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# Optimal Trade and Environmental Policies under International Duopoly: Green Technology Rivalry

Normizan bin Bakar normizan@uum.edu.my
Rusmani binti Musa rusmani@uum.edu.my
Bakti bin Hasan Basri bakti@uum.edu.my
Pusat Pengajian Ekonomi, Kewangan dan Perbankan
Universiti Utara Malaysia

## ABSTRACT

We analyze the optimal research and development of green technology taxes (subsidies) in a three-stage game model of an international Cournot duopoly. The governments simultaneously determine the environmental policies in the first stage. In the second stage, the firms simultaneously determine the green technology levels and in the third stage set the output. There are one firm in a home country and one firm in a foreign country which produce homogeneous goods and export to the third-market country. By assuming that the green technology is a cost-increasing R&D, this paper finds that it is not overused to minimize the total costs.

Keywords: strategic trade policy, green technology, strategic environmental policy

## INTRODUCTION

A number of governments subsidize research and development (R&D) activities of producing green technology[1] by its domestic firms. The subsidy is particularly given to industries in which firms are competing in international imperfect competition market. Our paper presents a positive analysis to explain such trade strategy policies in the context of an imperfectly competitive world where the R&D of green technology (GT-R&D) rivalry between firms plays a significant role[2].

In this study, we focus on possible subsidization of cost-increasing R&D such as, for instance, the Japan and USA subsidization of green technology in producing hybrid vehicles. In contrast to the previous studies[3],we assume that GT-R&D is a cost-increasing R&D. Inventing the GT-R&D means that the cost of production rises.

The argument on a strategic environmental policy has been developed by many analysts, among others by Barrett (1994). This strategic environmental policy considers the production activities of the two firms that generate pollution emissions, which cause purely local damage. The models with based on imperfect competition marketwere successful in explaining the tragedies of an ‘ecological dumping’ and ‘race-to-bottom’. In contrast to that study, we assume that the firms do not generate pollution emissions thus no abatement costs to be considered. However, the GT-R&D is invented to fulfill green productsdemand or to create green technology trend[4].

In this paper, we employa strategic R&D policy framework of Spencer and Brander (1983), including the assumption that firms are Cournot competitors in the product market. In their study on process R&D, Spencer & Brander (1983) find that countries would not choose to subsidize R&Dif the export subsidies available. The process R&D is assumed to be cost-decreasing R&D. In contrast,

[1]A definition of green technology or green product is given as follow:(Chapple, 2008) “At its most basic level, the green economy is the clean energy economy, consisting primarily of four sectors: renewable energy (e.g. solar, wind, geothermal); green building and energy efficiency technology; energy-efficient infrastructure and transportation; and recycling and waste-to-energy.The green economy is not just about the ability to produce clean energy, but also technologies that allow cleaner production processes, as well as the growing market for products which consume less energy, from fluorescent light bulbs to organic and locally produced food”

[2]A number of studies have incorporated an environmental issue into the strategic trade model. For instance,a survey on international trade and environmental policy has been done by(Sturm D. , 2001)(Sturm D. M., 2003)(Sturm & Ulph, 2002)(Ulph, 2002). A study of domestic pollution or production pollution has extensively been developed, for instance (Yanase, 2010) amongst others.

[3]Previous studies assumed that R&D is a cost-decreasing R&D. For instance,a study of international R&D rivalry has been pioneered by (Spencer & Brander, 1983) and extended by (DeCourcy, 2005)amongst others.

[4]Toyota kept the Prius’s prices low because in the long run, they wanted the hybrid drivetrain to be viewed as an mainstream technology(Sallee, 2011).

regarding that innovation is costing, we assume that GT-R&D increases production costs. In addition, in our paper, export subsidies are not considered because World Trade Organization (WTO) codes restrict direct export subsidies. Among others, our study finds that GT-R&D is not overused to minimize total costs and the government's policy is positive. It also shows that government's subsidy encourages a firm to invest in green technology.

The motivation for government policy in our paper is similar to the previous studies (e.g. (Barrett, 1994) which assumed that a country attempts to capture a larger share of production or rent shifting. However, the difference in our paper is that the national incentive does not arise from damage costs.Becausethe pollution is assumed to be a consumption-pollution in that it occurs in the third country.

Strategic behaviors of agents in our model are similar to the Spence & Brender (1983), which GT-R&D is assumed to be undertaken before the associated output is produced. The firms anticipate the effect of R&D on the resolution of output shares. The efficacy of government policy in this paper arises from the assumption that a government can credibly commit itself to R&D subsidies before the R&D decision are made by private firms. In contrast to the previous studies (e.g. (Barrett, 1994)(Sturm D. , 2001)which assumed the local damage, our model assumes a pollution by consumption (consumption-pollution) which occurs in a consuming country.

The rest of this paper is organized as follows. Section 2 explains the basic setup of the model and the results in the quantity competition stage. Section 3presents and discusses the results of subsidy of GT-R&D. Section 4 contains concluding remarks.

**MODEL**

Consider two symmetric countries, home and foreign, with one firm each, which sell their entire output in a third country. The model is based on a three-stage game played by two competing firms, and two competing governments. In the first stage, the governments choose R&D subsidies. In the second stage, the firms choose R&D levels, and the third stage, choose output levels.

Each firm $i$ produces output $x^i$ at variable cost $C^i$, which includes all costs except GT-R&D, and earns revenue $R^i(x^1, x^2) = p(x^1 + x^2)x^i$. The GT-R&D level of firm $i$ is denoted $g^i$ and costs $a^i$ per unit. The profit function of firm $i$ is then denoted

$$\pi^i(x^1, x^2; g^i) = R^i(x^1, x^2) - C^i(x^i; g^i) - \alpha^i g^i \tag{1}$$

Outputs $x^1$ and $x^2$ are assumed homogeneous. Therefore, using subscripts to denote derivatives, this implies

$$R^i_j < 0 \text{ and } R^i_{ij} < 0 \tag{2}$$

The effect of an increase in cost-increasing GT-R&D is, of course, to increase $C^i$ given $x^i$, and the rate of increase increases as $x^i$ rises. Marginal cost $C^i_x$ is assumed to rise as $g^i$ increases:

$$C^i_g > 0 \text{ and } C^i_{gg} < 0 \tag{3}$$

The Nash equilibrium in output is characterized by first order conditions:

$$\pi^i_{x^i} = R^i_{x^i}(x^1, x^2) - C^i_{x^i}\left(x^i; g^i\right) \tag{4}$$

Where $R^i_{x^i} \equiv p(x^1 + x^2) + p'(x^1 + x^2)x^i$. And second order conditions

$$p^i_{x^i x^i} = R^i_{x^i x^i} - C^i_{x^i x^i} < 0 \tag{5}$$

We also assume that own effects of output on marginal profit dominate cross effects, giving rise to the following condition;

$$D = p^1_{11}p^2_{22} - p^1_{12}p^2_{21} > 0 \tag{5*}$$

This condition holds globally and ensures uniqueness and global stability of the equilibrium.

The solution $x^1$ and $x^2$ to (4) depend on $g^1$ and $g^2$ and can be written as:

$$x^1 = f^1(g^1, g^2) \text{ and } x^2 = f^2(g^1, g^2). \tag{6}$$

Output depend on marginal cost, which depend on $g^i$. In increase in cost-increasing GT-R&D by firm 1 will increase marginal cost, shift its reaction function inward and decrease its output and market share, as illustrated in Figure 1 by the move from R to S. The reaction functions in the diagram are downward sloping. Thisfollow from total differentiation of (4) with respect to $x^1$ and $x^2$ holding $g^1$ and $g^2$ constant, which yields the slope of the reaction function, $dx^i / dx^j = - R^i_{x^1 x^2} / p^i_{x^1 x^1}$ , which is negative from (2) and (5).

Total differentiating of (4) with respect to $x^1$ and $x^2$ and $g^1$ yields:

$$f^i_{g^i} = dx^i / dg^i = \frac{C^i_{x^i g^i} p^2_{x^2 x^2}}{D} < 0 \text{ and } \quad f^j_{g^i} = dx^j / dg^i = - \frac{C^i_{x^i g^i} p^2_{x^2 x^1}}{D} > 0 \quad (7)$$

Using (3), (5), and (5*), (7) shows that a firm's Nash equilibrium level of output is decreasing in own GT-R&D and increasing in the other firm's GT-R&D.

**Proposition 1.***The GT-R&D lowers own output and increases the rival output.*

Rewritten the profit function as functions of $g^i$ , we analyze the GT-R&D levels that firm choose in the preceding stage. Let $J$ represent the profit function for firm $i$ :

$$J \; ^{o} \; p^i(f^1(g^1, g^2), f^2(g^1, g^2); g^1) \quad (8)$$

The Nash equilibrium in R&D levels using (1), (4), and (8) is characterized by the first order conditions for each firm:

$$J^i_{g^i} = p^i_{x^i} f^i_{g^i} + p^i_{x^j} f^j_{g^i} - C^i_{g^i} - a = 0$$

$$= R^i_{x^j} f^j_{g^i} - C^i_g - a = 0 \quad (9)$$

Since $p^i_{x^i} = 0$ and $p^i_{x^j} = R^i_{x^j}$ . The second order condition is

$$J^i_{g^i g^i} = R^i_{x^j} f^j_{g^i g^i} + f^j_{g^i}(dR^i_{x^i} / dg^i) - C^i_{xg} f^i_{g^i} - C^i_{gg} < 0 \quad (10)$$

And assume the condition analogous to (5*)

$$D = J^1_{g^1 g^1} J^2_{g^2 g^2} - J^1_{g^1 g^2} J^2_{g^2 g^1} > 0 \quad (10^*)$$

From (9), (2), and (7) it is clear that firms do not minimize costs, as these firms set

$$R^i_{x^j} f^j_{g^i} = C^i_g + a < 0 \quad (11)$$

This result, (11), is dissimilar with the Spencer and Brander (1983), given that domestic GT-R&D causes the rival outputs rise. Intuitively, R&D is not overused in that GT-R&D is not used to minimize total costs for the output chosen.

**Proposition 2.***GT-R&D is not overused to minimize the production costs*

## TRADE POLICY

In this section we demonstrate that trade (industrial) policy, in form of GT-R&D subsidies can enable a domestic firm to capture a larger share of the world market so as to increase profits and rent. We do not examine the export subsidy as it is prohibited by the WTO.

The government is introduced as an agent that can set subsidy rates on GT-R&D expenditure in a period before the firms spend on GT-R&D. The assumption that the government can pre-commit itself to such subsidies is similar to the previous studies (e.g.(Barrett, 1994)(Spencer & Brander, 1983)(Sturm D. , 2001).

Redefine the profit function of firm with a subsidy, $s$ , per unit of GT-R&D as follow

$$J^1(g^1, g^2; s) = R^1(x^1, x^2) - C^1(x^1; g^1) - (a - s)g^1 \quad (12)$$

The point of interest concerns the effects of subsidy on GT-R&D levels. The subsidy shifts out the R&D reaction function of the domestic firm, increasing its equilibrium GT-R&D and reducing the GT-R&D undertaken by the foreign firm, provided reaction functions are downward sloping. These results are obtained by total differentiation of the first order conditions of (12).

$$dg^1 / ds = - \frac{J^2_{x^2 x^2}}{D} > 0 \text{ and } dg^2 / ds = \frac{J^2_{x^2 x^1}}{D} < 0 \quad (13)$$

**Proposition 3.** *A domestic GT-R&D subsidy increase domestic GT-R&D and reduced foreign GT-R&D given* $J^2_{x^2x^1} < 0$. *If* $J^2_{x^2x^1} > 0$, *foreign GT-R&D rises.*

***The optimal domestic GT-R&D subsidy***

The optimal subsidy is found by maximizing net domestic welfare. The welfare is defined as follow

$$w^1(s) = J^1(g^1, g^2; s) - sg^1 \tag{14}$$

From (1), the domestic welfare (14), with subsidy, is just the profit of the domestic firm (earns from exports) when there is no subsidy.

The level of GT-R&D chosen by the domestic firm is the level which maximizes its profit within the confines of the behavior which characterizes the two-stage Nash Equilibrium. If a firm violates this equilibrium it risks the possibility it will earn lower profit in the unstable situation which follows. By providing a subsidy to firms, the government alters the perceived cost structure and thus changes the set of actions which are compatible with the two-stage Nash equilibrium. This allows the domestic firm to earn higher profit net of the subsidy.

For the present, however, we examine the incentives facing a single government. We might also mention that the use of benefit function (14) involves the usual assumptions necessary for partial equilibrium surplus analysis. In particular if GT-R&D is not subsidized the private cost of R&D reflects its full social opportunity cost.

From (14) the first order condition for the welfare maximizing subsidy is

$$dw^1/ds = J^1_1 f^1_s + J^1_2 f^2_s + J^1_s - g^1 - sg^1_s \tag{15}$$

From (12) , (9), (13), the subsidy is as follow

$$s = J^1_2 \frac{dg^2}{dg^1} \tag{16}$$

The optimal GT-R&D subsidy is equal to the increase in own profit from a reduction in the foreign firm's GT-R&D brought about by an increase in own GT-R&D.

**Proposition 4.** *The optimal subsidy is positive.*

***Noncooperative international equilibrium***

This GT-R&D rivalry does have a beggar-thy-neighbor aspect. By imposing a subsidy, country 1 gains at the expense of country 2.

Rewritten the welfare function as follow

$$W^i(s^1, s^2) = g^i(g^1, g^2; s^i) - s^i g^i \tag{17}$$

Which earned by each country when bot have subsidized GT-R&D. this the same form as (14) since the subsidy of country 2, $s^2$, affects the profits of firm 1 only indirectly through its impact on GT-R&D levels. The non-cooperative equilibrium occurs where $¶W^1/¶s^1 = 0$ and $¶W^2/¶s^2 = 0$ and implies positive subsidies.

$$s = p^i_j \left(dg^j / dg^i\right) \tag{18}$$

If the two firms are similar, total rent is lower and both countries earn less rent at the non- cooperative equilibrium than they would if they had been able to come to an agreement not to subsidize GT-R&D. Both producing countries are then worse off by their subsidization of GT-R&D rivalry. Consuming countries, of course, gain from the fall in prices which results from greater production.

## CONCLUDING REMARKS

National governments play a significant role in certain international market, particularly newly developed green technologies. In such industries which often have only a few firms invests in developing the technologies. These firms have a clear understanding that they are involved in a strategic game which foreign firms and national governments are players.

This paper examines such a market which domestic firm and foreign firm compete for market shares in the third market.The approach is similar with a volume of previous papers in the R&D rivalry. The strategic game played by firms leads them to not overused GT-R&D in the absence of government policy. The government has incentive to subsidies the GT-R&D to enable the domestic firm to capture a larger share in the industry[5]. Furthermore, this incentive encourages a firm to do more 'green R&D' even without a tough environmental regulation as proposed by the 'Porter hypothesis'.

We should emphasize that the analysis presented here is not in any sense a recommendation that environmental policies be strategically used. There are a number of ways that this paper could be extended. For instance, adding the supranational institution that rules the market of green products or assuming a domestic oligopoly competition would provide some interesting result.

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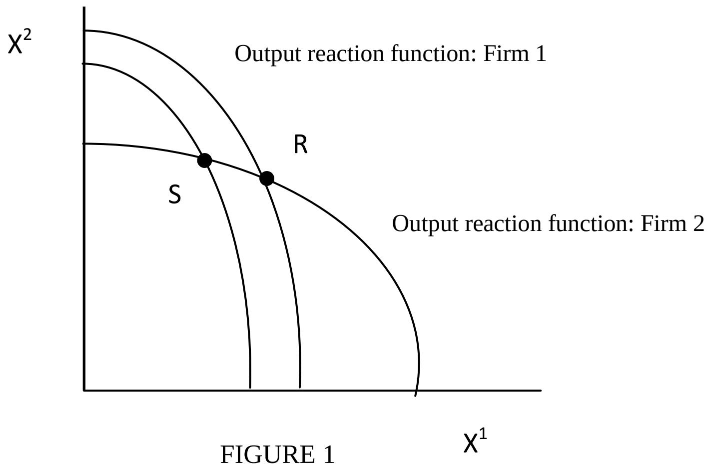


FIGURE 1

[5] A government should help its domestic firm to invest in environmentally friendly technology. For instance, a comment by (Juan, 2011), argues that a subsidy policy of one government can encourage firm.