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## Agglomeration, Segmentation and Technology Choice

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# Agglomeration, Segmentation and Technology Choice

Yukiko Sawada\*

## Abstract

This paper presents a simple two country model in which firms in manufacturing sector can choose a technology level (high or low). I show how trade cost and/or productivity level affect technology choice by firms in each country where production circumstance differs. In particular, if the productivity level of high technology is medium, firms locating in country employ high technology and other firms in developing country do low technology. In this case, improving the productivity of high technology makes the welfare level of a consumer in low technology country decrease.

JEL Classification: : F10; F12

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# 1 Introduction

To capture the characteristic of market structure, economic performance, welfare level of the country in international trade theory, we often have discussed the difference of production technology. We also have well known such a topic in traditional trade theory, as a "comparative advantage" which was supposed by David Ricard in 1817; the difference of production technology they have generates the comparative advantage, becoming the source of international trading. Production technologies have highly evolved over a long periods of time, and firms can adopt the high technology to produce goods efficiently today. As well as we can consume goods from all over the world, we can share many ideas and knowledge immediately and firms all over the world also can share upgraded technologies through technology trading. Though most of high technology was developed in the leading industrialized countries like the U.S. or European nations, it has been used in many other countries till this day. Some developing countries have been remarkably developed in the way of innovating a new method from leading industrialized countries. For example in the postwar iron industry in Japan have been remarkably developed by adopting foreign new technologies. On the other hand, all the countries couldn't have succeeded to adopt more productive technologies. Hence, there exists the technology gap in many countries even if new highly productive technology is developed and they have choice of adopting it.

One of the main reasons for existing such a technology gap is that production circumstance differs among countries. When we try to adopt a new technology in the country where it isn't developed, we tend to bear more costs than developed country to adapt it to. In many developing countries gigantic infrastructure of society such as financial organizations, communication and major railways is poor, Even if technology innovation arises and new technology is available to them, they might be unable to adopt it because of unprofitableness.

Do all the countries receive the benefit of improving technology? We must consider the effects of advance in technology on the economy expanding the international trade.

This paper analyzes under what condition technology gap among countries emerges and how it affects the welfare levels of consumers in each country. We incorporate technology choice by firms in simple trade model in which there are two sector, two country and one production factor and firms in manufacturing sector compete via monopolistic competition. We can show how trade cost and productivity level of technology determine firm's agglomeration pattern and technology choice by firms in the equilibrium. Furthermore, we analyze how exogenous change of these parameters affects on welfare levels of consumers in each country and discuss the implication Firms can choose a production technology from two types of technology: high technology or low technology High technology means productivity of producing goods is high. Hence, productivity of high technology is higher than low technology whereas high technology is more costly than low ones. In other words, a firm must pay a higher fixed cost when it adopts high technology. Moreover, I assume two kinds of asymmetry properties about countries: market size and entry cost. Former is that

one country is large, and the other one is small. The latter assumption is more important: High technology employed in large country is made available at a lower cost than same one in small country. It is found that in equilibrium firms locating in developed country employ higher technology and other firms in developing country do lower technology. In this case I also find that improving the productivity of higher technology doesn't always improve consumer's welfare in both countries: an increase in productivity always decreases the welfare level of in developing countries while it increases that of developed countries.

My model is based on Helpman and Krugman(1985) in which they assume that all firms adopt the same technology. I incorporate technology choice in their model.

There are many theoretical literature focused on production technology in trade theory.<sup>1</sup>

In terms of technology choice in new trade theory, Yeaple(2005) have the similarity to my model<sup>2</sup>. In his paper, firms choose both their individual production technologies and types of workers and he explains what gives rise to the difference between exporter and non-exporter. A distinguishing feature of his model is the complementarity between the technology and skills of labor. Hence, technology choices of firms change by the distribution of labor's skill. In equilibrium, the interaction between the characteristics of competing technologies with trade costs and with heterogeneous labor gives rise to firm heterogeneity. However, in my model, we try to analyze technology gap between countries while Yeaple's model cannot discuss. We can also discuss the effect of market size. The key difference between the present model and Yeaple's model is that the effects of difference in fixed cost between countries. Although in his paper entry cost is identical, in my model there exists a difference in ease of entry because entry regulations, financial supports or absorbing costs to new technology varies between countries. By assuming such a difference, I can focus on the relationship between adopted technology and production environment and get more implications about economic performance..

The reminder of the paper is organized into four sections. In the first, I present model. In the second I characterize the model's equilibrium. In the third, I analyze the effect of a reduction in international trading cost and an increase in productivity on the welfare level of consumers, and derive the implication of technology innovation and trade liberalization. The final section concludes.

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<sup>1</sup>Melitz (2003) model in which each firm faces uncertain productivity determined by its distribution provides a rationale for the widely observed phenomenon that only high productivity firms export to foreign markets and then, many subsequent researches have been accumulated: Baldwin and Okubo(2006), Bernard et al. (2003), Bernard et al. (2003, 2007), Melitz and Ottaviano (2008). They assume that technology gap between firms is given by the distribution function.

<sup>2</sup>Bustos(2011) also incorporate technology choice in trade model with heterogeneous firms. Same as Yeaple's model, she represents the change in industrial structure in the country rather than between countries

## 2 The model

There are two countries, 1 and 2. Variables referring to the country 1 have the subscript 1, and those referring to the country 2, 2. Each country is endowed with a fixed amount of labor,  $L_1$  and  $L_2$ , respectively.

I assume that agents in both countries obtain utility from the consumption of homogeneous agricultural goods and differentiated manufactured goods. Labor can be used to produce agricultural goods and differentiated manufactured goods. While labor can be mobile between sectors in the same country, it cannot be mobile between the different countries.

### 2.1 Demand

The utility function of the agents in countries  $i$  ( $i = 1, 2$ ) is given by

$$U_i = A_i + \mu \ln M_i, \quad (1)$$

where

$$M_i = \left[ \int_0^{n_i} m_{ii}(j)^{\frac{\sigma-1}{\sigma}} dj + \int_0^{n_{i'}} m_{i'i}(j')^{\frac{\sigma-1}{\sigma}} dj' \right]^{\frac{\sigma}{\sigma-1}}, \sigma > 1, \quad i, i' \in \{1, 2\}, \quad i \neq i'. \quad (2)$$

Here,  $A_i$  is the consumption of agricultural goods in country  $i$ ,  $M_i$  is the consumption of the composite of manufactured goods in country  $i$ , and  $\mu$  is a positive parameter.  $m_{ii'}(j)$  denotes the consumption of manufactured variety  $j$  in country  $i'$  produced in country  $i$ .  $n_i$  is the number of varieties produced by a firm in country  $i$ .  $\sigma$  represents the elasticity of substitution among differentiated goods.

Their budget constraint becomes

$$y_i \geq \sum_{i'=1}^2 \int_0^{n_{i'}} p_{i'i}(j) m_{i'i}(j) dj + A_i, \quad (3)$$

where  $p_{i'i}(j)$  denotes the price of the manufactured variety  $j$  in country  $i'$  produced in country  $i$  and  $y_i$  denotes the income level in country  $i$ . I take homogeneous agricultural goods as the numeraire. Then, I can obtain the following demand functions, as follows:

$$m_{i'i} = \frac{p_{i'i}(j)^{-\sigma}}{P_i^{1-\sigma}} \mu, \quad (4)$$

$$A_i = y_i - \mu, \quad (5)$$

$$P_i = \left[ \sum_{i'=1}^2 \int_0^{n_{i'}} p_{i'i}(j)^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}}, \quad (6)$$

where  $P_i$  is called the ‘price index’ in country  $i$ .

## 2.2 Production

### 2.2.1 Agriculture sector

Here, we describe the production structure of the agricultural sector. The agricultural good market is perfectly competitive. I assume that in both countries, one unit of agricultural goods is produced with one unit of labor and that the international trade of homogeneous goods incurs no trade costs. Therefore, the equilibrium wages in the two countries are both  $w_1 = w_2 = 1$ . Assuming that income is comprised of a wage,  $y_i = w_i = 1$ .

### 2.2.2 Manufacturing sector and technology choice

In the manufacturing sector, manufacturing firms operate under the Dixit-Stiglitz (1977) type monopolistic competition. Each firm produces differentiated goods, and each variety is produced by one firm. There are two technologies for producing each variety of M-goods. The amount of goods a worker can produce is given by  $\phi_z$  where  $z$  is an index to indicate which of the two technologies is using. Let  $z \in \{H, L\}$ , where  $z = H$  refers high tech technology for producing M, and  $z = L$  refers low tech technology for producing M. Since high technology is more productive than low one, I assume  $a_H > a_L = 1$ .

To produce with technology  $z \in \{H, L\}$  in country  $i$ , a firm in country  $i$  is required to pay a fixed cost  $f_i^z$ . This fixed cost depends on which technology the firm employs and which country it locates in: We assume

$$f_1^L = f_2^L \equiv f_L, \quad (7)$$

$$f_i^H > f^L \quad (8)$$

$$f_2^H > f_1^H. \quad (9)$$

First assumption means that firms in both countries incur the same level of fixed cost if they adopt the technology  $L$  for taking it as an already-known technology or old technology. The second one means that new technology or high technology is costly. We must bear the huge cost to adopt a new technology or high technology because of large equipment investment, payment of license fee etc. Moreover, we consider this cost tend to vary from country to country for a cultural or political difference: support system by the government like a subsidy to adopt a high technology and the infrastructure building. We describe it in the third one. In other words, we assume that country 1 has an advantage in introducing technology  $H$  over country 2. This is a key assumption to our model. This assumption is a reflection of a real economy in which the degree of entry barrier differs from one country to another.

Potential firms can freely enter production activities as long as the profits are positive and can choose to employ the more profitable technology. Under this production structure, each manufacturing firm sets the following constant markup price:

$$p_{11}^z = p_{22}^z = \frac{\sigma}{(\sigma - 1)a_z}. \quad (10)$$

where  $p_{ii}^z$  denotes the price of the manufactured good in country  $i$  produced in country  $i$  by technology  $z$ . The international trade of manufactured goods incurs ‘iceberg’-type trade costs. If a firm in one country sends one unit of its good to the other country, it must dispatch  $\tau$  units of the good.  $\tau - 1 > 0$  represents the trade costs. Thus, the price of imported manufactured goods in country  $i$  becomes  $\tau p_{i'}$  and  $i \neq i'$ . The price index in country  $i$  can be written as,

$$P_i = \frac{\sigma}{\sigma - 1} [\alpha n_i^H + n_i^L + \varphi(\alpha n_{i'}^H + n_{i'}^L)]^{\frac{1}{1-\sigma}}, \quad i, i' \in \{1, 2\}, \quad i \neq i', \quad (11)$$

where  $\varphi \equiv \tau^{1-\sigma}$  and  $\alpha \equiv a_H^{\sigma-1}$ .  $\varphi$  represents the freeness of trade.  $\varphi = 0$  corresponds to the case of autarky, whereas  $\varphi = 1$  implies free trade. In other words, increasing  $\varphi$  means trade liberalization.  $\alpha$  represents the gap of productivity between technologies and  $\alpha \geq 1$ . From Eq. (4) to (10), profits of a firm in country 1 and 2 can be expressed as follows:

$$\pi_i^H = \frac{\mu\sigma^{-\sigma}\alpha}{(\sigma - 1)^{1-\sigma}} (L_i P_i^{\sigma-1} + \varphi L_{i'} P_{i'}^{\sigma-1}) - f_i^H \quad (12)$$

$$\pi_i^L = \frac{\mu\sigma^{-\sigma}}{(\sigma - 1)^{1-\sigma}} (L_i P_i^{\sigma-1} + \varphi L_{i'} P_{i'}^{\sigma-1}) - f^L. \quad (13)$$

### 3 Equilibrium

Since firms in the same country face the same profit, they must choose the same technology. Which technology they choose depends on the fixed cost and productivity of high technology. If  $\alpha < \frac{f_i^H}{f^L}$ , all firms in country  $i$  adopt technology L. If  $\frac{f_i^H}{f^L} < \alpha$ , they do technology H. Assuming that in equilibrium there are firms that locate in country 1 and other firms that locate in country 2, then I can obtain the following lemma:

**Lemma 1** 1. If  $\alpha < \frac{f_1^H}{f^L}$ , then all firms in country 1 and country 2 choose technology L.

2. If  $\frac{f_1^H}{f^L} < \alpha < \frac{f_2^H}{f^L}$ , firms in country 1 adopt technology H whereas firms in country 2 do technology L.

3. If  $\frac{f_2^H}{f^L} < \alpha$ , then all firms choose technology H.

When  $\alpha$  is too low ( $\frac{f_1^H}{f^L} > \alpha$ ), all firms choose technology L. It's consistent with results of Helpman and Krugman(1985). On the other hand, when  $\alpha$  is moderate firms in country 1 can only adopt technology H, firms in country 1 adopt technology H whereas firms in country 2 adopt technology L. There exists a technology gap between countries in this case. When  $\alpha$  is higher, all firms in not only country 1 but also country 2 can choose technology H since adopting technology H is profitable in both countries.

Here, I derive the number of manufactured goods when  $\frac{f^H}{f^L} < \alpha < \frac{f_2^H}{f_1^L}$ <sup>3</sup>. Firstly, I focus on the equilibrium that the manufacturing firms locate in both countries, that is

$$\pi_1^H = \pi_2^L. \quad (14)$$

From Eq. (12), (13) and (14), the relationship between  $n_1^H$  and  $n_2^L$  is given by

$$n_1^H = \frac{\mu[\varphi(L_1 + L_2)f_1^H - (L_1 + \varphi^2 L_2)f^L \alpha]}{\alpha[\varphi(L_1 + L_2)f^L \alpha - (\varphi^2 L_1 + L_2)f_1^H]} n_2^L. \quad (15)$$

The numerator of Eq. (15) is always negative, but the denominator of that depends on  $\varphi$ . Therefore, the equilibrium must be satisfied as follows:

$$\varphi(L_1 + L_2)f^L \alpha < (\varphi^2 L_1 + L_2)f_1^H. \quad (16)$$

If  $\pi_1^H > \pi_2^L$ , then the firms agglomerate in country 1. When  $\varphi$  is too high, this full agglomeration arises. Let  $\varphi(\alpha)$  which satisfies

$$\varphi(L_1 + L_2)f^L a_H^{\sigma-1} = (\varphi^2 L_1 + L_2)f_1^H. \quad (17)$$

If  $\varphi < \varphi(\alpha)$ , then in equilibrium, the manufacturing firms locate in both countries. When  $\varphi > \varphi(\alpha)$ , all of manufacturing firms locate in country 1. In other words, full agglomeration tends to take place when trade cost is low. From Eq. (15) and free-entry condition of  $\pi_1 = 0$ , I can obtain the number of manufacturing firms locating in country 2 is given by

$$n_2^L = \frac{\mu\alpha[\varphi(L_1 + L_2)f^L \alpha - (\varphi^2 L_1 + L_2)f_1^H]}{\sigma(f^L \alpha - f_1^H \varphi)(f^L \alpha \varphi - f_1^H)}. \quad (18)$$

This is how the following proposition can be obtained:

**Proposition 1** *If  $\frac{f^H}{f^L} < \alpha < \frac{f_2^H}{f_1^L}$ , firms locating in country 1 employ technology H and firms in country 2 employ technology L in equilibrium. If trade liberalization arises and  $\varphi$  is greater than  $\varphi(a_H)$ , then all firms agglomerate in country 1.*

If high technology is less-developed and doesn't have much higher productivity worthing cost in country 2, there exists the technology gap. To obtain the implication of this model clearly, we consider the case of  $L_1 > L_2$ .<sup>4</sup> We consider the effects of change in productivity level of high technology on the number of manufacturing firms. Differentiating  $n_1^H$  and  $n_2^L$  with respect to  $\varphi$ , I can get the following equations:

$$\frac{\partial \ln n_1^H}{\partial \alpha} = f^L \varphi \left[ \frac{(\varphi^2 - 1)L_2 f_1^H}{[\varphi(L_1 + L_2)f_1^H - (L_1 + \varphi^2 L_2)f^L \alpha][f^L \alpha - f_1^H \varphi]} - \frac{\varphi}{f^L a_H^{\sigma-1} \varphi - f_1^H} \right] > 0$$

,

$$\frac{\partial \ln n_2^L}{\partial \alpha} = \frac{\varphi(L_1 + L_2)f^L}{\varphi(L_1 + L_2)f^L \alpha - (\varphi^2 L_1 + L_2)f_1^H} + \frac{\varphi(f^L \alpha + f_1^H)(f^L \alpha - f_1^H)}{\alpha(f_1^H - f^L \alpha \varphi)(f^L \alpha - f_1^H \varphi)} < 0.$$

Therefore, the following lemma can be obtained:

<sup>3</sup>I can similarly derive in other cases. See Appendix B

<sup>4</sup>We can discuss the other cases,  $L_1 \leq L_2$  similarly.



Figure 1: The patterns of agglomeration and technology choice

**Lemma 2** *Productivity improvement of technology H increases the number of manufacturing firms locating in country 1 which adopt high technology but decreases that of manufacturing firms in country 2 which adopt low one.*

Intuitively, technology improvement increases the profit of firms locating in country 1 because of cutting down a marginal cost and then some manufacturing firms entry to the large country.

This figure illustrates the patterns of agglomeration and technology choice. Thus far, we analyzed the case of  $\frac{f_1^H}{f^L} < \alpha < \frac{f_2^H}{f^L}$ . We can do in the other cases in similar way. Which technology firms in each country adopts and whether full agglomeration arises or not depend on the combination of  $\varphi$  and *alpha*. This can be summarized as in figure 1.ice in equilibrium. Vertical axis represents productivity level  $\alpha$  of technology H ( $\alpha > 1$ ). Horizontal axis represents the freeness of trade,  $\varphi$  ( $0 < \varphi < 1$ ). It can be observed how firms modify location and technology choice with each change of  $\alpha$  and/or  $\varphi$ . If  $\alpha$  and  $\varphi$  lie in the domain of (I) in Fig. 1, firm in country 1 employ technology H and firm in country 2 do technology H. If  $\alpha$  and  $\varphi$  lie in the domain of (II), firm in country 1 employ technology H and firm in country 2 do technology L. If  $\alpha$  and  $T$  lie in the domain of (III), firm in country 1 employ technology L and firm in country 2 do technology L. If  $\alpha$  and  $T$  lie in the domain of (IV), all firms employ technology H and agglomerate in country 1. If  $\alpha$  and  $T$  lie in the domain of (V), all firms employ technology L and agglomerate in country 1.

## 4 Welfare Analysis

In this section, I examine the welfare effects of trade liberalization and technology innovation. Technology innovation means improving the productivity of H technology firm which can produce the M goods at lower cost (increasing  $\alpha$ ). First, substituting Eq.(4) to (1) I can get the following indirect utility functions in both countries,

$$V_1 = 1 - \mu + \mu \left[ \ln \frac{\mu(\sigma - 1)}{\sigma} \right] + \frac{1}{\sigma - 1} \ln \frac{\mu\alpha(1 - \varphi^2)L_1}{\sigma(f_1^H - f^L\alpha\varphi)} \quad (19)$$

$$V_2 = 1 - \mu + \mu \left[ \ln \frac{\mu(\sigma - 1)}{\sigma} \right] + \frac{1}{\sigma - 1} \ln \frac{\mu\alpha(1 - \varphi^2)L_2}{\sigma(f^L\alpha - f_1^H\varphi)}. \quad (20)$$

### 4.1 The effect of trade liberalization

Trade liberalization means falling trade cost  $\tau$ (increasing  $\varphi$ ). By differentiating each equation with respect to  $\varphi$ , I can obtain the following proposition (See appendix C for the proof).

**Proposition 2** *Falling trade cost increases the welfare levels in both countries and widens the welfare gap between countries*

Intuitively, falling trade cost decreases the prices of all the imported M-goods, which increases the demands for them while domestic goods remain unchanged. Hence consumption of all differentiated goods increases and welfare level of all consumer improve.

### 4.2 The effect of technology innovation

Differentiating Eq. (19), (20) with respect to  $\alpha$ , I can obtain the following proposition (See Appendix D for the proof).

**Proposition 3** *Assume that  $\frac{f_1^H}{f^L} < \alpha < \frac{f_2^H}{f^L}$ <sup>5</sup>.*

(A). *The welfare of a consumer in country 1 is increasing with  $\alpha$ .*

(B). *The welfare of a consumer in country 2 is decreasing with  $\alpha$*

To illustrate implications, I present the relationship between productivity and the indirect utility as in Fig. 2. As Fig. 2-(a) shows, improving productivity of technology H always increases the welfare level of consumers in country 1. But Fig. 2-(b) shows it decreases that of consumers in country 2 when productivity level of technology H is medium. In this case, The welfare in country 2 is always lower than the case when productivity is low. Why does it happen? The reason is because increasing in  $\alpha$  has two effects: positive effect and negative effect. Positive effect is to increasing total demand of manufacturing goods produced in country 1. Negative effect is to decrease that of manufacturing goods produced in country 2. For a consumer in country 2, negative effect is greater than positive one. Additionally there are two

<sup>5</sup>In this section I focus on this case. For the other cases, see Appendix E.

Figure 2: relationship between welfare and productivity

highly important things. In this case, the welfare in country 2 is always lower than the case when productivity is low ( $\alpha < \frac{f_1^H}{f^L}$ ). Even if productivity becomes so high that firms in country 2 can employ technology H and  $\alpha$  is little over  $\frac{f_2^H}{f^L}$ , then the welfare in country 2 is still lower. This implies that technology innovation works better for a consumer in large country, but if technology level is at an early age, a bit improvement of high technology makes those who in small country poor.

## 5 Concluding remarks

In this paper, I show the relationship between productivity of technology and technology (or location) choice, and examine how technology innovation affects technology choice of firms and welfare levels of consumers. I develop the simple two countries trade model with technology choice. Firms face two types of decisions: technology and locating choice. They can choose a technology from two types technology and decide which country they locate. Technology employed by firms is high or low technology. Productivity of high technology is higher than low technology and high technology is more costly than low ones. Moreover, I assume that there are large country and small country and that high technology employed in large country is made available at a lower cost than same one in small country. The latter of my assumption means that large country has an advantage in adopting high technology.

Then it is found that in equilibrium firms locating in developed country employ higher technology and other firms in developing country do lower technology. I also find that improving the productivity of higher technology doesn't always improve a consumer's welfare in both countries. In particular, when productivity level of

high technology is medium, the welfare of a consumer in small country decreases with a small technological improvement. Additionally, I consider the effects of trade liberalization on location choice and welfare levels.

Finally, I comment on a future work. In this paper, I analyze the static trade model. In the next place, I will extend this model to a dynamic model in which productivity of technology varies through time. In my paper, the effect of investment to R&D is not considered. It should be investigated that extension.

## Appendix

### A The proof of Lemma 1

Assuming that  $\pi_1^H = 0$ , the following equation is satisfied:

$$\frac{\mu\sigma^{\sigma-1}}{\sigma-1}(L_1P_1^{\sigma-1} + \varphi L_2P_2^{\sigma-1})\alpha = f_1^H. \quad (21)$$

Substituting (26), I can rewrite Eq. (13) as follows:

$$\pi_1^L = \frac{f_1^H}{\alpha} - f^L. \quad (22)$$

If  $\alpha < \frac{f_1^H}{f^L}$ ,  $\pi_1^L > 0$ , which induces firms to employ technology L. Hence, increasing  $n_1^L$ , it's a contradiction. Therefore,  $\frac{f_1^H}{f^L} < \alpha$  must be satisfied. Next, assuming that  $\pi_1^L = 0$ , the following equation is satisfied:

$$\frac{\mu\sigma^{\sigma-1}}{\sigma-1}(L_1P_1^{\sigma-1} + \varphi L_2P_2^{\sigma-1}) = f^L. \quad (23)$$

Substituting (23), I can rewrite Eq.(12) as follows:

$$\pi_1^H = f^L\alpha - f_1^H. \quad (24)$$

Reprising the same argument, I can show that  $\alpha < \frac{f_1^H}{f^L}$  must be satisfied. I can show similarly on country 2 in the same way as above.

### B The cases other than $\frac{f_1^H}{f^L} < \alpha < \frac{f_2^H}{f^L}$

When  $\alpha < \frac{f_1^H}{f^L}$  holds, any firm employs technology L because the productivity of technology is not high enough to recover the fixed cost of technology H. Therefore, this case is consistent with Helpman and Krugman(1985). When  $\frac{f_2^H}{f^L} < \alpha$  holds, any firm employs technology H because the productivity of technology H is high enough to recover its fixed cost. If  $\pi_1^H > \pi_2^H$ ,  $n_1^H > 0$  and  $n_2^H = 0$  in equilibrium. From Eq. (12),

$$n_1^H = \frac{\mu}{\sigma f_1^H}(L_1 + L_2)$$

holds. Substituting it to Eq. (13), T must satisfy following equation:

$$\pi_2^H = \frac{(\varphi^2 L_1 + L_2)f_1^H - \varphi(L_1 + L_2)f_2^H}{\varphi(L_1 + L_2)} < 0. \quad (25)$$

Let  $\bar{\varphi}$  satisfy LHS of Eq. (25) are equal to zero. When  $\varphi > \bar{\varphi}$ ,  $n_1^H > 0$  and  $n_2^H = 0$  is the equilibrium. Hence, I assume that  $\varphi < \bar{\varphi}$ . From free entry conditions, I consider the following equations:

$$\pi_1^H = \pi_2^H = 0.$$

The relationship between  $n_1^H$  and  $n_2^H$  is given by

$$n_1^H = \frac{\varphi(L_1 + L_2)f_1^H - (L_1 + \varphi^2 L_2)f_2^H}{\varphi(L_1 + L_2)f_2^H - (\varphi^2 L_1 + L_2)f_1^H} n_2^H. \quad (26)$$

Then, substituting (26) into (??), I can obtain the number of manufacturing firms locating in country1 and country 2 is given by

$$n_1^H = \frac{\mu\varphi(L_1 + L_2)f_1^H - (L_1 + \varphi^2 L_2)f_2^H}{\sigma(f_2^H - f_1^H\varphi)(f_2^H\varphi - f_1^H)} \quad (27)$$

$$n_2^H = \frac{\mu\varphi(L_1 + L_2)f_2^H - (\varphi^2 L_1 + L_2)f_1^H}{\sigma(f_2^H - f_1^H\varphi)(f_2^H\varphi - f_1^H)}. \quad (28)$$

In this case, The number of firm is independent from  $a$ .

## C The proof of Proposition 2

Differentiating Eq. (19) and (20) with respect to  $\tau$ , we can obtain the following equations:

$$\frac{\partial V_1}{\partial \varphi} = \frac{\mu[(\varphi^2 + 1)f^L\alpha - 2\varphi f_1^H]}{(\sigma - 1)(1 - \varphi^2)(f_1^H - f^L\Phi T)} > 0$$

$$\frac{\partial V_2}{\partial \varphi} = \frac{\mu[(\varphi^2 + 1)f_1^H - 2\varphi f^L\alpha]}{(\sigma - 1)(1 - \varphi^2)(f^L\alpha - f_1^H\varphi)} > 0$$

. Second equation is formed because in equilibrium

$$\alpha < \frac{(\varphi^2 + 1)f_1^H}{2\varphi f^L}$$

must be satisfied.

## D The proof of Proposition 3

Differentiating Eq. (19) and (20) with respect to  $a$ , I can obtain the following equation:

$$\frac{\partial V_1}{\partial \alpha} = \frac{\mu}{\sigma - 1} \left[ \alpha^{-1} + \frac{f^L \varphi}{f_1^H - f^L \alpha \varphi} \right] > 0 \quad (29)$$

$$\frac{\partial V_2}{\partial \alpha} = \frac{-\mu f_1^H \varphi}{\alpha (f^L \alpha - f_1^H \varphi)} < 0 \quad (30)$$

because  $\frac{f_1^H}{f^L} < \alpha < \frac{f_2^H}{f^L}$  and (16) hold.

## E The derivation of Figure. 2

When  $\alpha < \frac{f_1^H}{f^L}$  holds, all firms employ L technology. Then, indirect utility is obtained as follows:

$$V_1 = 1 - \mu + \mu \left[ \ln \frac{\mu(\sigma - 1)}{\sigma} + \frac{1}{\sigma - 1} \ln \frac{\mu(1 + \varphi)L_1}{\sigma f^L} \right], \quad (31)$$

$$V_2 = 1 - \mu + \mu \left[ \ln \frac{\mu(\sigma - 1)}{\sigma} + \frac{1}{\sigma - 1} \ln \frac{\mu(1 + \varphi)L_2}{\sigma f^L} \right]. \quad (32)$$

This implies welfare level is independent from  $\alpha$  because no firm employ H technology. When  $\frac{f_1^H}{f^L} < \alpha < \frac{f_2^H}{f^L}$ , firms locating in country 1 employ H technology and firms locating in country 2 employ L technology. Then, indirect utility is obtained as follows:

$$V_1 = 1 - \mu + \mu \left[ \ln \frac{\mu(\sigma - 1)}{\sigma} + \frac{1}{\sigma - 1} \ln \frac{\mu(1 - \varphi^2)L_1 \alpha}{\sigma (f_1^H - f_2^H \varphi)} \right], \quad (33)$$

$$V_2 = 1 - \mu + \mu \left[ \ln \frac{\mu(\sigma - 1)}{\sigma} + \frac{1}{\sigma - 1} \ln \frac{\mu(1 - \varphi^2)L_2 \alpha}{\sigma (f_2^H - f_1^H \varphi)} \right]. \quad (34)$$

Considering the effect of increase in  $a$ , I derive equations as follows:

$$\frac{\partial V_1}{\partial \alpha} = \frac{\partial V_2}{\partial \alpha} = \mu \alpha^{-1} > 0, \quad (35)$$

$$\frac{\partial^2 V_1}{\partial \alpha^2} = \frac{\partial^2 V_2}{\partial \alpha^2} = -\mu \alpha^{-2} < 0. \quad (36)$$

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