Stay or Leave?: Choice of Plant Location with Cost Heterogeneity*

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Abstract

In a two-country model, we examine location choices by two domestic firms when they serve only domestic market and their cost structures are different. Whether the firm that has more incentive to undertake foreign direct investment is more efficient or less efficient than the other depends on the difference in their marginal costs and the presence of fixed costs. We may have multiple equilibria. A small change in trade costs may drastically change plant locations. Moreover, a decrease in trade costs may reduce domestic welfare.

Keywords: foreign direct investment; heterogeneous firms; location choices

JEL Classification: F12, F21, F23

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1 Introduction

Foreign direct investment (FDI) has been growing rapidly. In particular, the world flow of FDI has dramatically increased in the last decade. Although there are a number of reasons for FDI, a typical one is low production costs in the host country. Many firms shift their production facilities to developing countries such as China because of low wages. Recently, China has attracted huge amount of FDI from developed countries and become the "world's factory". When FDI is made in developing countries due to low wages, the main purpose of FDI is usually not to serve the host market but to export products to other markets including the source country, because the host market is not very attractive due to the low income level.[1] For example, a number of Japanese firms undertake FDI in China and ASEAN countries to serve the Japanese market.[2]

It is observed in many industries that some firms undertake FDI while some others stay at home. An interesting question is why this happens. This paper tackles this question. Specifically, we pay our attention to the inter-firm cost asymmetry. We construct a simple oligopoly model and examine how cost heterogeneity affects firms' location choices. In our model, there are two countries (domestic and foreign) and two domestic firms whose marginal costs (MCs) are different. The two firms choose their production locations to serve the domestic market. We find that a more efficient firm is more likely to undertake FDI than a less efficient firm when the cost difference is larger in the foreign production than in the domestic production. When the cost difference is smaller in the foreign production, on the other hand, which firm is more likely to undertake FDI depends on some other factors such as FCs.

There are many studies which analyze location choices of multinational firms (MNFs): the choice between exports and FDI (local production) and the choice between domestic production and FDI.[3] However, the cost asymmetry among firms with the same nationality has been paid little attention.[4] To our best knowledge, location choices among heterogeneous firms with the same nationality have not been analyzed.[5]

Qiu and Tao (2001) examines the choice between FDI and exports by two heterogeneous firms. In their paper, fixed costs (FCs) are assumed away and heterogeneity stems only from different MCs. Their main focus is on the relationship between local content requirement (LCR) and location choice. They show that the less efficient firm undertakes FDI if two firms are located in different countries. Using a monopolistic competition model, Helpman et al. (2004) show a

[1] When products are exported to the source country, it is called vertical FDI. It is also sometimes called "reverse imports" (from the viewpoint of the source country). When products are exported to countries other than the source country, it is called export-platform FDI.

[2] We should note that the Chinese market has been getting more attractive for foreign firms because of rapid economic growth and a huge population.

[3] For recent studies of MNFs, see Markusen (2002) and Barba Navaretti and Venables (2004).

[4] A typical model assumes a single firm in each country. See, for example, Dei (1990) and Horstmann and Markusen (1992). In their models, firms serve both domestic and foreign markets.

[5] Assuming two identical domestic firms (potential MNFs), Yomogida (2004) considers the choice between FDI and domestic production. He shows the possibility of socially undesirable FDI.

reason why exporting firms and MNFs coexist.[6] In their model, cost heterogeneity also plays a crucial role.

Ishikawa and Miyagiwa (2005) extends our static analysis to a dynamic framework. They specifically investigate the relationship between the inter-firm cost asymmetry and the timing of international outsourcing or FDI. In particular, they show that a more efficient firm does not always undertake FDI before a less efficient one.

Section 2 presents the basic model. We explain our model and the effect of trade-cost reduction on firms' profits in different regimes. We analyze the choice of plant locations without plant-specific FCs in Section 3 and that with plant-specific FCs in Section 4. Section 5 concludes the paper.

2 Basic Model

We consider a duopoly model where there are two countries (domestic and foreign) and two domestic firms (firms 1 and 2). Both firms produce a homogeneous good in either domestic country or foreign country and serve only domestic market.[7] The model involves two stages of decision. In stage 1, both firms simultaneously choose their plant locations.[8] The plant locations are determined by Nash equilibrium. In stage 2, the firms compete in quantities with Cournot conjectures. The game is solved by backward induction.

The inverse demand function is given by

$$P = P(X); \quad P' < 0, \tag{1}$$

where X and P are, respectively, the demand and consumer price. We define the elasticity of the slope of the inverse demand function for the following analysis:

$$\epsilon(X) \equiv -\frac{XP''(X)}{P'(X)}.$$

The (inverse) demand curve is concave if $\epsilon(X) \leq 0$ and convex if $\epsilon(X) \geq 0$. In the following analysis, we assume $\epsilon(X) < 1$, which implies that goods produced by two firms are strategic substitutes (i.e., $P' + P''x_i < 0$ where x_i is the output of firm i $(i = 1, 2)$).[9]

The profits of firm i $(i = 1, 2)$ are given by

$$\Pi_i(x_i; t) = (P(X) - t)x_i - C_i(x_i), \tag{2}$$

where t is a specific trade cost such as transport costs and $C_i(\cdot)$ is the cost function. The firms incur the trade cost when they produce in the foreign country. The cost function of firm i $(i = 1, 2)$ is given by

[6] Originally, Melitz (2003) considers the coexistence of exporting firms and non-exporting firms.

[7] For example, all goods produced in export processing zones must be exported. We deal with a case where both domestic and foreign markets are served as well as a case where only foreign market is served elsewhere (Ishikawa and Komoriya, 2006).

[8] Ishikawa and Miyagiwa (2005) consider the case of preemption in a dynamic framework.

[9] For details, see Furusawa et al. (2003).

$$C_i(x_i) = \begin{cases} c_i x_i + f_i \\ c_i^* x_i + f_i^* \end{cases}$$

where c_i and f_i are respectively a constant marginal cost (MC) and a plant-specific fixed cost (FC). An asterisk denotes foreign variables or parameters. We assume that firm 1 is more efficient than firm 2 in the sense that $c_1 < c_2$ and $c_1^* < c_2^*$; and that the MC is lower in the foreign country, i.e., $c_i > c_i^*$ for $i = 1, 2$.

The first-order conditions of the profit maximization are $(i = 1, 2)$

$$\frac{\partial \Pi_i}{\partial x_i} = P + P' x_i - (C_i' + t) = 0. \tag{3}$$

The second-order sufficient conditions $(i = 1, 2)$:

$$2P' + P'' x_i = P'(2 - \epsilon \sigma_i) < 0 \tag{4}$$

and

$$|\Omega| = P'(3P' + P''X) = (P')^2(3 - \epsilon) > 0 \tag{5}$$

where $\sigma_i \equiv x_i/X$ and

$$\Omega \equiv \begin{pmatrix} 2P' + P''x_1 & P' + P''x_1 \\ P' + P''x_2 & 2P' + P''x_2 \end{pmatrix}$$

are satisfied with $\epsilon(X) < 1$.

We first examine the effects of a change in t on equilibrium profits. For this, we need to obtain the effects of a change in t on outputs. When firm i produces in the domestic country but firm j produces in the foreign country, we have

$$\begin{pmatrix} \frac{dx_i}{dt} \\ \frac{dx_j}{dt} \end{pmatrix} = \frac{1}{|\Omega|} \begin{pmatrix} 2P' + P''x_j & -(P' + P''x_i) \\ -(P' + P''x_j) & 2P' + P''x_i \end{pmatrix} \begin{pmatrix} 0 \\ 1 \end{pmatrix}.$$

Thus, the effects on outputs are

$$\frac{dx_i}{dt} = -\frac{P' + P''x_i}{|\Omega|} > 0, \quad \frac{dx_j}{dt} = \frac{2P' + P''x_i}{|\Omega|} < 0, \quad \frac{dX}{dt} = \frac{P'}{|\Omega|} < 0. \tag{6}$$

Using the first-order condition and (6), we can obtain

$$\frac{d\Pi_i}{dt} = \frac{P'x_i}{|\Omega|}(2P' + P''x_i) > 0. \tag{7}$$

$$\frac{d\Pi_j}{dt} = -\frac{(P')^2 x_j}{|\Omega|}(4 - \epsilon - \epsilon\sigma_i) < 0. \tag{8}$$

Thus, when t lowers, the profits of firm i decrease and those of firm j increase.

When both firms produce in the foreign country, we have

$$\begin{pmatrix} \frac{dx_1}{dt} \\ \frac{dx_2}{dt} \end{pmatrix} = \frac{1}{|\Omega|} \begin{pmatrix} 2P' + P''x_2 & -(P' + P''x_1) \\ -(P' + P''x_2) & 2P' + P''x_1 \end{pmatrix} \begin{pmatrix} 1 \\ 1 \end{pmatrix}.$$

Thus, the effects on outputs are

$$\frac{dx_1}{dt} = \frac{P' + P''(x_2 - x_1)}{|\Omega|} < 0, \quad \frac{dx_2}{dt} = \frac{P' + P''(x_1 - x_2)}{|\Omega|} < 0, \quad \frac{dX}{dt} = \frac{2P'}{|\Omega|} < 0. \tag{9}$$

Using the first-order condition and (9), we can obtain ($i = 1, 2$)

$$\frac{d\Pi_i}{dt} = -\frac{2P'x_i}{|\Omega|}(P' + P''x_j) < 0. \tag{10}$$

Therefore, when both firms produce in the foreign country, they gain from a lower t.

3 Location Choices without FCs

We examine firms' location choices. As a benchmark, we examine a case where there exist no FCs in this section. Without FCs, the firm's decision does not depend on the other firm's decision. That is, there exist dominant strategies for both firms. Firm i ($i = 1, 2$) produces in the domestic country if and only if

$$\Delta c_i \equiv c_i - c_i^* \leq t.$$

If t is high enough, both firms choose domestic production. If t is low enough, on the other hand, both firms choose foreign production. It is possible that one firm produces in the domestic country while the other firm produces in the foreign country. Whereas firm 1 produces in the domestic country and firm 2 produces in the foreign country if $\Delta c_1 \leq t < \Delta c_2$, firm 1 produces in the foreign country and firm 2 produces in the domestic country if $\Delta c_2 \leq t < \Delta c_1$. Intuitively, the firm which can save the cost more by foreign production has more incentive for FDI. When $\Delta c_1 = \Delta c_2$, both firms simultaneously shift their production from the domestic country to the foreign country as t falls.

Proposition 1 *Suppose that there exist no FCs. If* $\max\{\Delta c_1, \Delta c_2\} \leq t$, *both firms produce in the domestic country. If* $\Delta c_i \leq t < \Delta c_j$ $(i, j = 1, 2; i \neq j)$, *firm* i *produces in the domestic country while firm* j *produces in the foreign country. If* $\min\{\Delta c_1, \Delta c_2\} > t$, *both firms produce in the foreign country.*

To obtain some more insight, we specify the cost function of firm i ($i = 1, 2$) as follows:

$$C_i(x_i) = \begin{cases} c_i x_i = a_i w x_i \\ c_i^* x_i = a_i^* w^* x_i \end{cases} \tag{11}$$

where a_i and w are, respectively, labor coefficient and the wage rate, which are exogenously given and constant. It is assumed that $a_1 < a_2$, $w > w^*$, $a_i \leq a_i^*$, and $a_i w > a_i^* w^*$. Then firm i ($i = 1, 2$) produces in domestic country if and only if

$$a_i w \leq a_i^* w^* + t.$$

Figure 1 illustrates this condition. Firm 1 produces in the domestic (foreign) country in the region below (above) line 1, while firm 2 produces in the domestic (foreign) country in the region below (above) line 2. Whereas panel (a) shows the case where $a_1^*/a_1 > a_2^*/a_2$ holds, panel (b) shows the case where $a_1^*/a_1 < a_2^*/a_2$. $a_1^*/a_1 > a_2^*/a_2$ ($a_1^*/a_1 < a_2^*/a_2$) could be the case if it is relatively difficult (easy) to transfer more efficient technology to the foreign country.

There are three regions in panel (a) and four regions in panel (b). Both firms produce in the domestic (foreign) country when w is relatively low (high) and t is relatively high (low), that is, (t, w) is in region DD (region FF). Whereas firm 1 produces in the domestic country and firm 2 produces in the foreign country in region DF, firm 1 produces in the foreign country and firm 2 produces in the domestic country in region FD. We should note that region FD never appears in panel (a). Moreover, it can be seen in panel (b) that as t falls, both firms simultaneously shift their locations from the domestic country to the foreign country at point S (where two lines intersect).

The location choice depends on the relative technology gap between two countries, a_i^*/a_i ($i = 1, 2$). If the gap is larger for firm 1 than for firm 2 (i.e., $a_1^*/a_1 > a_2^*/a_2$), then firm 2 (i.e., the less efficient firm) always has more incentive to undertake FDI. In the case where $a_1^*/a_1 < a_2^*/a_2$ holds, however, firm 2 (firm 1) has more incentive for FDI either if both t and w and are relatively high (low).

It is obvious that a change in t does not affect the profits of both firms in region DD. In region DF (region FD), a decrease in t benefits firm 2 (firm 1) and hurts firm 1 (firm 2) (see (7) and (8)). In region FF, both firms gain from a decrease in t (see (10)).[10] Similarly, in region DD, both firms benefit from a decrease in w. In region DF (region FD), a decrease in w benefits firm 1 (firm 2) and hurts firm 2 (firm 1).

We next examine the effect of a change in t on domestic welfare. We define the domestic welfare W as the sum of consumer surplus and firms' profits:[11]

$$W \equiv U(X) - P(X)X + \Pi_1 + \Pi_2 \tag{12}$$

where $dU/dX = P$. When both firms produce in the foreign country, a lower t benefits them. The consumers also benefit because the price falls. As t falls, therefore, domestic welfare improves. In the following, we examine the case where firm i produces in the domestic country and firm j produces in the foreign country ($i, j = 1, 2; i \neq j$). Differentiating (12) with respect to t, we have

$$\begin{aligned} \frac{dW}{dt} &= -XP'\frac{dX}{dt} + \frac{d\Pi_i}{dt} + \frac{d\Pi_j}{dt} \\ &= -\frac{(P')^2}{|\Omega|}[\{5 - \varepsilon(1 + \sigma_i)\}x_j + (\varepsilon\sigma_i - 1)x_i]. \end{aligned}$$

[10] If we allow $P' + P''x_i > 0$, firm 2 could lose in region B.

[11] In the analysis of welfare, we assume for simplicity that t is transport costs. Since both firms are domestic, a tariff is just a transfer within the domestic country. Moreover, if a lower tariff induces FDI, domestic welfare jumps up because the tariff revenue is generated.

If x_i (x_j) is sufficiently small, then $dW/dt < 0$ ($dW/dt > 0$) holds, that is, a decrease in t improves (lowers) domestic welfare. When $\varepsilon \neq 0$, $dW/dt < 0$ if $\sigma_i < \left(-\sqrt{-10\varepsilon + 2\varepsilon^2 + 9} + 3\right)/2\varepsilon$. When $\varepsilon = 0$, $dW/dt < 0$ if $\sigma_i < 5/6$ which always holds with $i = 2$.[12]

Intuitively a lower t is beneficial, because the total supply rises and the domestic consumers gain. However, an increase in the output of the less efficient firm at the expense of the more efficient firm is detrimental.[13] When the latter effect dominates the former, domestic welfare deteriorates. In Figure 1, therefore, a decrease in t reduces domestic welfare only if (t, w) is in region C.

We obtain the following proposition.

Proposition 2 *When both firms produce in the foreign country, a decrease in t improves domestic welfare. A lower t raises domestic welfare if only the more efficient firm produces in the foreign country, but may reduce it if only the less efficient firm produces in the foreign country.*

4 Location Choices with FCs

In this section, we introduce plant-specific FCs into our analysis. Once FCs are present, the production-location decisions also depend on the output levels. The decision by a firm affects that of the other firm. This leads to many cases to examine. In the following analysis, therefore, we focus on the case with linear demand: $P = A - aX$ (i.e., $\epsilon = 0$).

Furthermore, we assume $\Delta f_i \equiv f_i^* - f_i > 0$ ($i = 1, 2$) and $f_i = 0$ for simplicity.[14] We let DD (FF) and DF (FD) respectively denote the case where both firms are located in the domestic (foreign) country and the case where firm i ($i = 1, 2$) is located in the domestic (foreign) country while firm j ($j = 1, 2; i \neq j$) is located in the foreign (domestic) country. For example, Π_i^{FD} is the profits of firm i when firm i produces abroad and firm j produces at home.

Given that the rival firm (firm j) produces in the domestic country, firm i will undertake FDI if $\Pi_i^{FD} - \Pi_i^{DD} (\equiv \Delta\Pi_i^D) > 0$. Since $\Delta f_i = f_i^* > 0$, firm i may choose to stay in the domestic country even if $\Delta c_i > t$. We let t_i^D denote the trade cost that makes $\Pi_i^{FD} = \Pi_i^{DD}$ hold. That is, at t_i^D, firm i is indifferent between domestic production and FDI, given that the rival firm stays in the domestic country. Similarly, given that the rival firm produces in the foreign country, firm i will undertake FDI if $\Pi_i^{FF} - \Pi_i^{DF} (\equiv \Delta\Pi_i^F) > 0$.[15] We also let t_i^F denote the trade cost that leads to $\Pi_i^{FF} = \Pi_i^{DF}$.

$\Delta\Pi_i^k$ ($i = 1, 2; k = D, F$) is derived in Appendix A (see (A1) and (A2)). To facilitate the following analysis, we illustrate $\Delta\Pi_i^k = 0$ in Figures 2 and 3. Whereas Figure 2 shows the case where $\Delta c_1 > \Delta c_2$ holds, Figure 3 shows the case where $\Delta c_1 < \Delta c_2$. When $f_i^* = 0$, $\Delta\Pi_i^k = 0$ holds at $t = \Delta c_i$. Moreover, when $f_i^* > 0$, $\Delta\Pi_i^k = 0$ holds at some t which is less than Δc_i; and

[12] Assuming linea demand: $P(X) = A - aX$, $c_j^* + t < (4A + 7c_i)/11$ is equivalent to $\sigma_i < 5/6$.

[13] See also Lahiri and Ono (1988).

[14] This kind of FCs could be monitoring costs and/or communication costs.

[15] Neary (2005) calls $\Delta\Pi_i^D$ and $\Delta\Pi_i^F$ the offshoring gain.

$\Delta\Pi_i^k = 0$ is downward-sloping.[16] By noting

$$\Delta\Pi_i^D - \Delta\Pi_i^F = \frac{4(\Delta c_i - t)(\Delta c_j - t)}{9a} \quad (j = 1, 2; i \neq j), \tag{13}$$

$\Delta\Pi_i^D = 0$ and $\Delta\Pi_i^F = 0$ intersect with each other at $t = \Delta c_j$ as well as at $t = \Delta c_i$. In Figure 2 (Figure 3), $\Delta\Pi_i^D = 0$ is located above $\Delta\Pi_i^F = 0$ when $0 \leq t < \Delta c_2$ $(0 \leq t < \Delta c_1)$ and vice versa when $\Delta c_2 \leq t < \Delta c_1$ $(\Delta c_1 \leq t < \Delta c_2)$.

The following lemma is immediate.

Lemma 1 *Regardless of the rival's location, firm i produces in the domestic country when* $t \geq \max\{t_i^D, t_i^F\}$ *but in the foreign county when* $t < \min\{t_i^D, t_i^F\}$. *When* $t_i^D < t < t_i^F$ $(t_i^F < t < t_i^D)$, *firm i is located in the domestic (foreign) country if the rival produces in the domestic country, but in the foreign (domestic) country if the rival produces in the foreign country. Moreover,* $t_i^D < \Delta c_i$ *and* $t_i^F < \Delta c_i$ *when* $f_i^* > 0$, *while* $t_i^D = t_i^F = \Delta c_i$ *in the absence of FCs (i.e.,* $f_i^* = 0$*).*

Depending on the relative sizes of t_i^D and t_i^F $(i = 1, 2)$, we have different location patterns. Since there are four critical values, there are 24 possible orders. However, some of them are not possible. The following Lemmas are useful to eliminate those irrelevant cases.

Lemma 2 *If* $t_i^D < t_i^F$, *then* $t_j^F < t_j^D < \Delta c_j < t_i^D < t_i^F$.

Proof. See Appendix B. ■

Lemma 3 *If* $t_2^D \leq t_1^D$, *then* $t_2^F < t_1^F$.

Proof. See Appendix B. ■

Using Lemma 2, we can eliminate 16 cases. And using Lemma 3, we can eliminate one more case $(t_1^F < t_2^F < t_2^D < t_1^D)$. That is, the following seven cases are possible: $t_j^F < t_j^D < t_i^D < t_i^F$, $t_j^F < t_j^D < t_i^F < t_i^D$, $t_j^F < t_i^F < t_j^D < t_i^D$ $(i, j = 1, 2; i \neq j)$, and $t_2^F < t_1^F < t_1^D < t_2^D$.[17]

Invoking Lemma 1, we examine the plant locations determined by Nash equilibrium. For example, suppose $t_2^F < t_2^D < t_1^D < t_1^F$. We first consider the strategy of firm 1. Recalling the definition of t_1^D and t_1^F, firm 1 produces in the domestic country if $t > t_1^F$ and in the foreign country if $t < t_1^D$ regardless of firm 2's strategy. If $t_1^D < t < t_1^F$, firm 1 chooses the same location as firm 2 does. The strategy of firm 2 is as follows. Regardless of firm 1's strategy, firm 2 produces in the domestic country if $t > t_2^D$ and in the foreign country if $t < t_2^F$. Given firm 1's location, firm 2 chooses the different location if $t_2^F < t_2^D$. This is summarized in Case I of Table 1. Thus, we obtain the following Nash equilibrium. If $t > t_1^D$, both firms produce in the domestic country. If $t_2^F < t < t_1^D$, firm 1 produces in the foreign country while firm 2 produces in the domestic country. If $t < t_2^F$, both firms produce in the foreign country. Thus, a lower t leads to more incentive for the more efficient firm (i.e., firm 1) to undertake FDI. In this way, we can find Nash equilibrium.

In view of Table 1, we can summarize the location patterns as follows.

[16] $t \leq \Delta c_i$ is necessary for firm i to undertake FDI.

[17] In Appendix A, we show that these seven cases actually exist.

Case I. $t_j^F < t_j^D < t_i^D < t_i^F$	$t < t_j^F$	$t_j^F < t < t_j^D$	$t_j^D < t < t_i^D$	$t_i^D < t < t_i^F$	$t_i^F < t$
Best response of firm i ($R_i(D)$, $R_i(F)$)	(F,F)	(F,F)	(F,F)	(D,F)	(D,D)
Best response of firm j ($R_j(D)$, $R_j(F)$)	(F,F)	(F,D)	(D,D)	(D,D)	(D,D)
Nash equilibrium (firm i, firm j)	(F,F)	(F,D)	(F,D)	(D,D)	(D,D)
Case II. $t_j^F < t_j^D < t_i^F < t_i^D$	$t < t_j^F$	$t_j^F < t < t_j^D$	$t_j^D < t < t_i^F$	$t_i^F < t < t_i^D$	$t_i^D < t$
Best response of firm i ($R_i(D)$, $R_i(F)$)	(F,F)	(F,F)	(F,F)	(F,D)	(D,D)
Best response of firm j ($R_j(D)$, $R_j(F)$)	(F,F)	(F,D)	(D,D)	(D,D)	(D,D)
Nash equilibrium (firm i, firm j)	(F,F)	(F,D)	(F,D)	(F,D)	(D,D)
Case III. $t_j^F < t_i^F < t_j^D < t_i^D$	$t < t_j^F$	$t_j^F < t < t_i^F$	$t_i^F < t < t_j^D$	$t_j^D < t < t_i^D$	$t_i^D < t$
Best response of firm i ($R_i(D)$, $R_i(F)$)	(F,F)	(F,F)	(F,D)	(F,D)	(D,D)
Best response of firm j ($R_j(D)$, $R_j(F)$)	(F,F)	(F,D)	(F,D)	(D,D)	(D,D)
Nash equilibrium (firm i, firm j)	(F,F)	(F,D)	(F,D) or (D,F)	(F,D)	(D,D)
Case IV. $t_2^F < t_1^F < t_1^D < t_2^D$	$t < t_2^F$	$t_2^F < t < t_1^F$	$t_1^F < t < t_1^D$	$t_1^D < t < t_2^D$	$t_2^D < t$
Best response of firm 1 ($R_1(D)$, $R_1(F)$)	(F,F)	(F,F)	(F,D)	(D,D)	(D,D)
Best response of firm 2 ($R_2(D)$, $R_2(F)$)	(F,F)	(F,D)	(F,D)	(F,D)	(D,D)
Nash equilibrium (firm 1, firm 2)	(F,F)	(F,D)	(F,D) or (D,F)	(D,F)	(D,D)

Table 1: Best response of each firm and Nash equilibrium

1. Cases I and II. $t_j^F < t_j^D < t_i^D < t_i^F$ $(i, j = 1, 2; i \neq j)$ or $t_j^F < t_j^D < t_i^F < t_i^D$ $(i, j = 1, 2; i \neq j)$: In these cases, if $t \geq t_i^D$ $(t < t_j^F)$, both firms produce in the domestic (foreign) country. If $t_j^F \leq t < t_i^D$, firm i produces in the foreign country while firm j produces in the domestic country.

2. Case III. $t_j^F < t_i^F < t_j^D < t_i^D$ $(i, j = 1, 2; i \neq j)$: As in the first four cases, both firms produce in the domestic (foreign) country if $t \geq t_i^D$ $(t < t_j^F)$. If either $t_j^F \leq t < t_i^F$ or $t_j^D < t < t_i^D$, firm i produces in the foreign country while firm j produces in the domestic country. However, if $t_i^F < t < t_j^D$, there are two possible equilibria. In one equilibrium, firm i produces in the foreign country while firm j produces in the domestic country; and vice versa in the other equilibrium.

3. Case IV. $t_2^F < t_1^F < t_1^D < t_2^D$: If $t \geq t_2^D$ $(t < t_2^F)$, both firms produce in the domestic (foreign) country. If $t_1^D < t < t_2^D$ $(t_2^F < t < t_1^F)$, firm 1 produces in the domestic (foreign) country while firm 2 produces in the foreign (domestic) country. If $t_1^F < t < t_1^D$, there are two possible equilibria.

The following should be noted. First, in all cases, both firms produce in the domestic country if $t \geq \max\{t_1^D, t_2^D\}$ but in the foreign country if $t < \min\{t_1^F, t_2^F\}$. Second, in the first four cases, the location patterns are similar to those in the case without FCs. This similarity arises, because $\max\{t_j^D, t_j^F\} < \min\{t_i^D, t_i^F\}$ holds in those four cases. Third, multiple equilibria arise when neither of the firms has a dominant strategy. The intuition for multiple equilibria is as follows. For both firms, the "actual" MCs are lower if they produce in the foreign country.[18] However, if both firms produce in the foreign country, competition becomes so keen that neither firm cannot cover its FC and one of them would rather stay in the domestic country. Thus, only one firm is located in the foreign country. The presence of FCs plays a crucial role here.

We obtain the following proposition.

Proposition 3 *If $t_j^F < t_i^F < t_j^D < t_i^D$ $(i, j = 1, 2; i \neq j)$, a small change in t may completely reverse the location choices at both t_i^F and t_j^D. If $t_2^F < t_1^F < t_1^D < t_2^D$, the complete reversal does occur at either t_1^F or t_1^D.*

We should note that Proposition 2 is still valid with FCs. However, in contrast to the case without FCs, at the critical levels, the profits of the firm which undertakes FDI are the same, while those of the other firm discontinuously drop. This is because the actual MC of the firm undertaking FDI becomes lower, which in turn decreases the price. In particular, we can show the following proposition.

Proposition 4 *At critical levels of t, domestic welfare jumps up if only the more efficient firm switches its production from the domestic country to the foreign country but goes down if only the less efficient firm switches its production from the domestic country to the foreign country. When plant locations are completely reversed, consumer surplus jumps up if only the firm, whose FDI can save its real MC more than the rival's, undertakes FDI, the profits of a firm are larger when it produces abroad than when the rival does, and the effects of complete reversal on domestic welfare are generally ambiguous.*

Proof. See Appendix B. ■

5 Concluding Remarks

Using a simple, two-country, duopoly model, we have analyzed location choices by the firms. Specifically, both firms are domestic; they are heterogeneous in the sense that their MCs are different; and they serve only domestic market. When the trade costs are neither very high nor very low, one of the two firms has incentive to undertake FDI in the foreign country. In the absence of FCs, the difference between the MC of the domestic production and that of the foreign production are crucial. In the presence of FCs, we may have multiple equilibria. Moreover, the production location may not monotonically change as the trade costs change. We have also shown that a lower trade cost may lead to lower domestic welfare.

In our analysis, we can reinterpret FDI as international outsourcing. In particular, it is often considered that firms have to incur FCs to undertake FDI but do not in the case of outsourcing. Thus, one may think that FDI and outsourcing, respectively, correspond to the case with and without FCs.

[18] The actual MCs includes the trade costs. That is, the actual MCs of firm i are c_i (i.e., the real MC) if it produces at home and $c_i^* + t$ if it produces abroad.

Appendix A

In this appendix, we show that the location patterns obtained in the case with FCs actually exist. We have

$$\begin{aligned}
\Pi_i^{DD} &= a\left(\frac{A-2c_i+c_j}{3a}\right)^2, \\
\Pi_i^{FD} &= a\left(\frac{A-2c_i^*+c_j-2t}{3a}\right)^2 - f_i^*, \\
\Pi_i^{DF} &= a\left(\frac{A-2c_i+c_j^*+t}{3a}\right)^2, \\
\Pi_i^{FF} &= a\left(\frac{A-2c_i^*+c_j^*-t}{3a}\right)^2 - f_i^*.
\end{aligned}$$

The firm i's incentive to undertake FDI is determined by

$$\Delta\Pi_i^D \equiv \Pi_i^{FD} - \Pi_i^{DD} = a\left(\frac{A-2c_i^*+c_j-2t}{3a}\right)^2 - a\left(\frac{A-2c_i+c_j}{3a}\right)^2 - f_i^*, \tag{A1}$$

$$\Delta\Pi_i^F \equiv \Pi_i^{FF} - \Pi_i^{DF} = a\left(\frac{A-2c_i^*+c_j^*-t}{3a}\right)^2 - a\left(\frac{A-2c_i+c_j^*+t}{3a}\right)^2 - f_i^*. \tag{A2}$$

Differentiating above two equations with respect to t, we obtain

$$\frac{d\Delta\Pi_i^D}{dt} = -\frac{4}{9a}\left(A-2c_i^*+c_j-2t\right), \tag{A3}$$

$$\frac{d\Delta\Pi_i^F}{dt} = -\frac{4}{9a}\left(A-c_i-c_i^*+c_j^*\right). \tag{A4}$$

Given that firm j produces in the domestic country, firm i will undertake FDI if the following condition holds:

$$\Delta\Pi_i^D > 0 \Leftrightarrow t < \frac{1}{2}\left\{(A-2c_i^*+c_j) - \sqrt{(A-2c_i+c_j)^2 + 9af_i^*}\right\} \equiv t_i^D. \tag{A5}$$

Similarly, given that firm j produces in the foreign country, firm i will undertake FDI if the following holds:

$$\Delta\Pi_i^F > 0 \Leftrightarrow t < (c_i - c_i^*) - \frac{9af_i^*}{4\left(A-c_i-c_i^*+c_j^*\right)} \equiv t_i^F. \tag{A6}$$

We can easily verify that $t_i^D < \Delta c_i$ and $t_i^F < \Delta c_i$ when $f_i^* > 0$, while $t_i^D = t_i^F = \Delta c_i$ in the absence of FCs (i.e., $f_i^* = 0$).

Suppose $A = 20$, $a = 2$, $c_1 = 4$, $c_2 = 5$, $c_2^* = 3$, $F_1 = 3$, and $F_2 = 3$.

1. $t_2^F < t_2^D < t_1^D < t_1^F$ ($t_1^D = 2.240$, $t_1^F = 2.250$, $t_2^D = 1.094$, $t_2^F = 0.962$) holds when c_1^*=1.00; and $t_1^F < t_1^D < t_2^D < t_2^F$ ($t_1^D = 0.290$, $t_1^F = 0.209$, $t_2^D = 1.094$, $t_2^F = 1.097$) when $c_1^* = 2.95$.

2. $t_2^F < t_2^D < t_1^F < t_1^D$ ($t_1^D = 1.740$, $t_1^F = 1.729$, $t_2^D = 1.094$, $t_2^F = 1.000$) when $c_1^* = 1.50$; and $t_1^F < t_1^D < t_2^F < t_2^D$ ($t_1^D = 0.740$, $t_1^F = 0.682$, $t_2^D = 1.094$, $t_2^F = 1.069$) when $c_1^* = 2.50$.

3. $t_2^F < t_1^F < t_2^D < t_1^D$ ($t_1^D = 1.120$, $t_1^F = 1.080$, $t_2^D = 1.094$, $t_2^F = 1.044$) when $c_1^* = 2.12$; and $t_1^F < t_2^F < t_1^D < t_2^D$ ($t_1^D = 1.060$, $t_1^F = 1.017$, $t_2^D = 1.094$, $t_2^F = 1.048$) when $c_1^* = 2.18$.

4. $t_2^F < t_1^F < t_1^D < t_2^D$ ($t_1^D = 1.090$, $t_1^F = 1.049$, $t_2^D = 1.094$, $t_2^F = 1.046$) when $c_1^* = 2.15$

We differentiate t_i^D and t_i^F with respect to f_i^* and evaluate it at $f_i^* = 0$:

$$\left.\frac{\partial t_i^D}{\partial f_i^*}\right|_{f_i^*=0} = -\frac{9a}{4\left(A - 2c_i + c_j\right)},$$
$$\left.\frac{\partial t_i^F}{\partial f_i^*}\right|_{f_i^*=0} = -\frac{9a}{4\left(A - c_i - c_i^* + c_j^*\right)},$$

the signs of which are negative if $c_i < c_j$ and $c_i^* < c_j^*$. We have

$$\left.\frac{\partial t_i^D}{\partial f_i^*}\right|_{f_i^*=0} - \left.\frac{\partial t_i^F}{\partial f_i^*}\right|_{f_i^*=0} = \frac{9a\left(-c_i + c_i^* + c_j - c_j^*\right)}{4\left(A - 2c_i + c_j\right)\left(A - c_i - c_i^* + c_j^*\right)}.$$

The sign depends on the numerator, because the denominator is positive. That is, the sign is positive (negative) if and only if $c_j - c_i > c_j^* - c_i^*$, i.e., $\Delta c_i < \Delta c_j$ ($c_j - c_i < c_j^* - c_i^*$, i.e., $\Delta c_i > \Delta c_j$).

Appendix B

Proof of Lemma 2. First, we prove $\Delta c_j < t_i^D < t_i^F$. In Figures 2 and 3, $t_i^D < t_i^F$ at some $f_i^* (> 0)$ implies that $\Delta\Pi_i^F = 0$ is located to the right of $\Delta\Pi_i^D = 0$, which holds if and only if $\Delta c_j < t < \Delta c_i$. Thus, $\Delta c_j < t_i^D < t_i^F$ must be the case when $t_i^D < t_i^F$. Next, we prove $t_j^F < t_j^D < \Delta c_j$. Since $\max\{t_j^D, t_j^F\} < \Delta c_j$, either $t_j^F < t_j^D$ or $t_j^D < t_j^F$ holds. Suppose $t_j^D < t_j^F$. Then, in view of the first part of the proof, $\Delta c_i < t_j^D < t_j^F$ is necessary. This is contradiction, because $\Delta c_j < t_i^D < t_i^F < \Delta c_i$. Thus, $t_j^F < t_j^D < \Delta c_j$. ■

Proof of Lemma 3. When $t_1^D < t_1^F$ holds, it is obvious that $t_2^F < t_1^F$ from Lemma 2. Thus, it is sufficient to consider only the case where $t_1^D > t_1^F$ holds. First, we suppose a combination of FCs (f_1^* and f_2^*) under which $t_2^D = t_1^D$ holds. Because $t_i^D < \Delta c_i$ ($i = 1, 2$), $t_1^D = t_2^D < \min\{\Delta c_1, \Delta c_2\}$ holds. Using (13), we find $\Delta\Pi_1^D - \Delta\Pi_1^F = \Delta\Pi_2^D - \Delta\Pi_2^F > 0$. Because $\Delta\Pi_1^D = \Delta\Pi_2^D = 0$ at t_1^D (t_2^D), we find $\Delta\Pi_1^F = \Delta\Pi_2^F < 0$. Differentiating $\Delta\Pi_1^F$ (A1) and $\Delta\Pi_2^F$ (A2) with respect to t and rearranging those, we can obtain

$$\left|\frac{d\Delta\Pi_1^F}{dt}\right| = \left|\frac{d\Delta\Pi_2^F}{dt}\right| + \frac{4}{9a}\left\{2\left(c_2^* - c_1^*\right) + \left(c_2 - c_1\right)\right\}. \quad \text{(A7)}$$

Since $c_1 < c_2$ and $c_1^* < c_2^*$, (A7) means that the absolute value of the slope of $\Delta\Pi_1^F$ is greater than that of $\Delta\Pi_2^F$. This implies that the required additional reduction of t for $\Delta\Pi_1^F = 0$ is smaller than that for $\Delta\Pi_2^F = 0$. Thus, $t_2^F < t_1^F$ holds. Next we suppose a combination of FCs under which $t_2^D < t_1^D$ holds. Because $t_2^D < t_1^D$ and $t_i^D < \Delta c_i$ $(i = 1, 2)$, we have three possible orders, $t_2^D < t_1^D < \Delta c_1 < \Delta c_2$, $t_2^D < t_1^D < \Delta c_2 < \Delta c_1$ and $t_2^D < \Delta c_2 < t_1^D < \Delta c_1$. In view of Figure 2, the third order implies $t_1^D < t_1^F$ and hence $t_2^F < t_1^F$ from Lemma 2. Thus, it is sufficient to consider the first two orders. These orders imply $t_2^D < t_1^D < \min\{\Delta c_1, \Delta c_2\}$. Then, $\Delta\Pi_1^D - \Delta\Pi_1^F$ (or $-\Delta\Pi_1^F$) at t_1^D is smaller than $\Delta\Pi_2^D - \Delta\Pi_2^F$ (or $-\Delta\Pi_2^F$) at t_2^D. Thus, we can also prove $t_2^F < t_1^F$ as in the case of $t_2^D = t_1^D$. ■

Proof of Proposition 4. First, we consider the first claim of Proposition 4. When the actual marginal costs of two firms are m_i and m_j $(i, j = 1, 2$ and $i \neq j)$, consumer surplus is

$$CS = \frac{a}{2}\left(\frac{2A - m_i - m_j}{3a}\right)^2.$$

Firm i's FDI makes its actual marginal cost lower. The effect of a reduction of m_i on consumer surplus is

$$\frac{\partial CS}{\partial m_i} = -\left(\frac{2A - m_i - m_j}{9a}\right) < 0$$

whose sign is always positive (as long as Cournot interior solutions exist). Since the profits of firm j are

$$\Pi_j = a\left(\frac{A + m_i - 2m_j}{3a}\right)^2,$$

the effect of a reduction of m_i on the profits is given by

$$\frac{\partial \Pi_j}{\partial m_i} = \frac{2}{3}\left(\frac{A + m_i - 2m_j}{3a}\right) > 0.$$

By noting that firm i's profits are continuous at the critical levels of t: t_i^D and t_i^F, the change of domestic welfare is given by

$$\frac{\partial CS}{\partial m_i} + \frac{\partial \Pi_j}{\partial m_i} = \frac{m_i - m_j}{3a}.$$

Thus, the following condition holds:

$$m_i > m_j \Leftrightarrow \frac{\partial CS}{\partial m_i} + \frac{\partial \Pi_j}{\partial m_i} > 0.$$

This means that FDI undertaken by the firm with lower actual marginal cost always improves domestic welfare. Taking into account this finding, we investigate three cases of the location changes: from (D, D) to (F, D), from (D, D) to (F, D) , and from (F, D) to (F, F). In the first and second cases, since the actual marginal costs at (D, D) are c_1 and c_2 and $c_2 > c_1$, domestic welfare rises. In the third case, the actual marginal costs are c_1^* and c_2 at (F, D). Suppose $c_1^* + t \geq c_2$. Then $c_1^* + t > c_1$ because $c_2 > c_1$. Obviously, firm 1 will not undertake FDI at this trade cost. Thus, $c_2 > c_1^* + t$ and domestic welfare falls.

Next, we consider the second claim of Proposition 5. Complete reversal arises in Cases III and IV. We have two cases: from (D, F) to (F, D) and from (F, D) to (D, F). The difference of consumer surplus between two regimes is,

$$\begin{aligned} CS^{(F,D)} - CS^{(D,F)} &= \frac{a}{2}\left(\frac{2A - c_1^* - t - c_2}{3a}\right)^2 - \frac{a}{2}\left(\frac{2A - c_1 - c_2^* - t}{3a}\right)^2 \\ &= \frac{1}{18a}\left(c_1 - c_1^* - c_2 + c_2^*\right)\left\{(2A - c_1^* - t - c_2) + (2A - c_1 - c_2^* - t)\right\}. \end{aligned}$$

Therefore,

$$c_1 - c_1^* > c_2 - c_2^* \Leftrightarrow c_2^* - c_1^* > c_2 - c_1 \Leftrightarrow CS^{FD} > CS^{DF}.$$

This means that consumer surplus is larger when the firm which can save the real marginal cost more by FDI switches its production from the domestic country to the foreign country than when the other firm does. The difference of firm i's profits $(i = 1, 2)$ is

$$\Pi_i^{FD} - \Pi_i^{DF} = a\left(\frac{A - 2c_i^* - 2t + c_j}{3a}\right)^2 - a\left(\frac{A - 2c_i + c_j^* + t}{3a}\right)^2 - f_i^*.$$

When $t_2^F < t_1^F < t_2^D < t_1^D$, $\Pi_1^{FD} > \Pi_1^{DD}$ and $\Pi_1^{DF} \geq \Pi_1^{FF}$ hold at $t \in [t_1^F, t_2^D]$. Because $\Delta c_2 > t_2^D$, the rival's FDI lowers the firm 1's profits $(\Pi_1^{DD} > \Pi_1^{DF})$. Thus, $\Pi_1^{FD} > \Pi_1^{DD} > \Pi_1^{DF} \geq \Pi_1^{FF}$. Similarly, using $\Pi_2^{FD} \geq \Pi_2^{DD}$, $\Pi_2^{DF} > \Pi_2^{FF}$, and $\Delta c_1 > t_1^D$, we have $\Pi_2^{FD} \geq \Pi_2^{DD} > \Pi_2^{DF} > \Pi_2^{FF}$. Thus, $\Pi_1^{FD} > \Pi_1^{DF}$ and $\Pi_2^{FD} > \Pi_2^{DF}$. This finding is also applicable when $t_1^F < t_2^F < t_1^D < t_2^D$. When $t_2^F < t_1^F < t_1^D < t_2^D$ (i.e., in Case IV), $\Pi_1^{FD} \geq \Pi_1^{DD}$ and $\Pi_1^{DF} \geq \Pi_1^{FF}$ hold at $t \in [t_1^F, t_1^D]$. Using $\Delta c_2 > t_2^D$, $\Pi_1^{FD} \geq \Pi_1^{DD} > \Pi_1^{DF} \geq \Pi_1^{FF}$. Similarly, using $\Pi_2^{FD} > \Pi_2^{DD}$, $\Pi_2^{DF} > \Pi_2^{FF}$, and $\Delta c_1 > t_1^D$, we have $\Pi_2^{FD} > \Pi_2^{DD} > \Pi_2^{DF} > \Pi_2^{FF}$. Thus, $\Pi_1^{FD} > \Pi_1^{DF}$ and $\Pi_2^{FD} > \Pi_2^{DF}$. This means that the profits of firm i are larger when it produces abroad and the rival produces at home than vice versa.

Finally, we consider domestic welfare and the sum of profits. We can verify that the signs of the following equations are generally ambiguous.

$$\begin{aligned} W = \{&18a\,(F_2 - F_1) + 8Ac_1 - 11c_1^2 - 8Ac_1^* + 11c_1^{*2} - 8Ac_2 + 11c_2^2 + 8Ac_2^* - 11c_2^{*2} \\ &- 14c_1^*c_2 + 14c_1c_2^* + 14c_1t + 22c_1^*t - 14c_2t - 22c_2^*t\}/18a, \end{aligned}$$

$$\begin{aligned} \left(\Pi_1^{FD} + \Pi_2^{DF}\right) - \left(\Pi_1^{DF} + \Pi_2^{FD}\right) = \{&9a\,(F_2 - F)_1 + 2Ac_1 - 5c_1^2 - 2Ac_1^* + 5c_1^{*2} - 2Ac_2 + 5c_2^2 \\ &+ 2Ac_2^* - 5c_2^{*2} - 8c_1^*c_2 + 8c_1c_2^* + 8c_1t + 10c_1^*t - 8c_2t - 10c_2^*t\}/9a. \end{aligned}$$

For example, when $A = 20$, $a = 2$, $c_1 = 4$, $c_2 = 5$, $c_1^* = 1.50$, $c_2^* = 3$, $f_1^* = 6$, and $f_2^* = 3$, the signs are negative and positive, respectively. When $A = 20$, $a = 2$, $c_1 = 4$, $c_2 = 4.1$, $c_1^* = 2.93$, $c_2^* = 3$, $f_1^* = 3$, and $f_2^* = 3$, the signs are positive and negative, respectively. Thus, when complete reversal arises, domestic welfare may deteriorate regardless of which firm makes FDI. ■

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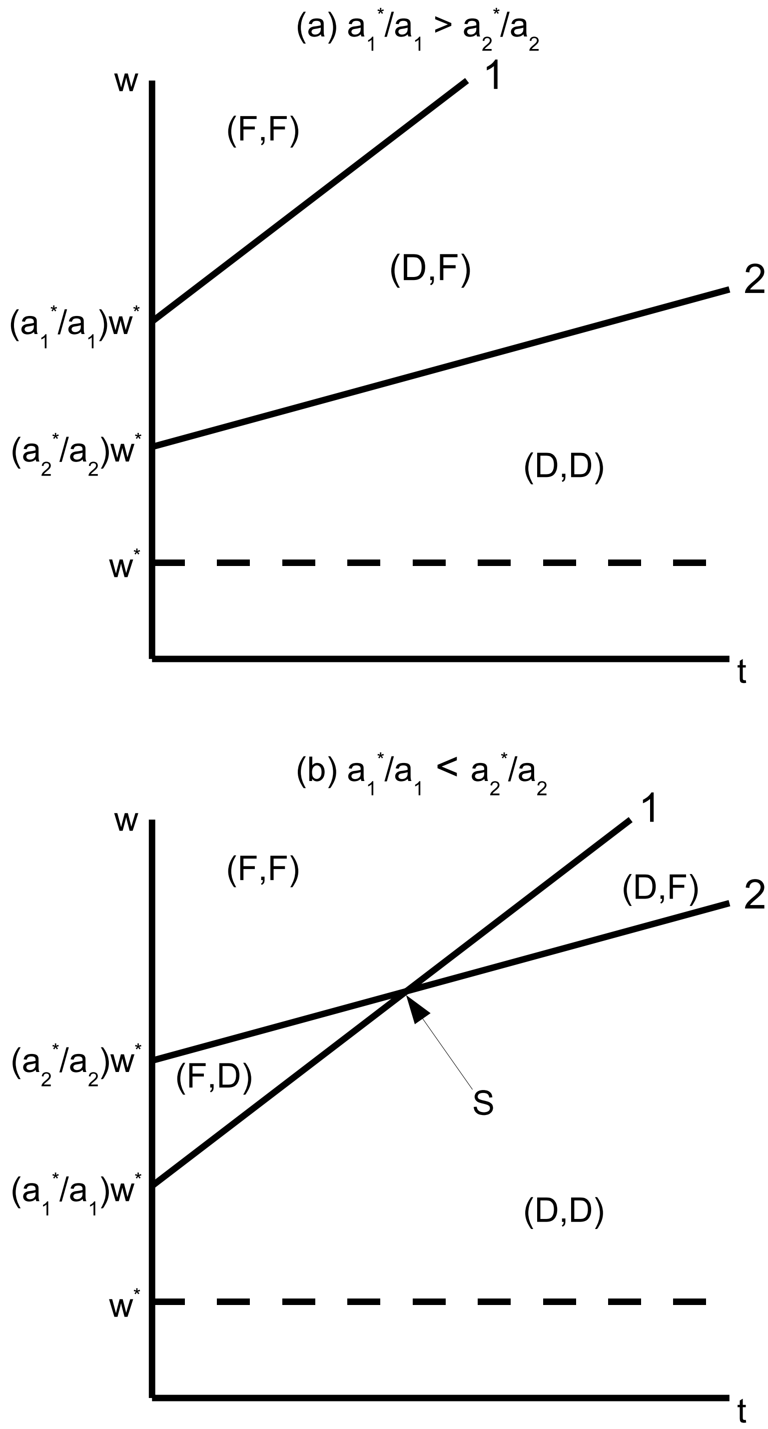

Figure 1: Domestic Market

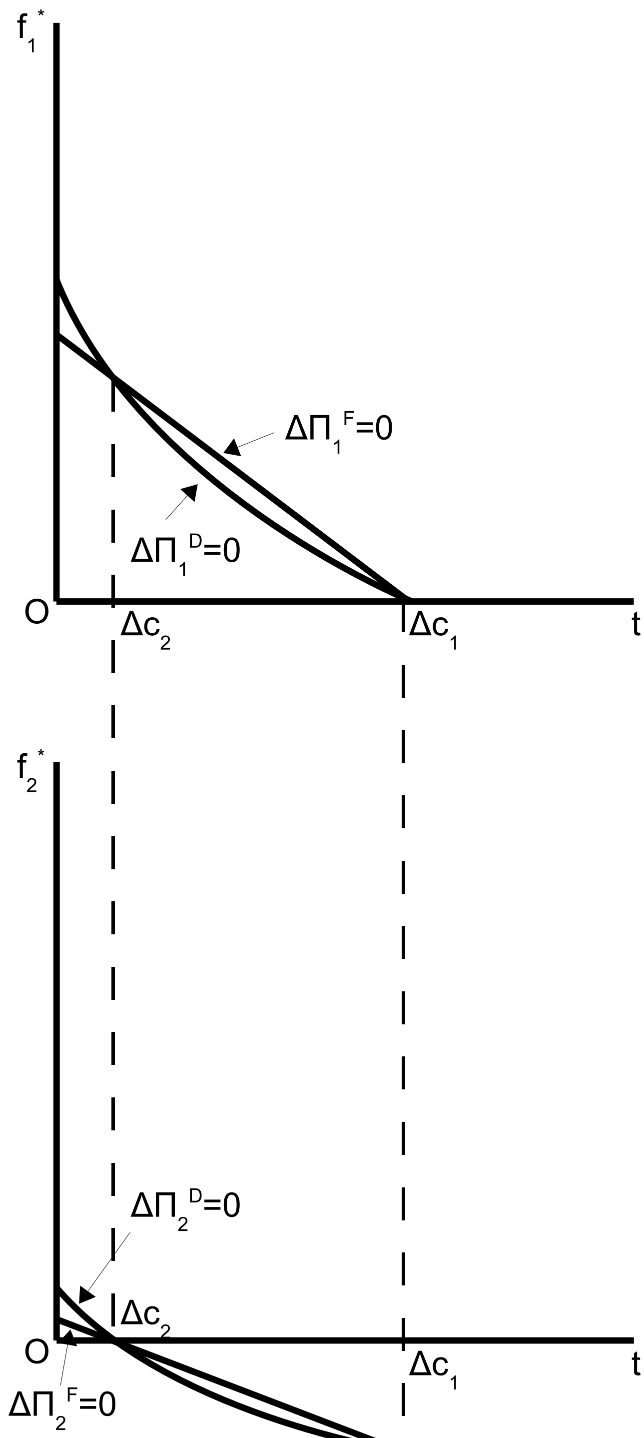

Figure 2: $\Delta c_1 > \Delta c_2$

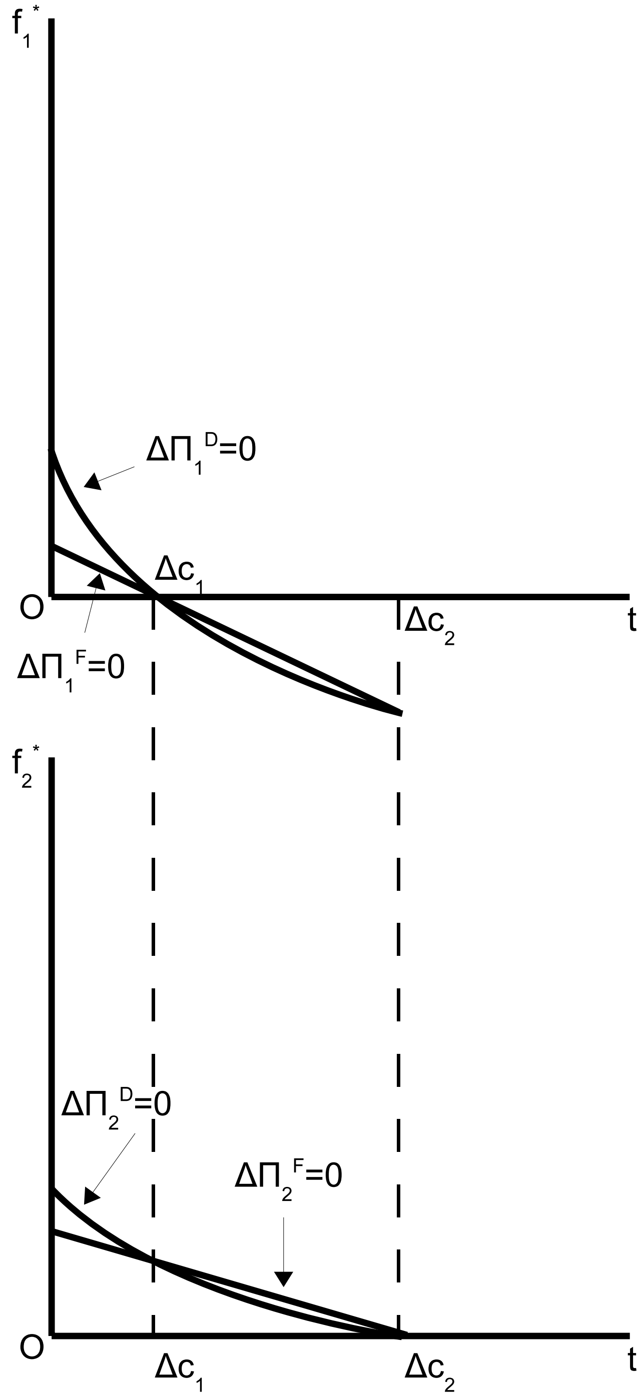

Figure 3: $\Delta c_1 < \Delta c_2$