GCOE Discussion Paper Series

Global COE Program
Human Behavior and Socioeconomic Dynamics

Discussion Paper No.83

Cost-reducing R&D investment, Labor market and trade

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September 2009

GCOE Secretariat
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September 3, 2009

Abstract

In this paper, I construct a two-country general equilibrium model in which oligopolistic firms export goods and undertake cost-reducing R&D investment. Each country imposes tariffs. A decrease in the tariff rates in both countries decreases cost-reducing R&D investment.

Keywords: R&D, Trade, Oligopoly
JEL classification: F12, F13

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*I am very grateful to Koichi Futagami for his considerable help. I have also benefited from comments and suggestion by Kenzo Abe, David Flath, Taiji Furusawa, Jota Ishikawa, Masao Oda, Hisayuki Okamoto, Yoshiyasu Ono, Kazuhiro Yamamoto, Akihiko Yanase and seminar participants at Seinan Gakuin University, the Japan Society of International Economics Kansai, the Japanese Economic Association and the 2009 Asian Pacific Trade Seminars. This article was previously entitled, "R&D and trade in a general equilibrium model".

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1 Introduction

In 1980s and 1990s, R&D investment has increased dramatically in the OECD countries. Braun (2008) explains that the ratio of industrial R&D expenditures to GDP has risen from 1% in 1979 to 1.43% in 1990 and 1.72% in 2004. In addition, international market become more openness recently. For example, Gao (2006) explains that average tariffs fell around 20% in 1995 to under 5% today. [1]

The purpose of this paper is to investigate the relationship between the trade liberalization and cost-reducing R&D expenditures: When international trade is facilitated, does the cost-reducing R&D expenditures increase?

In this paper, I construct a two-country general equilibrium model in which oligopolistic firms export goods and conduct cost-reducing R&D investment to reduce their marginal cost. Each country simultaneously imposes tariffs on import goods at the same rate. In each country, there are two types of labor: skilled labor and unskilled labor. The firms employ skilled labor not only to produce goods but also to conduct cost-reducing R&D investment while unskilled labor is used only to produce goods. I show that when the countries reduce their tariff rates, cost-reducing R&D investment decreases.

2 The model

There are two countries, Home and Foreign, indexed by $l \in \{H, F\}$ and these countries are symmetric. The population size in each country is equal to L. There are two types of labor in each country: skilled labor and unskilled labor. I assume that s is the proportion of skilled labor. Thus, sL is the number of skilled labor and $(1-s)L$ is the number of unskilled labor.[2] There are three types of goods; an agricultural good, and manufacturing goods 1 and 2. The agricultural good can be produced in both countries. Manufacturing good 1 is produced only in the Home country and manufacturing good 2 is produced only in the Foreign country. The firm producing manufacturing good 1 is named Firm 1 and the firm producing manufacturing good 2 is named Firm 2. I assume that Firms 1 and 2 compete

[1] Some empirical papers investigate the relationship between trade liberalization and R&D expenditures. Funk (2003) concludes that U.S manufacturing firms which sell their product to the U.S market decrease the R&D investment when the trade liberalization is promoted. On the other hands, U. S manufacturing firms with foreign sale increases the R&D investment. Scherer and Huh (1992) investigate that average U.S. high-tech firms reduce the R&D investment in the short run when the trade liberalization is promoted.

[2] I omit the process of skill acquisition and I assume that the supply of skilled and unskilled labor are given.

strategically by using their product quantities, that is, they engage in Cournot competition. Both countries levy tariffs on their imports of the manufacturing good and the tariff rate is denoted by τ.

2.1 Consumer

The utility function of the representative consumer in each country is given by

$$U^l(q_{1l}, q_{2l}, m_l) = m_l + a(q_{1l} + q_{2l}) - \frac{1}{2}\left[q_{1l}^2 + q_{2l}^2 + 2bq_{1l}q_{2l}\right], l \in \{H, F\}, b \in \{0, 1\}, \tag{1}$$

where m_l is the consumption of the agricultural good in country l, q_{1l} and q_{2l} respectively denote the consumption of the manufacturing goods produced by Firms 1 and 2, and a and b are positive parameters. The budget constraint of the consumer in country l is as follows:

$$m_l + p_{1l}q_{1l} + p_{2l}q_{2l} = E_l, l \in \{H, F\}, \tag{2}$$

where m_l is chosen to be the numeraire, p_{1l} and p_{2l} respectively denote the prices of the manufacturing goods produced by Firms 1 and 2, and E_l is the expenditure in country l. From the first-order condition of the consumer, I obtain the following inverse demand functions:

$$p_{1l} = a - q_{1l} - bq_{2l}, \tag{3}$$

$$p_{2l} = a - q_{2l} - bq_{1l}. \tag{4}$$

2.2 Production

2.2.1 Agricultural goods sector

Production of one unit of the agricultural good requires one unit of unskilled labor in both countries. I assume that the agricultural good market is perfect competitive and the agricultural good can be traded freely. Thus, the wage rate for unskilled labor in both countries is equal to unity.

2.2.2 Manufacturing goods sector

Firms 1 and 2 produce the manufacturing goods and conduct cost-reducing R&D investment to decrease their marginal costs of production. Production of the manufacturing good requires both skilled and unskilled labor. The production of one unit of the manufacturing good requires θ units of skilled labor and $\alpha(k_l) \in [0, \bar{\alpha}]$ units of unskilled labor in country l. k_l denotes the number of the skilled labor that is allocated to cost-reducing R&D investment in country l. I assume that $\partial\alpha(k_l)/\partial k_l < 0$ and $\partial^2\alpha(k_l)/\partial k_l^2 \geq 0$. The profit of Firm 1 is then given by

$$\pi_1 = p_{1H}q_{1H} + (p_{1F} - \tau)q_{1F} - (q_{1H} + q_{1F})(\alpha(k_1) + \theta w_H) - k_1 w_H, \tag{5}$$

where w_H is the wage rate for skilled labor in the Home country. Due to the inverse demand functions (3) and (4), the profit maximization of the firms leads to the following levels of output and R&D investment:

$$q_{1H} = \frac{1}{2}\left[a - bq_{2H} - (\alpha(k_1) + \theta w_H)\right], \tag{6}$$

$$q_{1F} = \frac{1}{2}\left[a - \tau - bq_{2F} - (\alpha(k_1) + \theta w_H)\right], \tag{7}$$

$$w_H = -(q_{1H} + q_{1F})\alpha^{'}(k_1). \tag{8}$$

I suppose that the wage rate of skilled labor is constant for the manufacturing good firms. Because I assume that Home and Foreign countries are symmetric, Firms 1 and 2 produce the same output level. Thus, both the level of R&D investment and the wage rate for skilled labor are the same in the both countries: $k_1 = k_2 \equiv k$ and $w_H = w_S \equiv w$. From (6) and (7), the output levels are given by

$$q_{1H} = q_{2F} = \frac{1}{4 - b^2}\left[(2 - b)a + b\tau - (2 - b)(\alpha(k) + \theta w)\right], \tag{9}$$
$$q_{1F} = q_{2H} = \frac{1}{4 - b^2}\left[(2 - b)a - 2\tau - (2 - b)(\alpha(k) + \theta w)\right], \tag{10}$$

when q_{1H} and q_{1F} take positive values. Because the purpose of this paper is to investigate the effect of tariffs, I focus on the case in which positive amounts of manufacturied goods are traded between the countries.

The demand for skilled labor derives from R&D investment and production of the manufacturing good. The demand for unskilled labor comes from production of the manufacturing good and the agricultural good. Because the supply of skilled labor is sL and that of unskilled labor is $(1 - s)L$, the labor market equilibrium conditions in country H is given by

$$sL = k_1 + \theta(q_{1H} + q_{1F}), \tag{11}$$
$$(1 - s)L = m_H^P + \alpha(k_1)(q_{1H} + q_{1H}), \tag{12}$$

where m_H^P denotes the labor demand of the agricultural good sector in country H.

3 Equilibrium

From (8), (9), and (10), I obtain the wage rate for skilled labor as follows:

$$w = \frac{-\alpha'(k)\left[2a - \tau - 2\alpha(k)\right]}{(2+b) - 2\theta\alpha'(k)}. \tag{13}$$

From (13), I obtain the output level of Firm 1 as follows:

$$q_{1H} + q_{1F} = \frac{A}{B}, \tag{14}$$

where $A \equiv 2a - \tau - 2\alpha(k) > 0,\ B \equiv (2+b) - 2\theta\alpha'(k) > 0$.

Inserting (13) and (14) into the skilled labor equilibrium condition, (11), yields the skilled labor equilibrium condition as follows:

$$sL = k + \frac{\theta A}{B}. \tag{15}$$

Totally differentiating (15) reveals that $\partial k/\partial\tau$ takes a positive value (see the Appendix). This result is summarized as the following proposition.

Proposition 1. *An increase in the tariff rate raises R&D investment.*

An increase in the tariff rate lowers the profitability of exporting manufacturing goods. Hence, both firms decrease their exports and the market becomes less competitive. Given their increased market power, both firms raise prices and lower output levels. Because of the skilled labor market equilibrium condition, more skilled labor can be allocated to R&D investment. Consequently, both firms increase R&D investment.

By differentiating (14) with respect to the tariff rate, τ, I obtain $\partial(q_{1H} + q_{1F})/\partial\tau < 0$ (see the Appendix). Thus, this results in the following lemma.

Lemma 1. *A decrease in the tariff rate raises the output level of both firms.*

A decrease in the tariff rate has a direct effect and an indirect effect. A reduction in the tariff rate directly increases output levels of the firms by facilitating exports. A fall in the tariff rate indirectly reduces output level of the firms. This is because the stimulus to exports brought about by the lower tariff makes the market more competitive, to which the firms respond by reducing their R&D investment; this then raises the marginal costs, which reduces output levels of the firms. However, the direct effect dominates the indirect effect.

I now investigate the effects of lowering the tariff rate on the wage rate of skilled labor. Differentiating the wage rate of skilled labor with respect to τ, I obtain $\frac{\partial w}{\partial \tau} < 0$ (see the Appendix). This result is summarized as the following proposition.

Proposition 2. *A decrease in the tariff rate increases the wage rate for skilled labor.*

From Lemma 1, a reduction in the tariff rate raises output levels of the firms. Then, because the firms demand skilled labor more to produce their goods, the demand of skilled labor increases the wage rate for skilled labor. Therefore, the wage gap between skilled and unskilled labor widens.

4 Welfare Analysis

In this section, I investigate the relationship between welfare and the tariff rate. In the country H, the consumption of the agricultural good m_H is derived from budged constraint (2) as follows:

$$m_H = E_H - p_{1H}q_{1H} - p_{2H}q_{2H}. \tag{16}$$

The expenditure in the country H, E_H, is consisted of wage rate, profit of the firm 1, and tariff revenue. Therefore, the expenditure in the country H is given by

$$E_H = wsL + (1-s)L + \pi_1 + \tau q_{2H}. \tag{17}$$

Then, substituting (17) to (16), I can derive the consumption of the agricultural good as follow:

$$m_H = (1-s)L - \alpha(k)(q_{1H} + q_{2H}). \tag{18}$$

By using (18), I can gauge the welfare level in the country H

$$U^H = (1-s)L + (a - \alpha(k))(q_{1H} + q_{2H}) - \frac{1}{2}\left[q_{1H}^2 + q_{2H}^2 + 2bq_{1H}q_{2H}\right]. \tag{19}$$

Differentiating by τ and substituting the consumption of manufacturing goods (9) and (10), I get

$$\frac{\partial U^H}{\partial \tau} = \frac{1}{4-b^2}\left[\frac{b-2}{b+2}(a-\alpha(k)) + \frac{2+b-b^2}{2+b}\frac{\alpha'(k)\theta A}{B} + \frac{3b^2-4}{4-b^2}\tau\right]$$
$$- \frac{1}{(2+b)}\left[2(a-\alpha(k)) + (q_{1H}+q_{2H})\right]\alpha'(k)\frac{\partial k}{\partial \tau}$$
$$- \frac{\theta}{(2+b)(2+b-2\theta\alpha'(k))}\left[2(a-\alpha(k))(1-2\theta\alpha'(k)) + (1+b)\tau\right]\frac{\partial w}{\partial \tau}. \quad (20)$$

The first term takes a negative value. The second term and the third term take positive values. Therefore, the effect of tariff rate is ambiguous. In order to get some clear results. I present a numerical example. In this example, the function $\alpha(k)$ is $3-k$. As for the parameters of the utility function I choose $a = 7.5$ and $b = 0.74$. The number of the population is $L = 10$ and the proportion of skilled labor is $s = 0.5$. The parameter of the skilled labor's productivity is $\theta = 0.3$. Figure 1 describes the relationship between the welfare level and the tariff rate τ. As Figure 1 shows, there exists the tariff rate which maximizes the welfare level in the contry H and optimal tariff rate is $\tau^* = -4.555$. Therefore the both countries subsidize the firms to their import goods.

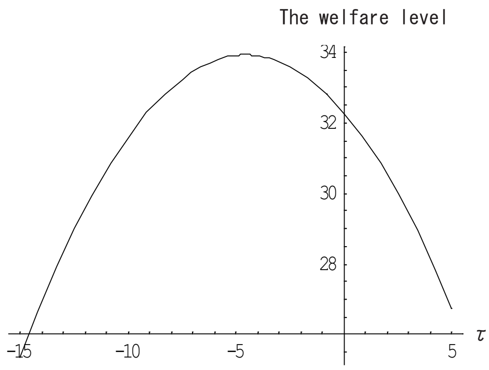

Figure 1: Numerical example

5 Conclusion

In this paper, I constructed a two-country general equilibrium model in which oligopolistic firms produce goods and undertake cost-reducing R&D investment. A reduction in the tariff rate increases the wage gap between skilled and unskilled labor. I also showed that a fall in the tariff rate decreases investment in cost-reducing R&D. This result differs from its of Braun (2008) and Haaland and Kind (2008). Their studies contributed analyzing relationship between the trade liberalization and R&D investment. They do not consider that the increased demand for skilled labor raised the wage rate of skilled labor because they do not incorporate the labor market. Therefore, although a fall in tariff rate raises firms' output levels, the marginal cost of R&D does not change. However, I incorporate the labor market. Therefore, I can obtain the opposite result.

A Appendix

A.1 Proof of Proposition 1

By totally differentiating (15), I obtain the following equation:

$$\frac{-\theta}{B}d\tau + (1 + \frac{\theta C}{B^2})dk = 0,$$

where $C \equiv -2\alpha'(k)B + 2\theta\alpha'' A > 0$. This equation can be rewritten as

$$\frac{dk}{d\tau} = \frac{\theta B}{B^2 + \theta C} > 0. \tag{A.1}$$

A.2 Proof of Lemma 1

To prove that an increase in the tariff rate decreases the output level of Firm 1, I differentiate (14) with respect to τ to obtain

$$\begin{aligned}\frac{\partial(q_{1H} + q_{1F})}{\partial\tau} &= \frac{1}{B^2}\left[-B + C\frac{\partial k}{\partial\tau}\right] \\ &= \frac{1}{B}\left[-1 + \frac{\theta C}{B^2 + \theta C}\right] \\ &= \frac{-B}{B^2 + \theta C} < 0.\end{aligned}$$

Thus, the result follows.

A.3 Proof of Proposition 2

Differentiating the wage rate for skilled labor with respect to the tariff rate, τ, yields the following:

$$\frac{dw}{d\tau} = \frac{\alpha^{'}(k)}{B} - \frac{1}{B^2}\left[\alpha^{''}(k)AB + \alpha^{'}(k)C\right]\frac{dk}{d\tau}.$$

By inserting (A.1) into the above equation, I obtain the following equation:

$$\frac{dw}{d\tau} = \frac{B\alpha^{'}(k) - \theta A\alpha^{''}(k)}{B^2 + \theta C} < 0. \tag{A.2}$$

The denominator of the above equation is positive because $B > 0$ and $C > 0$. The numerator of the above equation is negative because $\alpha^{'}(k) < 0$ and $\alpha^{''}(k) > 0$. Therefore, $\partial w/\partial\tau$ is negative.

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