How does trade openness affect R&D activities?*

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Abstract

This paper constructs a model in which international trade influences on R&D activities of firms. We show that trade openness influences on the R&D activities of firms, if innovation costs and fixed trade costs are intermediate values. If the fixed trade costs are relatively high and the innovation costs are relatively low, trade openness diminishes the R&D activities of firms. The relations between several exogenous parameters and the effect of trade openness are discussed.

Key Words: *Trade, Monopolistic competition, R&D*

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* The paper was entitled "Magagerial incentive and international trade". The authors would like to thank Takao Asano, Kohei Daido, Masahisa Fujita, Makoto Hanazono, Junichiro Ishida, Jota Ishikawa, Yoshitsugu Kanemoto, Tatsuro Kuroda, Naoko Nishimura, Ryoji Ohdoi, Tomoya Mori, Se-il Mun, Yasusada Murata, Yasuhiro Sato, Ayako Suzuki, Ken Tabata, Takaaki Takahashi, Joji Tokui for their helpful comments and suggestions. The authors gratefully acknowledges financial support from a Grant-in-Aid for Encouragement of Young Scientists from the Japanese Ministry of Education, Science and Culture. Needless to say, we are responsible for any remaining errors.

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1. Introduction

The general reduction in trade barriers increases numbers of competitors in industries.[1] Firms facing the increases in the number of competitors will consider how to overcome the problem. It is a way for those firms to engage R&D activities more to improve the efficiencies of their productions.

Roughly speaking, the reduction in trade barriers has two countervailing effects on the profitability of firms. First, the reduction in barriers gives opportunities to the firms to export their products and earn additional profits. Second, there is a possibility that tougher competition diminishes incentives to engage in R&D because residual demands that firms face shrink and then marginal gains of efforts decrease. If the former is more significant than the latter, the efficiencies of firms improve by the reduction in trade barriers.

Many researchers investigate whether exporting improves firm performance. Using the case of the Canada-U.S. Free Trade Agreement (FTA), Trefler (2004) deals with the impact of FTA-mandated tariff cuts.[2] He shows that the Canadian tariff concessions raised labor productivity by 15 percent in the most impacted, import-competing group of industries and that the U.S. tariff concessions raised labor productivity by 14 percent or 1.9 percent annually in the most impacted, export-oriented group of industries.[3] Contrary to the results in Trefler (2004), several papers show that globalization of competition does not always enhance productivity of firms. Bernard and Jensen (1999) also investigate whether good firms become exporters or whether exporting improves firm performance. They show that good firms become exporters; however, productivity and wage growth is not superior for exporters, particularly over longer horizons. Clerides *et al.* (1998) and Delgado *et al.* (2002) show similar results to Bernard and Jensen (1999).

Whether or not the trade barrier reduction, which induces tough global competition, improves productivity of firms is still ambiguous and a theoretical explanation for the problem is needed. We build a theoretical framework to discuss the problem. We employ a dynamic industry model a la Melitz (2003). We incorporate a simple R&D technology into a monopolistic competition model. Each firm produces a differentiated good and decides whether or not to engage its R&D activity which improves firm's productivity with some probability. If a firm decides to engage in its R&D activity, it has to incur a fixed innovation cost. If the R&D investment of a firm achieves success, the firm exports its products to foreign markets and has to incur per market fixed trade cost. In this paper, we analyze an autarky model and later study the international trade model. We compare these two cases and study the impact of trade on innovation activities of firms.

Our analysis shows that the innovation costs and the fixed trade costs play important roles: their values influence on impact of trade on innovation incentives of firms. If the innovation cost is large *or* the fixed trade cost is small, openness of trade enhances the innovation incentives of firms. If the innovation cost is small *and* the fixed trade cost is large, openness of trade diminishes the innovation incentives of firms.[4] In our analysis, we concentrates on the case in which firms which achieve success in their innovation can export their goods, while firms which fail in their

1 Although we concentrate our discussion on international trade, we can apply the discussion to the issues of deregulation waves, decreasing transport costs, the spread of IT, and so on.

2 See also Aw *et al.* (2000), Baldwin and Gu (2003), Bernard and Jensen (2004).

3 Trefler (2004) also suggests that much of the productivity gain is coming from market share shifts favoring high-productivity plants and that such share shifting would come about from the growth of high-productivity plants and the demise and/or exit of low-productivity plants. The property is a little similar to the theoretical explanation of Melitz (2003).

4 We exclude the cases in which openness of trade dose not influence on the innovation incentive of firms, that is, we do not consider the cases in which the innovation cost is low enough (*resp.* high enough) or the fixed trade cost is low enough (*resp.* high enough) because all firms engage (*resp.* no firm engages) in the innovation activities under both autarky and trade liberalization cases.

innovation or have not engaged in their innovation cannot export their goods. In this case, exporting firms have larger scales than non-exporters, those phenomenons are presented in many empirical researches. Therefore, we believe that our simple analysis properly captures real world situations and is able to provide several useful insight on the literature of international trade and industrial organization.

Roughly speaking, there are two effects of trade openness: (1) market enlargement effect (positive), (2) intensive competition effect (negative). The fixed trade cost and the innovation cost affect the relative significance of the market enlargement effect. As the fixed trade cost increases, the gross profit from exporting its product becomes small relatively (the relative significance of the market enlargement effect diminishes). The innovation cost indirectly affects the significance of the fixed trade cost on the market enlargement effect. As the innovation cost increases, the fixed trade cost becomes relatively smaller. That is, when the innovation cost is large, the significance of the fixed trade cost is not so large. Therefore, if the innovation cost is small *and* the fixed trade cost is large, openness of trade diminishes the innovation incentives of firms.[5]

This paper is related to the literature of the relationship between product market competition and innovation. Many papers show that innovation declines with competition (see, among others, Arrow (1962), Gilbert and Newbury (1982), Grossman and Helpman (1991), and Aghion and Howitt (1992)). This is not consistent with those paper mentioned above and the other empirical papers (see, for instance, Nickell (1996) and Blundell *et al.* (1999)). Along the line, Aghion *et al.* (2005) reexamine this relationship using panel data and show clear nonlinearity in the form of an inverted-U shape: given that the market is highly competitive, the milder the competitiveness, the higher the incentive to innovate; given the market is not so competitive, the milder the competitiveness, the lower the incentive to innovate. Using an endogenous growth model, they provide a theoretical explanation for the inverted-U shape property.

This paper is also related to several theoretical explanations for the relation between innovation and international trade provided by Ederington and McCalman (2004), Atkenson and Burstein (2007), and Costantini and Melitz (2007). Those paper shows that trade openness enhances the innovation activities of firms.[6] Our model is simpler than their model. Then, we can analyze the effect of innovation cost and fixed trade costs on the firms' innovation incentive, and we can analytically divide cases that trade enhances or diminishes firms' innovation incentive. Thus, our research is complement to those researches.

The remainder of this paper is organized as follows. Section 2 presents the basic model. Section 3 presents the result under autarky economy. Section 4 presents the result under open economy. Section 5 provides the comparison between those results. Section 6 concludes the paper.

2. The model

To describe a market equilibrium, we first consider the demand side. There are m variants of a differentiated (manufacturer) product. Market demand and consumer's benefits are determined from a representative consumer's utility function:

$$U \equiv \alpha \ln C_M + C_A; \tag{1}$$

where C_A is the quantity of the numéraire (agricultural goods), and C_M is defined:

$$C_M \equiv \left(\int_0^m x(i)^\rho di \right)^{\frac{1}{\rho}},$$

where $x(i)$ denotes the quantity of variant i and ρ

5 We explain the detail of the relation between the innovation incentives and openness of trade in Section 5.

6 Atkenson and Burstein (2007) shows that process innovation is progressed with trade openness. However, they also point out that the increase in process innovation is largely offset by a decline in product innovation.

$\in (0, 1)$, the parameterized consumer's preference for variety. The restriction on ρ ensures that products are substitutes, with a high ρ corresponding to a low preference for variety; when $\rho \to 1$, all goods are perfect substitutes, while preferences have the Cobb-Douglas form for $\rho \to 0$. The quantity demanded for variant i is:

$$x(i)=\alpha L p(i)^{-\sigma} G_M^{\sigma-1}, \tag{2}$$

where L denotes the market size, $\sigma=\frac{1}{1-\rho}$, and G_M is defined:

$$G_M \equiv \left(\int_0^m p(i)^{1-\sigma} di\right)^{\frac{1}{1-\sigma}}.$$

We now consider the supply side. Firm i produces variant i ($i \in [0, m]$). Each firm has a constant marginal cost, c_l without R&D activity. Each firm can improve its productivity with R&D activity. If a firm incurs its R&D costs $e(>0)$, the marginal cost of the firm becomes c_h with probability θ, where $c_h < c_l$ and $\theta \in (0, 1)$. In other word, its R&D activity results in failure with probability $1-\theta$ and the marginal cost is c_l. Therefore, firms without R&D activity and firms with R&D failure have the same marginal costs c_l, and firms with R&D success have the marginal cost c_h.

The production function of the agricultural goods (numéraire goods) is $x_A = l_A$. Perfect competition ensures that those goods are priced at a uniform marginal cost in all countries even though the global market is opened. The wage rate in this sector is unity because those goods are numéraire. Thus, $p_A = w = 1$.

Differentiated products are produced with constant returns to scale technology. Producing $x(i)$ units of variant i needs $c_i x(i)$ units of labor.

3. Autarky economy

The gross profit of firm i with cost c_j ($j \in \{h, l\}$) is (the word "gross" means that the profit does not include its investment cost):

$$\pi_i(c_j, m_h, m_l) \equiv \left(\frac{\alpha L}{\sigma}\right)\frac{c_j^{1-\sigma}}{mhc_h^{1-\sigma}+m_l c_l^{1-\sigma}} = \frac{\alpha L c_j^{1-\sigma}}{\sigma g_n(m_h, m_l)}, \tag{3}$$

where g_n is defined as follows:

$$g_n(m_h, m_l) \equiv m_h c_h^{1-\sigma} + m_l c_l^{1-\sigma}, \tag{4}$$

where m_h ($resp.$ m_l) is the amount of firms with the marginal cost c_h ($resp.$ c_l). Given the expected amounts of firms with marginal cost c_j (m_h and m_l), a firm decides to engage in R&D activities if and only if:[7]

$$\theta\left[\frac{\alpha L c_h^{1-\sigma}}{\sigma g_n(m_h, m_l)}\right] + (1-\theta)\left[\frac{\alpha L c_l^{1-\sigma}}{\sigma g_n(m_h, m_l)}\right] - e \geq \frac{\alpha L c_l^{1-\sigma}}{\sigma g_n(m_h, m_l)}. \tag{5}$$

The left-hand side ($resp.$ right-hand side) is the expected profit of firm i when it engages (dose not engage) in the R&D activities.

3.1 High productivity equilibrium

We now check the condition that all firms engages in the R&D activities. The gross profit of firm i is $\pi_i(c_j, \theta m, (1-\theta)m)$, when it's marginal cost is c_j ($c_j \in \{c_h, c_l\}$). From (5), the condition is

$$\lambda_h^{autarky} \equiv \frac{\theta\alpha L(c_h^{1-\sigma}-c_l^{1-\sigma})}{\sigma g_n(\theta m, (1-\theta)m)} \geq e. \tag{6}$$

If (6) is satisfied, all firms engages in the R&D activities under the autarky case. We call the equilibrium h_A equilibrium.[8]

3.2 Low productivity equilibrium

In this case, all firms do not engage in the R&D activities. The gross profit of firm i is $\pi_i(c_l, 0, m)$. From (5), firm's R&D condition is

$$\lambda_l^{autarky} \equiv \frac{\theta\alpha L(c_h^{1-\sigma}-c_l^{1-\sigma})}{\sigma g_n(0, m)} \leq e. \tag{7}$$

If (7) is satisfied, no firm engages in the R&D activities under the autarky case. We call the equilibrium l_A equilibrium. Since $c_h^{1-\sigma} > c_l^{1-\sigma}$, we can easily show that $\lambda_h^{autarky} < \lambda_l^{autarky}$.

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7 Because m_h and m_l depend on how many firms become efficient by their probabilistic investments, we use the term "expected".

8 We assume that $\alpha L/\sigma\, m - e \geq 0$, which is satisfied if L is sufficiently large.

3.3 Intermediate equilibrium

If the following inequalities hold, the economy is at the intermediate equilibrium.

$$\lambda_h^{autarky} \leq e \leq \lambda_l^{autarky}, \tag{8}$$

In the intermediate equilibrium, it is indifferent for each firm whether it engages to the R&D activity or not. That is, the inequality in (5) must be satisfied by the equality. The equation is:

$$\frac{\theta\alpha L(c_h^{1-\sigma}-c_l^{1-\sigma})}{\sigma g_n(m_h^A, m-m_h^A)}=e, \tag{9}$$

where $m_h^A \equiv \theta z^A (z^A \in [0, m])$ and z^A is the number of firms engaging in the R&D activities. From (9), we can easily derive the value of $m_h^A = \theta_z^A$:

$$m_h^A = \theta z^A = \frac{\alpha\theta L}{\sigma e} - \frac{m c_l^{1-\sigma}}{c_h^{1-\sigma}-c_l^{1-\sigma}}. \tag{10}$$

We can easily check that $m_h^A = \theta m$ ($resp.$ $m_h^A = 0$), when $e = \lambda_h^{autarky}$ ($resp.$ $e = \lambda_l^{autarky}$).

We summarize the relation between the investment cost (e) and the number of high productive firms with c_h (m_h) in Figure 1.

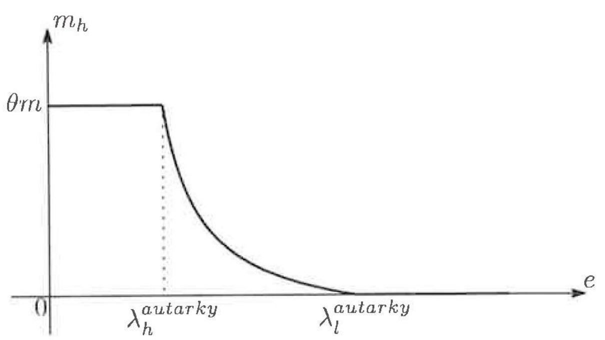

Figure 1 The relation between the investment cost and the number of high productive firms in the autarky economy

4. Openness of trade

There are symmetric $n+1$ countries. To export to other countries, firms must incur fixed costs, f_E (following Melitz (2003)). When a firm exports its product for a foreign country, the profit at the foreign country is:

$$\pi_i^e = \frac{\alpha L T^{1-\sigma} c_i^{1-\sigma}}{\sigma g_j(m_h, m_l)} - f_E, \tag{11}$$

where T is the standard iceberg transport cost and g_j (m_h, m_l) is defined as follows:

$$g_j(m_h, m_l) \equiv \begin{cases} m_h c_h^{1-\sigma} + m_l c_l^{1-\sigma} + n m_h (c_h T)^{1-\sigma} \\ \quad + n m_l (c_l T)^{1-\sigma} & \text{if all firms export } (j=a), \\ m_h c_h^{1-\sigma} + m_l c_l^{1-\sigma} + n m_h (c_h T)^{1-\sigma} & \text{if only firms with } c_h \text{ export } (j=h), \\ m_h c_h^{1-\sigma} + m_l c_l^{1-\sigma} & \text{if no firm exports } (j=n). \end{cases} \tag{12}$$

For the exogenous parameters, if the following inequalities in (13) are satisfied, firms with c_h (high productivity firms) export, while firms with c_l (low productivity firms) do not.

$$\underline{f}_E(m_h, m_l) \equiv \frac{\alpha L T^{1-\sigma} c_l^{1-\sigma}}{\sigma g_n(m_h, m_l)} < f_E \leq \frac{\alpha L T^{1-\sigma} c_h^{1-\sigma}}{\sigma g_n(m_h, m_l)} \equiv \bar{f}_E(m_h, m_l) \tag{13}$$

We assume that f_E satisfies the inequalities in (13). In this case, $g_j(m_h, m_l) = g_h(m_h, m_l)$.[9]

Given the expected amounts of firms with marginal cost c_j (m_h and m_l) in each country, a firm engages in the R&D activity if and only if:

$$\theta\left[\frac{(1+nT^{1-\sigma})\alpha L c_h^{1-\sigma}}{\sigma g_j(m_h, m_l)} - n f_E\right] + (1-\theta)\cdot \left[\frac{\alpha L c_l^{1-\sigma}}{\sigma g_j(m_h, m_l)}\right] - e \geq \frac{\alpha L c_l^{1-\sigma}}{\sigma g_j(m_h, m_l)}. \tag{14}$$

We rewrite (14) as follows:

$$\frac{\theta\alpha L[(1+nT^{1-\sigma})c_h^{1-\sigma}c_l^{1-\sigma}]}{\sigma g_j(m_h, m_l)} - \theta n f_E \geq e. \tag{15}$$

4.1 High productivity equilibrium

In this case, all firms engage in the R&D activities. If the effort leads to the cost reduction, the firm is able to export its products to n foreign countries, otherwise it supplies its products only to its domestic market. From (15), the condition that all firms engage in the R&D activities is

$$\lambda_h^{trade} \equiv \frac{\theta\alpha L[(1+nT^{1-\sigma})c_h^{1-\sigma}-c_l^{1-\sigma}]}{\sigma g_n(\theta m, (1-\theta)m)} - \theta n f_E \geq e. \tag{16}$$

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9 We think that the rest of the cases do not provide interesting insights.

If (16) is satisfies, all firms engage in the R&D activities under the case of trade openness. We call the equilibrium h_T equilibrium.

4.2 Low productivity equilibrium

In this case, each firm does not engage in its R&D activity. The gross profit of firm i is

$$\frac{\alpha L c_l^{1-\sigma}}{\sigma g_n(0,m)}. \tag{17}$$

Each firm supplies its products only to its domestic market. From (15), the firm's R&D condition is (note that, $g_j = g_n$ (see (12)) and the direction of the inequality is converse):

$$\lambda_l^{trade} \equiv \frac{\theta\alpha L[(1+nT^{1-\sigma})c_h^{1-\sigma} - c_l^{1-\sigma}]}{\sigma m c_l^{1-\sigma}} - \theta n f_E \leq e. \tag{18}$$

If (18) is satisfies, no firm engages in the R&D activities under the case of trade openness. We call the equilibrium l_T equilibrium.

4.3 Intermediate equilibrium

If the following inequalities hold, the economy is at the intermediate equilibrium.

$$\lambda_h^{trade} \leq e \leq \lambda_l^{trade} \tag{19}$$

In the intermediate equilibrium, it is indifferent for each firm whether it engages in its R&D activity or not. That is, the inequality in (15) must be satisfied by the equality. The equation is:

$$\frac{\theta\alpha L[(1+nT^{1-\sigma})c_h^{1-\sigma} - c_l^{1-\sigma}]}{\sigma g_h(m_h^T, m - m_h^T)} - \theta n f_E = e. \tag{20}$$

where $m_h^T \equiv \theta_z^T (z^T \in [0, m])$ and z^T is the number of firms engaging in the R&D activities. From (20), we can derive $m_h^T \equiv \theta z^T$:

$$m_h^T = \theta z^T = \frac{\alpha\theta L}{\sigma(e+\theta n f_E)} - \frac{m c_l^{1-\sigma}}{(1+nT^{1-\sigma})c_h^{1-\sigma} - c_l^{1-\sigma}}. \tag{21}$$

We can easily check that $m_h^T = \theta m$ (*resp.* $m_h^T = 0$), when $e = \lambda_h^{trade}$ (*resp.* $e = \lambda_l^{trade}$).

We summarize the relation between the investment cost e and the number of high productive firms with c_h in Figure 2.

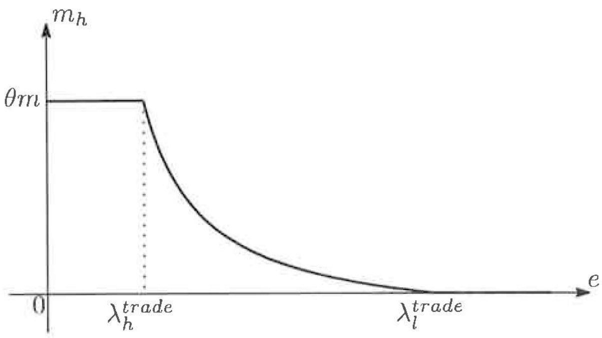

Figure 2 The relation between the investment cost and the number of high productive firms in the open economy

5. Comparison

We now discuss whether trade openness enhances the incentives of firms for their R&D investments. We first show the conditions of equilibrium outcomes. Second, we provide several results of comparative statics.

5.1 R&D enhancing trade openness

High productivity equilibrium We provide the necessary and the sufficient condition that trade openness always enhances the R&D incentives. To show the condition, we compare λ_h^{trade} in (16) with $\lambda_h^{autarky}$ in (6). The difference between them is:

$$\lambda_h^{trade} - \lambda_h^{autarky} = \frac{\theta\alpha L[(1+nT^{1-\sigma})c_h^{1-\sigma} - c_l^{1-\sigma}]}{\sigma g_n(\theta m, (1-\theta)m)} - \theta n f_E - \frac{\theta\alpha L(c_h^{1-\sigma} - c_l^{1-\sigma})}{\sigma g_n(\theta m, (1-\theta)m)}.$$

$\lambda_h^{trade} - \lambda_h^{autarky}$ is equal to zero if f_E is equal to

$$f_E^{c1} \equiv \frac{m\alpha L T^{1-\sigma} c_h^{1-\sigma} c_l^{1-\sigma}}{\sigma g_n(\theta m, (1-\theta)m)\, g_h(\theta m, (1-\theta)m)}. \tag{22}$$

where g_n and g_h are defined in (4) and (12). From (13) and (22), $f_E(m_h, m_l) < f_E^{c1}$ is always satisfied if $0 < \theta < 1$. From (10) and (21), we easily find that m_h^A and m_h^T are monotonically decreasing in e and $\partial m_h^A/\partial e < \partial m_h^T/\partial e < 0$ for any e.[10] Thus, if $f_E < f_E^{c1}$, $m_h^T \geq m_h^A$ for any e. This

[10] Differentiating m_h^A and m_h^T with respect to e, we have:

$$\frac{\partial m_h^A}{\partial e} = -\frac{\alpha\theta L}{\sigma e^2}.$$

$$\frac{\partial m_h^T}{\partial e} = -\frac{\alpha\theta L}{\sigma(e+\theta n f_E)^2}.$$

Simple calculation leads to $\partial m_h^A/\partial e < \partial m_h^T/\partial e < 0$.

results is summarized in the following proposition and Figure 3:

Proposition 1 *If $f_E < f_E^{c1}$, trade openness enhances the incentives of firms for their R&D investments if and only if $\lambda_h^{autarky} < e$.*

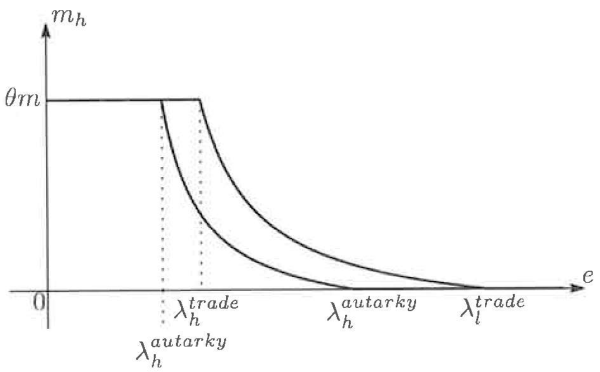

Figure 3 The effect of openness of trade in the case that the export incurs low fixed costs

Low productivity equilibrium We provide the necessary and the sufficient condition that trade openness always diminishes the R&D incentives. To show the condition, we compare λ_l^{trade} in (18) with $\lambda_l^{autarky}$ in (7). The difference between them is:

$$\lambda_l^{trade} - \lambda_l^{autarky} = \frac{\theta\alpha L[(1+nT^{1-\sigma})c_h^{1-\sigma} - c_l^{1-\sigma}]}{\sigma m c_l^{1-\sigma}} - \theta n f_E - \frac{\theta\alpha L(c_h^{1-\sigma} - c_l^{1-\sigma})}{\sigma m c_l^{1-\sigma}}. \quad (23)$$

$\lambda_l^{trade} - \lambda_l^{autarky}$ is equal to zero if f_E is equal to (see (13)):

$$f_E^{c2} \equiv \frac{\alpha L T^{1-\sigma} c_h^{1-\sigma}}{\sigma m c_l^{1-\sigma}} = \bar{f}_E(0, m) \quad (24)$$

If $f_E > f_E^{c2} = \bar{f}_E(0, m)$, all firms which succeed in R&D cannot export to foreign countries. However, $\bar{f}_E(0, m)$ is the maximum value of f_E in this setting.[11] There is no f_E such that $f_E > f_E^{c2} = \bar{f}_E(0, m)$. Therefore, we have the following proposition:

Proposition 2 *Under the range of f_E defined in (13), the following inequality always holds: $\lambda_l^{trade} \geq \lambda_l^{autarky}$. That is, trade openness does not always diminishes the incentives of firms for their R&D investments.*

Intermediate equilibrium We consider the rest of the cases: $f_E \in [f_E^{c1}, \bar{f}_E(0, m)]$. We rewrite equations (10) and (21):

$$m_h^A = \theta z^A = \frac{\alpha\theta L}{\sigma e} - \frac{m c_l^{1-\sigma}}{c_h^{1-\sigma} - c_l^{1-\sigma}}. \quad (10')$$

$$m_h^T = \theta z^T = \frac{\alpha\theta L}{\sigma(e + \theta n f_E)} - \frac{m c_l^{1-\sigma}}{(1+nT^{1-\sigma})c_h^{1-\sigma} - c_l^{1-\sigma}}. \quad (21')$$

As mentioned earlier, the following inequalities are satisfied for any e:

$$\frac{\partial m_h^A}{\partial e} < \frac{\partial m_h^T}{\partial e} < 0.$$

If $\lambda_h^{trade} < \lambda_h^{autarky}$, there exists a unique e^* which satisfies $m_h^A = m_h^T$. In this case, when $e \leq (>) e^*$, $m_h^A > (\leq) m_h^T$. In the case where f_E is on the range $[f_E^{c1}, \bar{f}_E(0, m)]$, when e is relatively small (*resp.* large), trade openness diminishes (*resp.* enhances) the R&D incentives (see also Figure 4).

Proposition 3 *In the case that f_E is on the intermediate range $[f_E^{c1}, \bar{f}_E(0, m)]$, openness of trade enhances the R&D incentive of firms if and only if $e^* < e$.*

Using Figure 5, we now summarize the results.

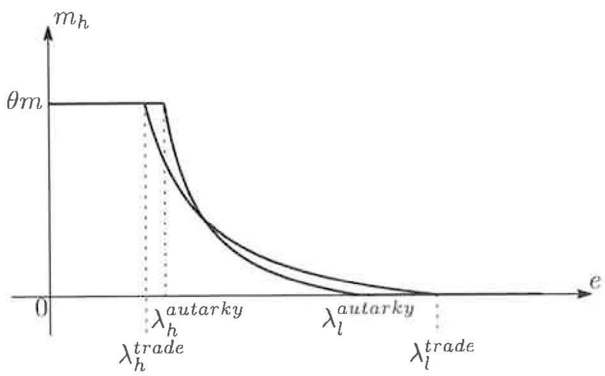

Figure 4 The effect of openness of trade in the case that the export incurs high fixed costs

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[11] In (12), $g_n(m_h, m_l)$ is minimized when $m_h = 0$. Therefore, $\bar{f}_E(m_h, m_l)$ in (13) is maximized when $m_h = 0$.

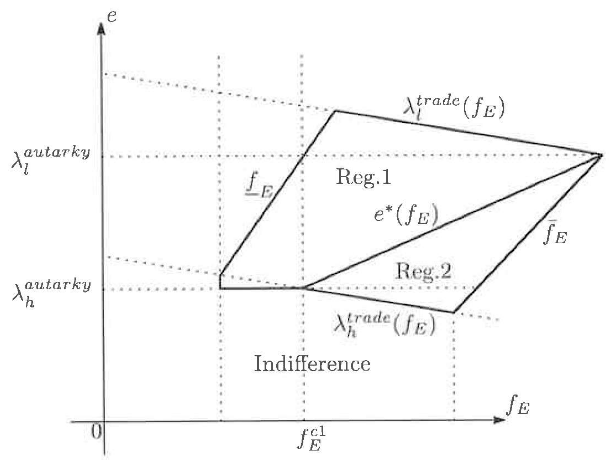

Figure 5　Innovation incentives and trade openness

Reg.1 (*resp*. Reg.2) in Figure 5 provides the parameter values of f_E and e in which trade openness enhances (*resp*. diminishes) the innovation incentives of firms.

This figure shows that if innovation cost has an intermediate value and fixed trade cost has an intermediate and relatively low value, trade raises the firms' innovation incentive. If innovation cost has an intermediate value and fixed trade cost has an intermediate and relatively high value, trade diminishes the incentive of firms. In the other cases, trade dose not influences on firms' innovation incentive. If innovation cost is low, all firms engage in the innovation activities both in autarky and openness of trade, while in the case that innovation cost is high, all firms do not engage in the innovation activities both in autarky and openness of trade. Therefore, if innovation cost is high or low, trade dose not influence on the firms innovation activities. If fixed trade costs is low, firms can export their goods to foreign countries regardless of innovation activities: all firms export their goods. In this case, two countervailing effects of openness of trade, which we discussed above, offset with each other. Then, trade openness has no effect on firms' innovation incentive. If fixed trade cost is high, all firms cannot export their goods. This case is the same to autarky.

If innovation cost has an intermediate value and fixed trade cost also has an intermediate value, firms which succeed innovation can export their goods, while firms which cannot succeed innovation and do not engage in innovation cannot export their goods. In this case, export firms have larger scale than non-export firms, which are presented in the many empirical researches. If innovation cost has an intermediate value and fixed trade cost has an intermediate and relatively low value, the market enlargement effect of trade overwhelms the intensive competition effect of trade, since fixed trade costs is relatively low. Then, in this case, trade openness enhances the innovation incentive of firms. On the other hand, in the case that innovation cost has an intermediate value and fixed trade cost has an intermediate and relatively high value, intensive competition effect overwhelms the market enlargement effect: trade openness decreases the innovation incentive of firms.

To understand the relation between the exogenous variables and the effect of trade openness, equation (21) is useful:

$$m_h^T = \theta z^T = \frac{\alpha\theta L}{\sigma(e+\theta n f_E)} - \frac{m c_l^{1-\sigma}}{(1+nT^{1-\sigma})\, c_h^{1-\sigma} - c_l^{1-\sigma}}. \tag{21''}$$

We first discuss the relation between n and the effect of trade openness. The value of n is directly related to two countervailing effects of trade openness: (1) market enlargement effect, (2) intensive competition effect. On the one hand, as the value of n increases, the market enlargement effect enlarges because a firm which achieves success in its innovation activity gets the opportunity to export its product to n foreign markets (see the second term of equation (21'')). On the other hand, as the value of n increases, the intensive competition effect enlarges because foreign firms which achieves success in their innovation activities enter their foreign markets and the entrances accelerate competition in each market (see the first term of equation (21'')). In this model, the former positive effect dominates the latter one.

We discuss the relation between f_E and the effect of trade openness. The value of f_E is directly related to the intensive competition effect which is negative. As the value of f_E increases, the negative effect enlarges. The significance of f_E depends on several values: e, n, and θ. When e is large, the marginal impact of the increase in f_E is small (see the first term of equation (21'')). The figure reflects the relation between e and f_E. When θ is large, the marginal impact of the increase in f_E is large because the number of firms which achieve success in their innovation increases in each country as the value of θ increases (see the first term of equation (21'')).

We now investigate how the several exogenous parameters influence the relation between trade openness and the innovation activities of firms. To investigate the matter, we define three variables:

$$H_a \equiv \bar{f}_E(m_h, m_l) - e^{*-1}(f_E),$$

$$H_b \equiv \bar{f}_E(m_h, m_l) - \underline{f}_E(m_h, m_l),\ H \equiv \frac{H_a}{H_b}.$$

H_a represents the range of f_E in which trade openness diminishes firms' innovation activities, given e. H_b is the range of f_E in which trade openness has some effects on firms' innovation activities, given e. A large (*resp.* small) H means that the region in which trade openness diminishes the innovation activities of firm is relatively larger (*resp.* smaller) than that in which trade openness enhances the innovation activities. Thus, if a change in one of the exogenous parameters reduces (*resp.* raise) H, the change has a positive (*resp.* negative) trade openness effect on the innovation activities of firm. Some calculations lead to the following results:

$$\frac{\partial H}{\partial m}<0,\ \frac{\partial H}{\partial n}>0,\ \frac{\partial H}{\partial L}>0,\ \frac{\partial H}{\partial \alpha}>0,\ \frac{\partial H}{\partial c_l}>0,$$

$$\frac{\partial H}{\partial c_h}<0,\ \frac{\partial H}{\partial \theta}>0. \tag{25}$$

The inequalities in (25) shows that as the value of m or c_l (*resp.* the value of θ, n, L, or α) increases (*resp.* decreases), trade openness tends to enhance firms' innovation activities.

To discuss the matter, we recall that trade openness has two effects on firms' innovation incentives: market enlargement effect and intensive competition effect.

When c_l(*resp.* c_h) is large (*resp.* small), the benefit of the success in R&D ($c_l - c_h$) is large. Even though each market is autarky, the incentive to innovate is high when $c_l - c_h$ is large. Once those markets are opened, however, the difference between c_l and c_h is not so important because *only* firms succeeding in R&D are major players in each market. Therefore, the market enlargement effect is important when $c_l - c_h$ is small.

When m is large, competition in each market is severe and then the incentive to innovate is low if each market is autarky. Once those markets are opened, a firm succeeding in R&D gets an opportunity to supply in foreign markets. As mentioned earlier, *only* firms succeeding in R&D are major players in each market. Therefore, when m is large, the market enlargement effect is important. We can apply the discussion on the properties of L and α. Those values represent the size of each domestic market. A large L (α) is equivalent to a small m. Therefore, when L (α) is large, the intensive competition effect is important.

When θ is high, many firms succeed in innovation activities and get high productivity. Once each market is opened, the number of firms succeeding in R&D becomes n times. Those firms supply their products to each market as major players. Therefore, when θ is high or n is high, the intensive competition effect is important.

6. Conclusion

This paper constructs a model in which international trade influences on R&D activities and productivity of firms. We show that trade openness influences on firms' R&D activities, if innovation costs and fixed trade costs have intermediate values. In this case, not all firms engage in R&D activities when each market is autarky. Under the case, if a fixed trade cost is relatively high, trade openness diminishes the R&D activities of firms. As the innovation cost decreases, the negative effect of trade openness enlarges. We also show that when the market size in each country is small or the significance of R&D investments is weak or the number of countries is small, trade openness enhances the incentives to engage in R&D activities.

The framework in this paper could be applied to the analysis on the progressive liberalization of the European insurance market in recent years. For many years, EU has gradually deregulated the financial services sector through a series of banking and insurance directives with a view to creating a single European market in financial services. The movement to create the single European market might be consistent with trade openness discussed in this paper (see, for instance, Fuentes *et al*., Cummins, J.D., Rubio-Misas (2006), Fenn *et al*. (2008)). Our results could provide a useful theoretical hypothesis concerning how trade openness affects on the efficiencies of those financial services.

Our model is a static model. We can extend our model to a dynamic model. In addition, there is not any knowledge spillover in our model. Knowledge spillover may influence on the innovation cost. Considering the model with knowledge spillover is a future research. We have assumed that there exist *ex ante* symmetric firms. *Ex ante* heterogeneity of firms could give an interesting insight to this research topic. These are considerable future researches.

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