\\&\quad\left.\times(6I-r^2)(a-c_m-c_s)^2\right)\\&\quad\times\left(8(8I-3r^2)^2(2I-r^2)^2\right)^{-1}\\&<0.\end{aligned}\tag{23}$$

Proposition 5. *The government's input subsidies for the manufacturer are lower than the product subsidies.*

(2) *Comparison of Welfare Is as Follows.*

$$\begin{aligned}W_1-W_2&=\frac{(4I+r^2)(a-c_m-c_s)^2}{8(8I-3r^2)}-\frac{I(a-c_m-c_s)^2}{2I-r^2}\\&=\frac{-(6I-r^2)^2(a-c_m-c_s)^2}{8(8I-3r^2)(2I-r^2)}<0.\end{aligned}\tag{24}$$

Proposition 6. *The social welfare under input subsidy policy is lower than the social welfare under product subsidy strategy.*

5. Conclusion

This paper analyzes two R&D subsidy strategies in a supplier-manufacturer supply chain when the manufacturer conducts

R&D to improve quality. By means of game theory, we analyze the optimal decisions of the players under two R&D subsidy strategies, that is, input subsidy strategy and product subsidy strategy. Finally, we compare the profits and welfare to explore the better R&D subsidy strategy and provide decision support for government to formulate subsidy policy. The results show that under input subsidy policy the production quantity, profit, quality improvement, government subsidies, and social welfare are lower than those of product subsidy policy. Therefore, the government should use product subsidy strategy to encourage enterprise R&D activities.

There are several directions for future research. Firstly, we assume a linear demand function; extending this model by changing the demand function may yield some more interesting results. Secondly, we have assumed that the supply chain consists of only one supplier and one manufacturer in this paper. In the future, we will allow two competing supply chains or multiple competing manufacturers to investigate the subsidy strategies. Finally, it will be interesting to consider a system with asymmetric information.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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References

[1] C. Lin, W. S. Chow, C. N. Madu, C. H. Kuei, and P. Pei Yu, "A structural equation model of supply chain quality management and organizational performance," *International Journal of Production Economics*, vol. 96, no. 3, pp. 355–365, 2005.

[2] R. Hujer and D. Radić, "Evaluating the impacts of subsidies on innovation activities in Germany," *Scottish Journal of Political Economy*, vol. 52, no. 4, pp. 565–586, 2005.

[3] P. A. David, B. H. Hall, and A. A. Toole, "Is public R&D a complement or substitute for private R&D? a review of the econometric evidence," *Research Policy*, vol. 29, no. 4-5, pp. 497–529, 2000.

[4] R. T. Gretz, J. Highfill, and R. C. Scott, "R&D subsidy games: a cost sharing approach vs. reward for performance," *Journal of Technology Transfer*, vol. 37, no. 4, pp. 385–403, 2012.

[5] T. J. Klette, J. Møen, and Z. Griliches, "Do subsidies to commercial R&D reduce market failures? Microeconometric evaluation studies," *Research Policy*, vol. 29, no. 4-5, pp. 471–495, 2000.

[6] I. Shin and H. Kim, "The effect of subsidy policies on the product quality improvement," *Economic Modelling*, vol. 27, no. 3, pp. 687–696, 2010.

[7] X. Zhang, X. Xu, and P. He, "New product design strategies with subsidy policies," *Journal of Systems Science and Systems Engineering*, vol. 21, no. 3, pp. 356–371, 2012.

[8] B. J. Spencer and J. A. Brander, "International R&D rivalry and industrial strategy," *The Review of Economic Studies*, vol. 50, no. 4, pp. 707–722, 1983.

[9] C. Fan and E. G. Wolfstetter, "Research joint ventures, optimal licensing, and the R&D subsidy policy," *The BE Journal of Theoretical Economics*, vol. 8, no. 1, article 20, pp. 1–20, 2008.

[10] J. Hinloopen, "Subsidizing cooperative and noncooperative R&D in duopoly with spillovers," *Journal of Economics*, vol. 66, no. 2, pp. 151–175, 1997.

[11] J. Haaland and H. J. Kind, "Cooperative and non-cooperative R&D policy in an economic union," *Review of World Economics*, vol. 142, no. 4, pp. 720–745, 2006.

[12] J. I. Haaland and H. J. Kind, "R&D policies, trade and process innovation," *Journal of International Economics*, vol. 74, no. 1, pp. 170–187, 2008.

[13] R. T. Gretz, J. Highfill, and R. C. Scott, "Strategic research and development policy: societal objectives and the corporate welfare argument," *Contemporary Economic Policy*, vol. 27, no. 1, pp. 28–45, 2009.

[14] R. D. Banker, I. Khosla, and K. K. Sinha, "Quality and competition," *Management Science*, vol. 44, no. 9, pp. 1179–1192, 1998.