R&D and trade in a general equilibrium model *

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Abstract

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

Keywords: R&D, Trade, Oligopoly
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1 Introduction

In many countries, the wage inequality between skilled and unskilled labor widens. International trade has played an important role in pushing up wage inequality. Many studies have investigated the interaction between the relative wages of high skilled to low skilled labor and international trade. Feenstra and Hanson (1995) and Leamer (1996) show that the increased openness of the U.S. economy has increased its wage inequality.

The purpose of this paper is to investigate the relation between international trade and inequality in the country: When international trade is facilitated, does the wage inequality increase? In this paper, I construct a two-country general

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equilibrium model in which oligopolistic firms export goods and conduct 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. Firms employ skilled labor not only to produce goods but also to conduct R&D investment while unskilled labor is used only to produce goods. I show that when the countries reduce their tariff rates, the wage gap between skilled labor and unskilled labor widens and 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. 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 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 The 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 consumption of the agricultural good in country l, q_{1l} and q_{2l} respectively denote 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. Thus, the wage rate for unskilled labor in both countries is equal to unity. I assume that the agricultural good can be traded freely.

2.2.2 Manufacturing goods sector

Firms 1 and 2 produce the manufacturing goods and conduct 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 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:

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

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

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

Because I assume that Home and Foreign countries are symmetric, Firm 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.

To 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 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. This result is consistent with empirical studies. I also showed that a fall in the tariff rate decreases investment in cost-reducing R&D. This result differs from those of Braun (2008) and Haaland and Kind (2008). By ignoring the labor market, these reseachers do not consider increased wage for skilled labor. Therefore, although a fall in tariff rate raises firms' output levels, the marginal cost of R&D does not change.

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, yeilds 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:

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

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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