



OPTIMAL CONCENTRATION AND R&D POLICIES UNDER DUAL GOVERNMENT GOALS

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ABSTRACT

The present study examines the optimal concentration and R&D subsidy/taxation policies under the dual government goals of maximizing current welfare and achieving technological superiority internationally (national champions) in an oligopolistic trading market. We find that, in order to maximize the domestic welfare, the optimal number of firms in the industry should increase in accordance with the increases in the R&D subsidies. If there are multiple firms in the domestic market, the optimal R&D policy should involve the imposition of an R&D tax and such taxation should increase as the number of firms increases. For the government to achieve its goal of seeking technological superiority, the optimal policy mix will be to increase the domestic concentration and reduce the R&D tax. When the importance of being technological superior to the government exceeds a certain level, the optimal R&D strategy will be to shift from an R&D tax to an R&D subsidy.

Keywords: Optimal concentration, R&D policy, Dual government goals.

JEL classification: L24, L13, L19, L38

INTRODUCTION

In a technology-intensive market where the domestic and foreign manufacturers face mutual global competition, if foreign manufacturers are more advanced technologically, it is reasonable to assume that the domestic manufacturers will allocate additional resources to R&D in an attempt to reduce the technological disparity and even to lead in the next generation technology. In industrial policy making, governments generally have two ultimate goals. One is to maximize the domestic welfare and the other is to improve its competitiveness by seeking to foster “national champions” and to build up domestic industries’ technological superiority internationally. The government’s goal in

seeking to become technologically superior internationally can thus be thought of as part of the government's concern for the future well-being of the country and in order to maximize the future domestic welfare. In contrast with most of the literature, which focuses on short-term welfare maximization, our assumptions in this paper are much more generalized. To better illustrate the effects in isolation from the single goal of maximizing current welfare and in conjunction with the dual goals, we also assume that the technology of foreign firms is known and given and that R&D interaction is non-existent. To sustain and to promote national competitiveness, governments initiate various instruments to advance in greater R&D capacities domestically in order to maximize not only the current national welfare but, most importantly, the future welfare. In fact, if a manufacturer is superior technologically, this implies that the manufacturer will be able to reduce its future production costs and increase profits, which in turn will contribute to the level of national welfare. In reflecting the circumstances of practical policy making, the present study considers the situation where the government has the above dual goals.

In the strategic trade literature, policy recommendations on various tools designed to provide assistance to exporting firms in international oligopolistic industries have been discussed extensively. Among these, the introduction of an optimal R&D policy has drawn a fair amount of discussion largely because while the World Trade Organization (WTO) prohibits explicit export subsidies, other types of investment subsidy such as R&D subsidies are not strictly banned. The R&D subsidy leads a domestic firm to capture a larger share of the world market and shifts profits from the foreign to the domestic country. This "business-stealing effect" can improve the domestic competitive position. Moreover, this strategic incentive in the form of an R&D subsidy shares similarities with the strategic trade policy literature on export subsidies. Thus the optimal R&D policy is to provide a subsidy if the government only has one policy (Spencer and Brander, 1983; Hinloopen, 1997; Qiu and Tao, 1998). However, if R&D and trade policies are adopted simultaneously, the optimal policy will be to tax R&D and subsidize exports (Spencer and Brander, 1983; Lahiri and Mesa, 2006). The R&D tax is used to restore the overinvestment in R&D and ensure higher domestic production efficiency. The export subsidy is also applied to rent shifting. Lahiri and Mesa (2006) extend the Spencer and Brander (1983) model by allowing volatility in exchange rates and an endogenous determination of the skilled wage rate and also derive the same result.

There are some other issues discussed in the literature on R&D policy. Qiu and Tao (1998) investigate the optimal R&D policy when firms engage in R&D cooperation (d'Aspremont and Jaquemin, 1988; Kamien *et al.*, 1992; Suzumura, 1992; Motta, 1996; De Courcy, 2005). Since the R&D spillover effect causes firms to underinvest in R&D, R&D cooperation tends to further increase the governments' incentive to subsidize their domestic firms' R&D investment. Lahiri and Ono (Lahiri and Ono, 1999) consider the concavity or convexity of the demand function in a closed economy. Because a price reduction caused by a reduction in the marginal cost as a

result of R&D investment increases the consumer's surplus more (less) than in the case of linear demand when the demand function is convex (concave), the optimal R&D policy is to tax (subsidize) if the demand function is concave (convex). By contrast, (Park, 2001) analyzes a strategic R&D policy where a hi-tech and a low-tech firm compete in a third country with vertically-differentiated products. If the product market is characterized by quantity competition, the high-tech (low-tech) firm's government has an incentive to subsidize (tax) its domestic firm's product R&D activities. This result can be illustrated as follows. When the high-tech (low-tech) firm concentrates its sales more towards higher (lower) valuation consumers, these higher (lower) valuation consumers are willing to pay more for an improvement in quality, and thus the marginal profitability of the high-tech firm's R&D investment increases. This provides the high-tech firm's government with an incentive to subsidize R&D. The opposite result applies in the case of the low-tech firm's government.

Besides the R&D subsidy being regarded as a strong catalyst for industrial policy in this study, we also include the strategic concentration policy as an alternative instrument. There are many justifiable economic reasons why the government should not intervene in domestic mergers and acquisitions. However, in view of the intense international competition and for the sake of maintaining national competitiveness, policy practices to influence domestic concentration are more commonly and effectively used than we might think. Such a concentration policy may even create a national monopoly as a result. One of the classic examples is the involvement of the Clinton administration on the Boeing and McDonnell Douglas merger in 1996. In the Far East such practices are also apparent. After the initiation of "Big Deals" in 1999, the South Korean government restructured and consolidated the chaebols to make several Korean industry sectors more internationally competitive by choreographing a series of mergers.

Studies on concentration policy are limited. Cowan (1989) builds a model with one importing and one exporting countries to investigate the export country's concentration and trade policies in the presence of import tariffs. He mentions that if the demand function were linear, trade liberalization alone would encourage a more competitive competition policy in the exporting country. This is because more competition reduces the import tariff. Moreover, exporters have no domestic competition in their export market. Thus, a more competitive competition policy can be adopted. Richardson (1999) develops a two-country model with home consumption and intra-industry trade to analyze the interaction between trade liberalization and competition policy. He finds that bilateral trade liberalization may lead to more competitive competition policies. The reason for this is that governments have incentives to increase the number of firms to increase the overall market share of domestic firms. The competition policy acts as a substitute for strategic trade policy. Horn and Levinsohn (2001) extend Richardson's model, and consider a merger that lowers the marginal cost of the participating firms. Similarly, both countries strive to increase their market share by increasing the number of firms. This is the pro-competition effect of liberalization. However, since

mergers lower marginal costs, the governments have incentives to pursue a lax merger policy in order to achieve low marginal costs for domestic firms. The optimal merger policy depends on these effects. Above all, a common feature of these studies is that they ignore the effect of concentration policy on a firm's R&D investment. However, empirical evidence shows that industrial concentration has a positive effect on R&D investment (Cohen and Levin, 1989; Vossen, 1999). It means that it is important to see how industrial concentration affects R&D investment. We take up this issue in this paper. If a concentration policy could be a plausible means, to what extent the domestic concentration is at its most optimal level is not yet clearly known. In this paper, we intend to provide usable guidelines for industrial policy-making by focusing on the strategic R&D policy in isolation and in conjunction with the strategic concentration policy. In addition to this, we also investigate the implications of the policy mix with the dual government goals.

With a view to maximizing the national welfare of the domestic country, the past literature on the optimal R&D policy recommendation has generated mixed results. In this paper, we find that the optimal R&D policy in isolation should involve the imposition of an R&D tax and such taxation should increase as the number of firms increases if there are multiple firms in the domestic market. Furthermore, if the government's goal is solely to maximize short-term welfare, under conditions of no R&D subsidy, the government should seek to increase the number of firms in an industry in order to intensify competition. If the policy is mixed with R&D subsidies, then the optimal number of firms should increase as the level of R&D subsidies provided increases. That is to say, if R&D subsidies are provided, the optimal market structure should become more concentrated (competitive). If the current government's goal also involves achieving technological superiority internationally, the optimal policy mix will be to increase the domestic concentration and reduce the R&D tax. When the importance that the government attaches to technological superiority reaches a certain level, the optimal R&D policy will shift from being an R&D tax to being an R&D subsidy. This paper is organized into five sections. Following this Introduction, Section 2 presents the model. Section 3 examines the firms' strategies and Section 4 considers the government's policies. Section 5 concludes the paper.

BASIC MODEL

In this paper, we employ a three-stage game. In the first stage, the domestic government decides on the optimal R&D subsidy policy and the optimal number of firms, with the goals of maximizing national welfare and achieving technological superiority. In the second stage, domestic manufacturers decide on how much to invest in R&D, with the aim of maximizing profits. In the third stage, the domestic and foreign manufacturers select their optimal outputs for export and engage in Cournot competition in the global market. We assume that n domestic and m foreign firms manufacture an identical product under Cournot competition and that all products manufactured are only exported to the global market. When the foreign manufacturers possess

mature/advanced production technology, the domestic manufacturers' R&D efforts are bolstered to close up the technological gap. We thus say that all m foreign manufacturers have marginal costs of c and the domestic manufacturers indexed by i have a marginal cost of $k - u_i$ ($i = 1, 2, \dots, n$), where u_i is the extent of the technology improvement of firm i measured by the reduction in marginal cost. It is reasonable to assume that there exists a positive correlation between the extent of technology improvement and the R&D inputs. Let firm i 's R&D inputs be $r(u_i)^2/2$ and this implies that the marginal cost of gaining a technology improvement is strictly positive and increasing. In addition, it is assumed that the domestic government subsidizes su_i for local manufacturers' R&D to improve their technology. That is to say, the R&D subsidies are based on the extent of the technology improvement achieved, and the manufacturers' real R&D expenditure is therefore $r(u_i)^2/2 - su_i$.

Let the inverse demand function of the global market be $p = a - Q$, where p is the market price, Q is total output, $Q = \sum x_i + \sum y_j$, x_i ($i = 1, 2 \dots n$) is the production of domestic manufacturer i , and y_j ($j = 1, 2 \dots m$) is the production of foreign manufacturer j .

Firms' Strategies

In the third stage of the game, the domestic and foreign manufacturers engage in Cournot competition in the global market. Under the assumptions noted above, the profit functions of the n domestic manufacturers and the m foreign manufacturers can be expressed as follows:

$$\pi_i^h = [a - (\sum x_i + \sum y_j) - (k - u_i)]x_i - r(u_i)^2/2 + su_i, \tag{1a}$$

$$\pi_j^f = [a - (\sum x_i + \sum y_j) - c]y_j, \tag{1b}$$

Where $i = 1, 2, \dots, n$ and $j = 1, 2, \dots, m$.

The first-order conditions for the domestic and foreign manufacturers' profit maximization are:

$$\frac{\partial \pi_i^h}{\partial x_i} = a - \sum_r x_l - x_i - \sum_m y_g - (k - u_i) = 0$$

$$\frac{\partial \pi_j^f}{\partial y_j} = a - \sum_r x_l - \sum_m y_g - y_j - (k - u_i) = 0$$

By solving the above equations simultaneously, we have the quantity produced for each individual manufacturer as:

$$x_i = \frac{1}{m+n+1} \left[a - (m+1)k + mc - \sum_{l=1}^n u_l + (m+n+1)u_i \right], \tag{3}$$

$$y_j = \frac{1}{m+n+1} \left[a - (n+1)c + nk - \sum_{l=1}^n u_l \right]. \quad (4)$$

From the two equations above, the aggregate domestic technological progress, $\sum u_i$, will cause domestic production to fall because of the intensified competition, while the individual technological progress, u_i , will cause domestic production to rise. For the same reason, the aggregate domestic technological progress, $\sum u_i$, will cause the foreign production to fall. Using the above two equations, the total quantity of production and the price can be determined as follows:

$$Q = \frac{1}{m+n+1} \left[(m+n)a - nk - mc + \sum_{l=1}^n u_l \right], \quad (5)$$

$$p = \frac{1}{m+n+1} \left[a + nk + mc - \sum_{l=1}^n u_l \right]. \quad (6)$$

The aggregate domestic technological progress, $\sum u_i$, will cause the total production in the market to rise because of the falling costs. Hence there will also be a certain fall in price. Using backward induction, we can determine the optimal domestic R&D inputs in the second stage of the game. Having determined the second-stage production volume, the domestic profit function can be rewritten as follows:

$$\pi_i^h = \frac{\left[a - (m+1)k + mc - \sum_{l=1}^n u_l + (m+n+1)u_i \right]^2}{(m+n+1)^2} - \frac{r}{2} u_i^2 + s u_i. \quad (7)$$

To decide on the R&D inputs, the first-order condition for firm i to maximize its profit is:

$$\frac{\partial \pi_i^h}{\partial u_i} = \frac{2(m+n)}{(m+n+1)^2} \left[a - (m+1)k + mc - \sum_{l=1}^n u_l + (m+n+1)u_i \right] - r u_i + s = 0 \quad (8)$$

By symmetry, we can determine the optimal R&D inputs of the domestic manufacturing firm i to be:

$$u_i = u = \frac{1}{(r-\phi)} \left\{ \frac{\phi}{m+1} \left[a - (m+1)k + mc \right] + s \right\} \quad i = 1, 2, \dots, n, \quad (9)$$

Where $\phi \equiv 2(m+1)(m+n) / (m+n+1)^2$. The second-order conditions for profit maximization are therefore $\phi - r < 0$.

It can be seen from equation (9) that an increase in r (the parameter of cost in R&D inputs) will cause the individual manufacturer's R&D inputs to fall ($\partial u / \partial r < 0$), while an increase in the government's R&D subsidy s will cause manufacturers to increase their R&D inputs, leading to

greater technology improvement ($\partial u / \partial s > 0$). In addition, apparently because $\partial u / \partial \phi > 0$, and $\partial \phi / \partial n = -2(m + 1)(m + n - 1) / (m + n + 1)^3 < 0$, and hence $\partial u / \partial n < 0$, we find that a larger number of domestic manufacturers will lead to lower R&D inputs and technology improvements for individual domestic manufacturers.

Having found out the optimal R&D decision for domestic manufacturers, the domestic and foreign quantities produced can be shown as:

$$x_i = x = \frac{1}{(m + n + 1)(r - \phi)} [r(a + mc) - (m + 1)(rk - s)],$$

$$y_i = y = \frac{1}{(m + n + 1)(r - \phi)} \left\{ \left[r - \frac{2(m + 1)}{m + n + 1} \right] a - \left[(n + 1)r - \frac{2(m + n)}{m + n + 1} \right] c + n(rk - s) \right\}$$

Under the symmetric solution of optimal R&D inputs, the profits of individual domestic manufacturers can be rewritten as:

$$\pi_i^h = \pi^h = \frac{[a - (m + 1)(k - u) + mc]^2}{(m + n + 1)^2} - \frac{r}{2}u^2 + su. \quad (10)$$

GOVERNMENT POLICIES

Having examined the optimal R&D input decisions for the domestic manufacturers, we can move a step further to consider the optimal domestic R&D subsidy and the optimal domestic market concentration with the dual policy goals of maximizing domestic welfare and achieving technological superiority in the first stage of the game.

To facilitate the later discussion in this paper, we begin by only assuming one policy goal of maximizing domestic welfare instead of the dual policy goals. Doing so will also allow us to draw convenient comparisons with the previous literature. As the domestic production can only be exported rather than consumed in the domestic market, the domestic welfare is therefore the total profits of all domestic manufacturers minus the R&D subsidies paid by the government. Thus

$$W = n\pi^h - nsu = n(\pi^h - su). \quad (11)$$

To form a benchmark where is no R&D, by assuming $u = s = 0$, we have welfare as

$$W = n\pi^h = \frac{n[a - (m + 1)k + mc]^2}{(m + n + 1)^2}. \quad (12)$$

The first-order condition for the determination by the government of the optimal number of firms n (with welfare maximization) is

$$\frac{\partial W}{\partial n} = \pi^h + n \frac{\partial \pi^h}{\partial n} = \frac{m-n+1}{(m+n+1)^3} [a - (m+1)k + mc]^2 = 0. \quad (13)$$

The optimal number of domestic manufacturers is hence $n^* = m + 1$. The intuition underlying this is straightforward. Under international Cournot competition, the optimal quantity of exports for the home country is a Stackelberg leader output, as mentioned by [Brander and Spencer \(1985\)](#). If the government is not providing export subsidies, then the only means to achieving the Stackelberg leader output is to alter the domestic market structure so that the number of domestic manufacturers is greater than the number of foreign manufacturers. One point worth noting is that, assuming that the marginal cost is fixed, the optimal number of domestic manufacturers is related only to the number of foreign manufacturers. It has nothing to do with the market size (a), domestic manufacturer's production cost (k), or foreign manufacturer's production cost (c).

In the sense of the Stackelberg leader mentioned above, it is indicated that the concentration policy can serve as a proxy for the export subsidy as shown in [\(Brander and Spencer, 1985\)](#). The concentration policy can be an instrument used to shift the foreign manufacturers' profits. This implies that the concentration policy is a good substitute for the export subsidy, especially when the export subsidy is prohibited in principle by the WTO.

If we now take the manufacturers' R&D inputs into consideration, but assume there are no government subsidies, i.e., $s = 0$, then the first-order condition for the optimal number of manufacturers becomes

$$\frac{\partial W}{\partial n} = \pi^h + n \left(\frac{\partial \pi^h}{\partial n} + \frac{\partial \pi^h}{\partial u} \frac{\partial u}{\partial n} \right) = 0. \quad (14)$$

In the above equation,

$$\frac{\partial \pi^h}{\partial u} = \frac{2(m+1)}{(m+n+1)^2} [a - (m+1)(k-u) + mc] - ru \quad (15)$$

Using the first-order conditions of equation (8) (with symmetry and where $s = 0$), the above equation can be rewritten as:

$$\frac{\partial \pi^h}{\partial u} = -\frac{2(n-1)}{(m+n+1)^2} [a - (m+1)(k-u) + mc] < 0 \text{ for } n > 1. \quad (16)$$

If there is only one domestic manufacturer ($n = 1$), then the above equation will give a result of zero, because this equation just represents the first-order condition of the optimal R&D inputs for a single manufacturer. However, if there is more than one domestic manufacturer, the above equation will lead to a negative result. This represents the fact that, as each manufacturer increases its R&D

inputs, individual manufacturers' profits will fall. This is because, when individual manufacturers are deciding their optimal R&D inputs on the basis of $\partial \pi_i^h / \partial u_i = 0$, all other manufacturers' R&D inputs are assumed to be unchanged. However, if all manufacturers increase their R&D inputs, all of them will see their profits fall as a result.

If we evaluate equation (14) under which $n = m + 1$ and remember that $\partial u / \partial n < 0$, we then have:

$$\left. \frac{\partial W}{\partial n} \right|_{n=m+1} = n \frac{\partial \pi^h}{\partial u} \frac{\partial u}{\partial n} > 0 \quad (17)$$

From the results obtained above, we can derive the following proposition:

Proposition 1 If manufacturers are engaging in R&D activities without the government subsidy, to maximize the domestic welfare, the optimal policy should be market de-concentration to intensify competition in the industry concerned.

The intuition behind this proposition is readily apparent. If the number of manufacturers n increases, then, because of the intensified competition, each manufacturer will cut back its production, causing the incentive for spending on R&D to diminish ($\partial u / \partial n < 0$). The reduction in R&D inputs by individual manufacturers will affect the profits of other manufacturers ($\partial \pi^h / \partial u < 0$), thereby resulting in an increase in overall profits and welfare ($(\partial \pi^h / \partial u)(\partial u / \partial n) > 0$).

It can thus be seen that, when domestic manufacturers are engaging in R&D, the government should design a policy to increase the number of domestic firms to intensify market competition.

However, if the provision of R&D subsidies by the government is now taken into account, from equation (14), the first-order condition in deciding the optimal number of firms is therefore

$$\frac{\partial W}{\partial n} = \pi^h + n \left[\frac{\partial \pi^h}{\partial n} + \left(\frac{\partial \pi^h}{\partial u} - s \right) \frac{\partial u}{\partial n} \right]. \quad (18)$$

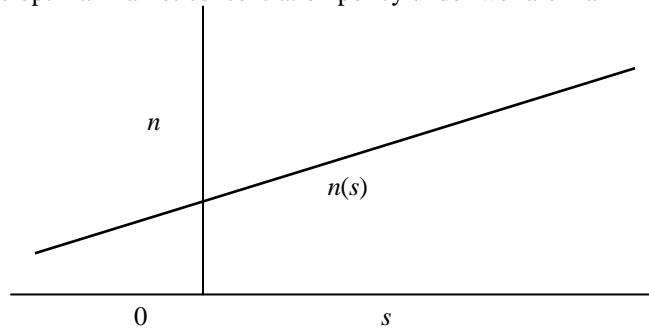
By comparing it with equation (14), equation (18) has an additional term $-ns(\partial u / \partial n)$. As $\partial u / \partial n < 0$, therefore $-ns(\partial u / \partial n) > 0$. The fact that this term is positive indicates that government R&D subsidies have a positive effect on the optimal number of manufacturers, giving us the following proposition:

Proposition 2 To maximize the domestic welfare, the optimal number of firms in the industry should increase in accordance with the increases in the amount of R&D subsidies. That is to say,

where R&D subsidies are provided, the optimal domestic market structure should be more fragmented (competitive).

The economic implications of this proposition are as follows. As the provision of R&D subsidies provides manufacturers with an incentive to increase R&D spending ($\partial u / \partial s > 0$), such an increase in manufacturers' R&D inputs will also lead to a fall in overall profits. Therefore, the government should make the industry more competitive by adopting a de-concentration policy to increase the number of manufacturers. In other words, the optimal number of manufacturers n^* should be an increasing function of government R&D subsidies s such that $n^* = n(s)$, $\partial n^* / \partial s > 0$. This relationship is shown in the $n - s$ plane in Figure 1 below.

Figure-1. The optimal market concentration policy under welfare maximization



We can now go on to consider the government's optimal R&D subsidy policy. From equation (11), the first-order condition for welfare maximization based on the optimal R&D subsidy policy is

$$\frac{\partial W}{\partial s} = n \left[\left(\frac{\partial \pi^h}{\partial u} \frac{\partial u}{\partial s} + \frac{\partial \pi^h}{\partial s} \right) - u - s \frac{\partial u}{\partial s} \right] = 0. \quad (19)$$

In the above equation, because $\partial \pi^h / \partial s = u$, the optimal R&D subsidy can be solved as

$$s^* = \frac{\partial \pi^h}{\partial u} = -\frac{2(n-1)}{(m+n+1)^2} [a - (m+1)(k-u) + mc] < 0 \text{ for } n > 1 \quad (20)$$

From the results of the above equation, we can obtain the following proposition:

Proposition 3 *If there is more than one manufacturer in the domestic market, to maximize the domestic welfare, the optimal R&D subsidy will be negative which means that the government should impose a tax on manufacturers' R&D activities.*

Because R&D activities will have a negative impact on profits, given that domestic welfare is measured by the total profits of all manufacturers, the total industry R&D inputs are outweighed by the optimal industry R&D inputs at the welfare maximization level. Therefore, the optimal R&D policy for the government to adopt is to levy tax on the manufacturers' R&D activity ($s^* < 0$) when

there is more than one domestic manufacturer. However, if there is only one domestic manufacturer ($n = 1$), then the optimal R&D subsidy is zero. This is because, when there is only one domestic manufacturer, that manufacturer's R&D activity will not affect the profits of other manufacturers. Furthermore, when deciding its R&D inputs, the profit maximization (welfare maximization) has already been taken into account by the manufacturer. Therefore, there is no need for the government to employ either subsidies or taxation.

From equation (20) we can also uncover the impact of the number of manufacturers on the optimal R&D subsidy policy. We differentiate the number of manufacturers n in equation (20) and obtain the following:

$$\frac{\partial s^*}{\partial n} = -\frac{2(m-n+3)}{(m+n+1)^3} [a - (m+1)(k-u) + mc] + \frac{2(n-1)(m+1)}{(m+n+1)^2} \frac{\partial u}{\partial n} < 0. \quad (21)$$

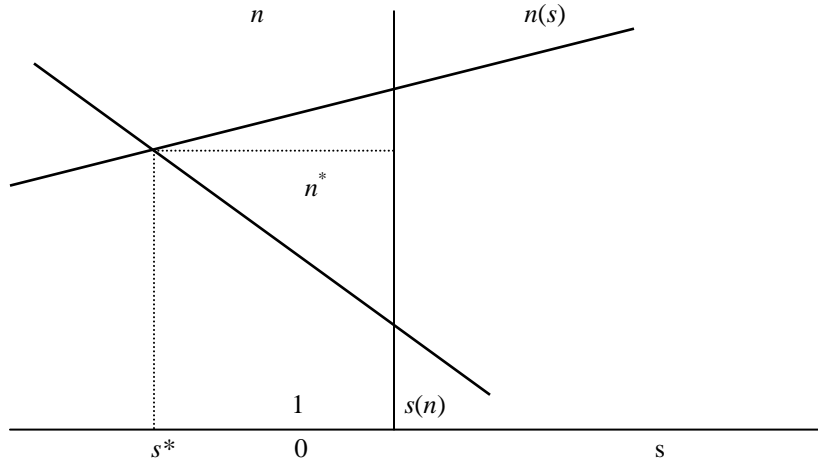
Since $\partial u / \partial n < 0$, as long as the number of foreign manufacturers m is not small, that equation (21) is negative will stand. In fact, the sufficient condition for that is $m > n - 3$. From the above outcome, we can derive the following proposition:

Proposition 4 If the number of foreign manufacturers is not too small, to maximize welfare, the government should levy higher taxation on the manufacturers' R&D input as the number of domestic manufacturers increases.

The intuition behind this proposition is also readily apparent. The more manufacturers there are in an industry, the greater the negative impact that a manufacturer's R&D inputs will have on the profits of other manufacturers, and so the higher the tax that the government should impose on manufacturers' R&D inputs. That is to say, the optimal R&D subsidy s^* should be a decreasing function of the number of manufacturers such that $s^* = s(n)$, $\partial s^* / \partial n < 0$.

This equation, together with the $n^* = n(s)$ referred to above, is shown on the $n - s$ plane in Figure 2. These two equations jointly determine the optimal market structure (number of firms) n^W and the government's optimal R&D subsidy policy s^W where the superscript of W denotes the welfare maximization status.

Figure-2.The optimal number of manufacturers and the optimal R&D subsidy (tax) policy under welfare maximization



Before engaging in a discussion of the other government goal, we can provide some brief intuitive observations regarding the two optimal policies. As mentioned earlier, the concentration policy can serve as a good profit-shifting instrument to substitute for the export subsidy. As the objective of profit-shifting is dealt with by the concentration policy, the R&D policy can be regarded as a tool to correct the overinvestment problem and hence the optimal R&D policy should be a tax (instead of a subsidy). The result of the optimal policy mix in this paper is therefore somewhat akin to (Spencer and Brander, 1983). Having discussed the optimal policy when the goal is to maximize domestic welfare, we can now move on to consider the government's other goal, that of achieving technological superiority. Governments often seek to impose R&D subsidies or controls on the number of firms in an industry to achieve technological superiority, i.e., to maximize the extent of firms' technological progress u .

The *extent* of the technological progress u is affected by the government's provision of R&D subsidies and by the government's policy with respect to the number of firms in the industry. If $\partial u / \partial s > 0$ (i.e., the larger the amount of the subsidies s , the more firms will spend on R&D, and the higher the level of technological progress that they will achieve), and if $\partial u / \partial n < 0$ (i.e., the more firms there are in a given domestic industry, the less individual firms will spend on R&D and the lower the level of technological progress that they will achieve), then if achieving technological superiority is the government's sole objective and there is no government budget constraint, the optimal level of the R&D subsidies s will be infinitely large, and the optimal number of firms in the industry n will be 1.

While the argument presented above is perfectly logical, there has never been a government that placed no limits on the amount of R&D subsidies provided. In other words, achieving technological superiority is never likely to be a government's sole objective. Technological superiority is

associated with a nation's future wellbeing. The most common situation is for a government to take both the current wellbeing and future wellbeing of the nation into account, and to try to strike an acceptable balance between the two, as with the trade-offs between consumption and investment.

Assuming that a government has two goals – the maximization of current welfare and the achievement of technological superiority – and that these objectives are given the weightings α and $1 - \alpha$, respectively, then the government's objective function will be $\Omega = \alpha W + (1 - \alpha)F$, where $F \equiv f(u) - n(ru^2/2 - su)$ represents the goal of technological superiority. If the sole goal is to achieve technological superiority, the objective function is, therefore, F where α is 0. In the objective function of F , $f(u)$ shows the benefits of being technologically superior, $f > 0$, $f < 0$. We can view $f(u)$ as the increment in future domestic welfare in present value form. If α is 1, this implies that the government's sole objective is the maximization of current welfare. Under these circumstances, the optimal market structure will be $n = n^W$, and the optimal R&D subsidy will be $s = s^W$.

Under the dual goals, the first-order conditions for selecting the optimal number of firms, n , and the R&D subsidy, s , are therefore

$$\frac{\partial \Omega}{\partial n} = \alpha \frac{\partial W}{\partial n} + (1 - \alpha) \frac{\partial F}{\partial n} = 0, \quad (22)$$

$$\frac{\partial \Omega}{\partial s} = \alpha \frac{\partial W}{\partial s} + (1 - \alpha) \frac{\partial F}{\partial s} = 0. \quad (23)$$

Under the above considerations in conjunction with technological superiority, the change in the optimal number of firms n and the R&D subsidy s can be found by evaluating the signs of $\partial \Omega / \partial n$ and $\partial \Omega / \partial s$ at $\partial W / \partial n = 0$ and $\partial W / \partial s = 0$. That is, if $\partial F / \partial n > (<) 0$, then the goal of being technologically superior will guide the government as it seeks to increase (decrease) the number of firms. On the other hand, if $\partial F / \partial s > (<) 0$, the goal of being technologically superior will cause the government to increase (decrease) the R&D subsidy.

We further express $\partial F / \partial n$ and $\partial F / \partial s$ as:

$$\frac{\partial F}{\partial n} = [f'(u) - n(ru + s)] \frac{\partial u}{\partial n} - \left(\frac{ru^2}{2} + su \right), \quad (24)$$

$$\frac{\partial F}{\partial s} = [f'(u) - n(ru + s)] \frac{\partial u}{\partial s} - nu. \quad (25)$$

When the technology improvement u increases, the square brackets in equations (24) and (25) represent its impact on the objective function F and its benefits shown in $f'(u)$. However, an increase in u must result from an increase in overall R&D inputs and triggered R&D subsidies. Hence, the costs associated with the increase in u are $n(ru + s)$. It is reasonable to assume that $f'(u) - n(ru + s) > 0$, otherwise to achieve F is unnecessary. In equation (24), since $\partial u / \partial n < 0$, therefore,

$\partial F / \partial n$ must be negative. This implies that when the number of domestic firms increases, the equilibrium level of technology improvement will decrease. This will jeopardize the goal of technological superiority. Besides, an increase in the number of firms will incur additional R&D costs and subsidies ($ru^2 / 2 + s$). Therefore, under such considerations in conjunction with technological superiority, given the value of s , the government should decrease the number of firms. In equation (25), because $\partial u / \partial s > 0$, the sign of $\partial F / \partial s$ is ambiguous. This means that when the R&D subsidy increases (or R&D tax decreases), the equilibrium level of technology improvement will increase which in turn advances the goal of technological superiority. However, the increase in the R&D subsidy (or decrease in the R&D tax) will be the fiscal burden nu of the government. Hence, under these considerations in conjunction with technological superiority, the optimal R&D subsidy could either increase or decrease. In the following discussion, we utilize the case where $\partial F / \partial s > 0$ by assuming that technological improvement generates a large enough benefit, that is, f^* is large to ensure that $\partial F / \partial s$ is positive.

The above discussion is shown diagrammatically in Figure 3 below.

Figure-3. Optimal number of firms and optimal R&D subsidy (or tax) policy under dual government goals

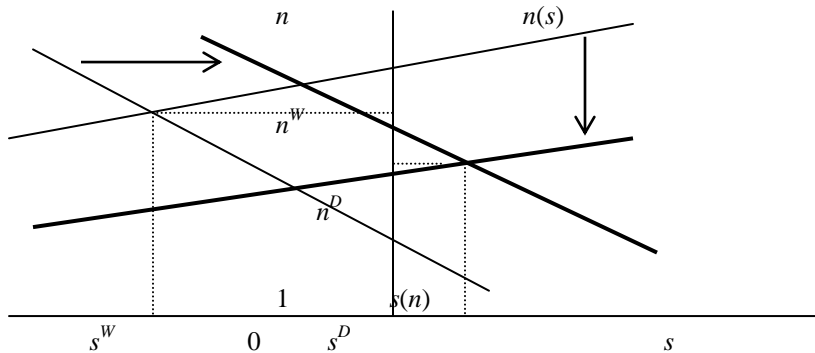


Figure 3 depicts the case mentioned above in which the level of the R&D subsidy, s , will increase according to the importance of technological superiority to the government. It can be seen from Figure 3 that, when the maximization of current welfare is not the government's sole objective, the optimal concentration policy will be to bring about a reduction in the number of firms in the industry, so the original $n(s)$ line will move downward. The optimal R&D subsidy policy in this case will be to increase the amount of the R&D subsidy (or reduce the R&D tax), so the original $s(n)$ line will move to the right. The optimal number of firms in the industry will thus fall ($n^D < n^W$), leading to an increase in the level of market concentration, and the optimal R&D subsidy will also fall ($s^D > s^W$). The higher the importance the government attaches to technological superiority, the greater will be the value of α , and the more the $n(s)$ line will move downwards and the $s(n)$ line will move to the right. In Figure 3, $s^D > 0$ represents the shift in the optimal R&D policy from an R&D tax to an R&D subsidy. We can thus derive the following proposition:

Proposition 5 Given that the technological improvement brings a large enough benefit, the more importance the government attaches to the objective of technological superiority, the more concentrated the optimal market structure will be with fewer firms in the industry and the reduced taxation of R&D. When the importance attached to technological superiority exceeds a certain level, the optimal R&D policy will shift from an R&D tax to an R&D subsidy.

In the real world, it is very unusual for a government to tax firms' R&D activity. Subsidizing R&D is a far more common practice. From the model presented in this paper, this fact would seem to confirm that maximizing short-term domestic welfare is not the sole government goal. Governments often have other objectives, such as achieving technological superiority.

The optimal R&D policy in the literature is generally considered as a positive government subsidy based on the following two reasons. The first is that the R&D has the spillover effect. The second reason is that it often has other policy objectives e.g. as a substitutable policy instrument when the imposition of the export subsidy is difficult. In this paper, we suggest that, besides the above two, the considerations of future welfare is the other reason for the government to employ R&D subsidizing policy.

CONCLUSION

In reflecting on the circumstances that are likely to exist, the study also considers the situation where the government has dual goals, i.e., where the government is seeking both to enhance short-term domestic welfare and to achieve technological superiority. We assume that technological superiority can be used as a proxy for the future (long-term) welfare of the nation. The present study employs an oligopolistic trade model to examine the optimal domestic concentration policy and optimal R&D subsidy/taxation policy.

The following findings are obtained. Firstly, if the government's objective is solely to maximize short-term welfare compared with the case where there is no R&D, the government should seek to increase the number of firms in an industry in order to intensify competition and hence avoid overinvestment in R&D. If the R&D and together with the subsidies are introduced, then the optimal number of firms in the industry should increase as the amount of R&D subsidies (taxes) provided increases (decreases). As regards the R&D policy, if there is more than one firm in the industry, the optimal R&D subsidy will be negative, i.e., the government should impose a tax on R&D activity to avoid overinvestment in R&D activities. Furthermore, the larger the number of firms in the industry, the more heavily the government should tax R&D. The implications of the composition of the optimal policy mix are that the optimal concentration policy serves as a profit-

shifting tool in a global market and the optimal R&D policy is used to correct for the R&D overinvestment problem.

If, besides seeking to maximize short-term domestic welfare, the government's goal is to seek to achieve technological superiority, the greater will be the importance that the government attaches to technological superiority, and the higher the level of market concentration (i.e., the reduction in the number of firms). In addition, provided that the benefits in terms of future welfare resulting from the technological improvement are large enough, the less heavily should the government tax R&D activity. When the importance that the government attaches to technological superiority reaches a certain level, the optimal R&D policy will shift from being an R&D tax to an R&D subsidy.

In the real world, it is extremely unusual to see governments impose a tax on firms' R&D activities. R&D subsidies and other measures used to stimulate R&D activities are far more common. The dual-government-goals model presented in this study provides a good explanation of this phenomenon. In other words, we can establish that the governments may not be the short-term welfare maximizers. In the case of most governments, the optimal policies are decided by their long-term welfare considerations. As for possible extensions of this paper, while restricting the R&D activity to a single country is helpful to the analysis, the inclusion of interaction among countries in terms of R&D could provide some more interesting results. It is also worth analyzing the policy interactions by taking the international R&D competition into account. In addition, although the R&D-related spillover effects have been amply discussed in the related literature, such effects involving technological spillover could be incorporated into a future study on dual policy goals, at either the domestic or international level.

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