Endogenous FDI Spillovers from Japan to Russia and China with Spillover-Prevention Costs

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February 2014

Abstract

This paper explores the role of FDI-spillover prevention costs in the strategic choice for a MNE of a developed country such as Japan about whether it perform FDI to an emerging economy such as Russia and China and about a degree of FDI spillovers that it allows. After discussing the exogenous spillover case in a duopoly model, this paper shows that with a quadratic prevention cost function, the MNE may choose a positive level of spillovers lower than the benchmark exogenous level, and also shows how endogenizing spillovers affect the home firm's decision on plant location. In the m-FDI-host-country firm case, the effects of the number of FDI-host country firms on the level of spillovers and the cutoff value of trade cost are not always monotonic.

JEL Classification: F12, F23, O33.
Keywords: FDI, Endogenous Spillovers, Spillover-prevention Costs.

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†The author thanks Akihito Asano, Taiji Furusawa, Jota Ishikawa, Naoto Jinji, Hideaki Murase, Noritsugu Nakanishi, Akihiko Yanase, participants of seminars at Australian National University, IDE-JETRO, Nagoya City University, and the University of New South Wales for their helpful comments. Financial supports from Grants-in-Aid for Scientific Research, JSPS (No. 21730204) and Nihon University are highly acknowledged. All remaining errors are the author's.

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1 Introduction

From the 1990s, many firms in developed countries have performed FDI in China and other Asian economies. However, some companies have chosen to keep their production facilities in their home countries. At the same time, FDI host countries want multinational enterprises (MNEs) to transfer their superior technology to domestic counterparts. Some MNEs reply to host countries' request positively while others do negatively. What causes such a difference? One concept that helps us understand these two problems together is FDI spillovers, i.e. a positive externality from MNEs to firms in the FDI host countries.

Channels of such technology spillovers may be wide-ranging. However, METI (2011) reports that for Japanese firms, two main channels are (1) locally hired staff, and (2) products on sale. As the first channel, former employees in a FDI host country take the firm's technology outside the firm and utilize it as employees of local companies or as entrepreneurs. Therefore, work conditions in FDI-performing firms and/or local labor-market condition, including outside offers, are important factors to affect how far FDI spillovers are likely to occur. The so called reverse engineering is a typical example of the second channel.

Various factors are discussed as causes of outward FDI, such as marginal-cost differences between the home and FDI host countries associated with a fixed cost of FDI (Horstmann and Markusen 1992), expectation of demand growth in the FDI host country (Rob and Vettas 2003), and heterogeneity in productivity among domestic firms (Helpman et al. 2004). About FDI spillovers, many empirical studies exist (Dimelis 2005, for instance), although the effects of internal FDI on productivity of domestic firms in various countries are mixed.

Among the previous theoretical literature on FDI spillovers, two papers are highly related with this article. Grünfeld (2006) develops a three-period model with two countries and two firms where firm d serves only market D while firm f may serve markets D and F. It is assumed that a firm's marginal cost depends on R&D investments by itself and the rival firm in case of FDI by firm f, and that FDI spillovers gets larger as firm d's R&D investment gets larger. The most interesting result is that for firm f, weak and strong absorptive capacity effects favor exports while medium-sized absorptive capacity effects favor FDI.

Sawada (2010) develops a two-firm model where the home firm with a higher constant marginal cost invests to gain spillovers of inward FDI by the foreign firm while the foreign firm invests to prevent it in the first stage, and they compete in quantity in the second stage. He shows that if the marginal cost difference between the two firms is above a critical level, the home firm invests less while the foreign firm invests more as the cost difference increases. The effect of cost difference is not monotonic: if the cost difference is below the critical level, an increase in the cost difference has a positive effect on the investment by the foreign firm but its effect on the investment by the home firm is ambiguous.

The purpose of this paper is to examine the role of spillover-prevention costs to determine the level of endogenous FDI spillovers to its rival firm(s). If fewer spillovers is not free, the MNE might seek an optimal level of spillovers with FDI.

The most important contribution of this paper will be to discuss endogenous FDI spillovers with the MNE's decision on the plant location, i.e. exports or FDI. The relationship between FDI spillovers and plant location is also discussed by both Grünfeld (2006) and Sawada (2010), but this paper differs from them about specification of FDI spillovers. In this paper only the FDI performing firm invests to decrease the degree of FDI spillovers while in the two papers both the firms in the FDI-source and FDI-host countries invest.

In Grünfeld (2006), a firm's investment increases its own ability to absorb rival's technology while in this paper, a firm's investment is to decrease rival's ability to absorb.[1] In Sawada (2010), a level of spillovers is determined by fixed costs of investments by firms in both the FDI-source and FDI-host countries. The former firm invests to absorb more from the rival while the latter firm does to prevent such spillovers. However, firms' expenditures for spillover-prevention do not always have fixed-cost property; according to METI (2011), three main ways of Japanese firms to "create black boxes (in their foreign subsidiaries)" to prevent FDI spillovers to foreign firms are (1) restricting local staff's access to information, (2) managing core parts/materials information as trade secret, and (3) exporting production equipment from Japan by sealing off knowhow in the equipment.

Although the setting about firms' investments in those two papers are more general, this paper's simple setting makes the model very tractable and many extensions are possible. For instance, This paper extends its duopoly model to those in which more than one firm in either FDI-source or FDI-host countries exist, while the two papers develop only duopoly models.

After discussing the exogenous spillover case, this paper shows that with a quadratic spillover-prevention cost function, the FDI-performing firm may choose a positive level of spillovers lower than the exogenous level, and also shows how endogenizing spillovers affect the home firm's decision on plant location. As extensions of the model, this paper explores a n-FDI-performing firm case and a m-FDI-host-country firm case separate. In the m-FDI-host-country firm case, numerical examples show that spillover-prevention cost is an important factor and that the effects of the number of FDI host country firms on the level of spillovers and on the cutoff value of trade cost are not always monotonic. An welfare analysis shows that in the duopoly case, endogenizing FDI spillovers shifts down the range of the trade cost where FDI is desirable for both the home firm and the foreign country from the exogenous spillover case.

[1] In the IO literature, firms' behavior of raising rivals' cost has been discussed. For instance, Banerjee and Lin (2003) develop a model of R&D competition in which a R&D investment decreases the firm's marginal cost and increases the price of the intermediate good at the same time, which, in turn, hurts its rivals.

The rest of this article is arranged as follows. Section two describes the duopoly model. Section three extends the model to oligopoly. Section four develops an welfare analysis in the duopoly model. Finally, section five concludes this paper.

2 Model

This paper develops a duopoly model based on Horstmann and Markusen (1992). Consider two countries, home and foreign, and a home firm plans to enter the foreign market either by exports or FDI. Assume that to export products to the foreign country, the home firm must pay a unit trade cost of t. After the decision on plant location, the home firm competes with a foreign firm by quantity of the same product. A linear inverse demand is assumed; $P = A - Q$ where P is the price of the product, Q is the total quantity, and A is a positive constant.

Suppose that marginal costs of the both firms are constant. The marginal cost of the home firm is c, and that of the foreign firm is $(1+d)c$, where d is a positive constant. Thus, the home (foreign) firm has a cost (dis)advantage and the degree of its (dis)advantage is captured by the parameter d. Suppose that FDI reduces the cost disadvantage to the foreign firm by s while exports does not at all. After FDI, the marginal cost of the foreign firm is $(1+d-s)c$. Such a decrease in the marginal cost is referred as "FDI spillovers" in this paper.[2]

First, as a benchmark, a case of exogenous spillovers is discussed. In this case, a degree of spillovers s is exogenous for both the home and foreign firms, as well as the trade cost t and other exogenous variables. Then endogenous spillovers, which the home firm may determine, are examined.

2.1 Benchmark: Exogenous Spillovers

Suppose that the level of spillovers due to FDI is s_0 and it is given to both the home and foreign firms. Then, the profits of the home and foreign firms with each of the plant location of the home firm are as follows.

$$\pi_h = \begin{cases} (A-x-y)x-(c+t)x & \text{No FDI, i.e. exports,} \\ (A-x-y)x-cx & \text{FDI.} \end{cases} \tag{1}$$

$$\pi_f = \begin{cases} (A-x-y)y-(1+d)cy & \text{No FDI,} \\ (A-x-y)y-(1+d-s_0)cy & \text{FDI.} \end{cases} \tag{2}$$

π_h and π_f are profits of the home and foreign firms respectively. x and y are quantity produced by the home and foreign firms respectively.

[2]One might assert that exports also make some spillovers although the degree is lower than that with FDI. However, for the tractability of the model, no spillovers with exports are assumed in this paper.

From the first order conditions, the quantity produced by the each firm in the each case is the following. When the home firm chooses exports (Case E),

$$x^E = \frac{A + (-1+d)c - 2t}{3}, \tag{3}$$

$$y^E = \frac{A + (-1-2d)c + t}{3}. \tag{4}$$

On the other hand, when the home firm chooses FDI (Case F),

$$x^F = \frac{A + (-1+d-s_0)c}{3}, \tag{5}$$

$$y^F = \frac{A + (-1-2d+2s_0)c}{3}. \tag{6}$$

By inserting the equilibrium outputs in each case to the profits (1) and (2), it is shown that $\pi_h = (x^i)^2$, where $i = E,\ F$, and that $\pi_f = (y^j)^2$, where $j = E,\ F$. This implies that comparing the outputs of a firm in the two cases is enough to compare the profits in the two cases. From equations (3) and (5), equilibrium outputs of the home firm in the two cases, the cutoff value of the trade cost is

$$t_c = \frac{s_0 \cdot c}{2}. \tag{7}$$

The home firm chooses FDI if the trade cost is higher than t_c. The counterpart of this condition in case of endogenous spillovers is discussed in the next subsection.

2.2 Endogenous Spillovers

Suppose that before deciding the plant location, the home firm may determine the degree of FDI spillovers s by itself. If making the level of spillovers lower than s_0, the level of FDI spillovers without any action by the home firm, needs additional costs, then an optimal value of s, which is still positive, might exist.

Assuming that the spillover-prevention cost function is quadratic, the profits of the home firm in case of FDI are

$$(A - x - y)x - cx - e(s_0 - s)^2$$

where e is a positive constant, which may reflect many factors affecting the firm's ability of spillover prevention. For instance, if the local labor market is tight and thus the firm must pay a higher wages than its local rivals to prevent headhunt, e can be high. With this quadratic cost function of spillover prevention, the cost is positive even if $s > s_0$. However, this paper shows that the level of spillovers optimally chosen by the home firm is lower than s_0.

The formulae of the profits of the home and foreign firms in case of exports are not changed. The model has two periods; decision on the degree of spillovers in

period one, and plant location and quantity competition in period two. The model is solved by backward induction.[3]

2.2.1 Period Two: Plant Location and Quantity Competition

The home firm chooses its optimal quantity associated with its optimal plant location, and the foreign firm chooses its optimal quantity. These decisions are made for a given level of spillovers with FDI. This implies that the first order conditions in period two are exactly the same as those in the benchmark case. Thus, equations (3) to (6), the equilibrium outputs of the two firms with the exogenous spillovers, hold with the endogenous spillovers too, although s_0 is now replaced by s.

2.2.2 Period One: Optimal Degree of Spillovers with FDI

Substituting the equilibrium outputs of the two firms in case of FDI (equations 5 and 6) into the profits of the two firms (the second line of equation 1 minus $e(s_0 - s)^2$ and the second line of equation 2) yields the profits of the two firms in period one if the home firm chooses FDI in period two;

$$\pi_h^{Period\ One} = \left\{\frac{A + (-1 + d - s)c}{3}\right\}^2 - e(s_0 - s)^2. \tag{8}$$

$$\pi_f^{Period\ One} = \left\{\frac{A + (-1 - 2d + 2s)c}{3}\right\}^2. \tag{9}$$

The home firm chooses s to maximize its profits. From the first order condition, the level of s maximizing the profits of the home firm is

$$s^* = \frac{9es_0 - c\{A + (-1 + d)c\}}{9e - c^2}. \tag{10}$$

Note that the lower bound for s^* is zero due to the definition of the spillovers. s^* is positive if (1) $e > \frac{c^2}{9}$ and if (2) $s_0 > \frac{c\{A+(-1+d)c\}}{9e}$. The first inequality is necessary for the second order condition to hold, and thus is assumed in this paper. The second inequality is likely to hold if $9e$ is much larger than c or if A is not too large. The second inequality is also assumed in the rest of this paper. Finally, one might ask if the level of spillovers at which the home firm sets is higher or lower than the exogenous level, s_0. The following lemma answers such a question.

Lemma 1 *The home firm makes the level of spillovers lower than the exogenous level, i.e.* $s_0 > s^*$.

[3]If the profits with exports are higher than those with FDI, the home firm chooses exports. In such a case, the investment for spillover prevention will not be realized.

Proof $s_0 - s^* = \frac{c}{9e-c^2}\{A+(-1+d-s_0)c\}$. The value inside the curly brackets is positive by the assumption that the output of the home firm with FDI is positive (equation 5). QED.

The prevention-cost parameter e have a positive effect on s^*. When the spillover prevention costs more, the home firm must allow more spillovers to save costs. The demand parameter A and the cost advantage parameter d have negative effects on s^*. Either a larger A or a larger d implies a larger profit opportunity. Thus, the home firm attempts to keep its cost advantage to utilize such an opportunity.

Inserting s^* into equations (8) and (9) yields equilibrium profits of the two firms, denoted by π_h^* and π_f^* respectively;

$$\pi_h^* = \frac{\{A+(-1+d-s_0)c\}^2 e}{9e-c^2}. \tag{11}$$

$$\pi_f^* = \left\{\frac{3e\{A+(-1-2d+2s_0)c\}-c^2(A-c)}{9e-c^2}\right\}^2 \tag{12}$$

By choosing s^*, the home firm increases its profits despite the costs of spillover prevention.[4]

If the level of FDI spillovers is endogenized, the value of trade cost equating the profits of the two locational modes is also changed. When the level of spillovers is equal to s_0, from equation (7), the cutoff level of trade cost is $\frac{s_0 \cdot c}{2}$. With endogenous spillovers, such a cutoff level is the solution for the following equation;

$$\frac{\{A+(-1+d-s_0)c\}^2 e}{9e-c^2} = \frac{\{A+(-1+d)c-2t\}^2}{9}.$$

The left hand side is the profits with endogenous FDI spillovers (equation 11), and the right hand side is the profits with exports, equal to the squared outputs (equation 3). The solution for the above equation, denoted by t_c^*, is

$$t_c^* = \sqrt{\frac{9e}{9e-c^2}} \cdot \frac{s_0 \cdot c}{2} + \left(1 - \sqrt{\frac{9e}{9e-c^2}}\right) \frac{A+(-1+d)c}{2}. \tag{13}$$

It is shown that $t_c^* < t_c = \frac{s_0 \cdot c}{2}$, which implies that the cutoff value of trade cost is lower with endogenous FDI spillovers than exogenous one. The following proposition summarizes the results.

Proposition 1 *In a duopoly model with a quadratic cost function of FDI-spillover prevention, endogenizing spillovers decreases the threshold of the trade cost for FDI.*

[4]If the home firm does not change the level of spillovers at s_0, from equation (5), its profits are $\frac{1}{9}\{A+(-1+d-s_0)c\}^2$, which is lower than the profits with $s = s^*$ (equation 11).

Proof $t_c^* < t_c$ is changed to $A+(-1+d-s_0)c > 0$, which holds by the assumption that the output with FDI is positive (equation 5) QED.

Proposition 1 implies that endogenizing spillovers makes FDI more likely, despite the costs of spillover prevention.[5] The cutoff value t_c^* has two terms. The first term is positive while the second term is negative. The first term captures the effect of spillover-prevention costs, which rises the threshold for FDI. The second term of the cutoff value t_c^* describes the effect of profit opportunity with FDI, which lowers the threshold. In the duopoly case, the second effect dominates the first one. However, as the model is extended to oligopoly, this property may change.

3 Effects of Market Structure

Suppose that more than one firm exist either in the home or foreign countries. In the former case, how to formulate FDI spillovers is an important question. The latter case may show how the market structure in the FDI host country affects the decisions on the plant location and FDI spillovers by the home firm.

3.1 n Home Firms

Suppose that $n(>1)$ identical firms exist in the home country and they play the two-period location-production game. The degree of spillovers may increase as more home firms perform FDI. However, the upper bound for the degree of spillovers is s_0. Thus, assume the following structure of FDI spillovers;

$$s = \frac{1}{n}\sum_{j=1}^{n} s_j$$

where s_j is the degree of spillovers from home firm j $(j = 1, \ldots, n)$. With this formula of FDI spillovers, the profits of home firm i and foreign firm, assuming that all home firms choose FDI, are as follows.

$$\pi_{h_i} = (A - \sum_{j=1}^{n} x_j - y)x_i - cx_i - e(s_0 - s_i)^2. \quad i = 1, \ldots, n. \tag{14}$$

$$\pi_f = (A - \sum_{j=1}^{n} x_j - y)y - (1 + d - \frac{1}{n}\sum_{j=1}^{n} s_j)cy. \tag{15}$$

[5]Note that as e gets higher, t_c^* goes to t_c. Because a higher e makes spillover prevention more difficult, the level of spillovers comes close to the exogenous level, i.e. spillovers without any prevention effort by the FDI-performing firm.

From the first order conditions in period two, the equilibrium outputs of the home firm i and the foreign firm are as follows.[6]

$$x_i^F = x^F = \frac{A + (-1 + d - s)c}{n + 2}. \quad i = 1, \ldots, n. \tag{16}$$

$$y^F = \frac{A + \{-1 - (n + 1)(d - s)\}c}{n + 2}. \tag{17}$$

Substituting the equilibrium outputs (equations 16 and 17) into the profits of the home firm i (equation 14) yields its objective function in period one.

$$\pi_{h_i}^{Period\ One} = \left[\frac{A + \left(-1 + d - \frac{1}{n}\sum_{j=1}^{n} s_j\right)c}{n + 2}\right]^2 - e(s_0 - s_i)^2. \quad i = 1, \ldots, n. \tag{18}$$

From the first order conditions with respect to s_i, a reaction function for the home firm i is as follows;

$$s_i = \frac{n^2(n + 2)^2 \cdot es_0 - n \cdot c\{A + (-1 + d)c\}}{n^2(n + 2)^2 \cdot e - c^2} + \frac{c^2}{n^2(n + 2)^2 \cdot e - c^2} \sum_{j \neq i} s_j. \quad i = 1, \ldots, n. \tag{19}$$

Assume $n^2(n + 2)^2 e > c^2$. This inequality corresponds to the assumption for the second order condition in the duopoly case. Note that the degree of spillovers by home firm i increases as the sum of spillovers of the all other firms increases. Therefore, FDI spillovers are strategic complements among the home firms.

From the first order conditions and the symmetry of the model among the home firms, the level of FDI spillovers by the home firm i maximizing its profits is;

$$s_i^* = s^* = \frac{n(n + 2)^2 \cdot es_0 - c\{A + (-1 + d)c\}}{n(n + 2)^2 \cdot e - c^2}. \quad i = 1, \ldots, n. \tag{20}$$

s^* increases as n increases.[7] Besides the strategic complementarity of s shown by the reaction function (equation 19), this might be due to free-rider property of investment; a home firm may save the cost of spillover prevention if other home firms invest. By de l'Hôpital's rule, as n goes to infinity, s^* converges to s_0, the level of spillovers when no investment for spillover prevention is done.

In case of the n-home firms, the cutoff value of the trade cost is the solution for the following equation;

$$\frac{\{(n + 2)^2 n^2 e - c^2\}\{A + (-1 + d - s_0)c\}^2 e}{\{(n + 2)^2 ne - c^2\}^2} = \frac{1}{(n + 2)^2}\{A + (-1 + d)c - 2t\}^2.$$

[6] The equilibrium outputs in case of exports are derived by replacing "3" in the denominators of the output equations (3) and (4) with $n + 2$.

[7] $\frac{\partial s^*}{\partial n} = (n + 2)(3n + 2)ce\{A + (-1 + d - s_0)c\}$. The value inside the curly brackets is positive by the assumption that the output of the home firm with FDI is positive (equation 5).

The left hand side, the profits with FDI, are derived by substituting s^* (equation 20) into the objective function of the home firm i in period one (equation 18). The right hand side is the profits with exports, equal to the squared equilibrium output with exports. The cutoff value of the trade cost, denoted by $t_c^{n^*}$, is

$$\begin{aligned} t_c^{n^*} &= \sqrt{\frac{(n+2)^4n^2e^2-(n+2)^2c^2e}{\{(n+2)^2ne-c^2\}^2}}\cdot\frac{s_0\cdot c}{2} \\ &\quad+\left(1-\sqrt{\frac{(n+2)^4n^2e^2-(n+2)^2c^2e}{\{(n+2)^2ne-c^2\}^2}}\right)\frac{A+(-1+d)c}{2}. \end{aligned} \tag{21}$$

One important question with this equation is whether extending the model to the n-home firms' one makes the cutoff value higher or lower than that with exogenous spillovers s_0. In the n-home firm case, the cutoff value with exogenous spillovers, denoted by t_c^n, is the same as in the duopoly case and is equal to $\frac{s_0\cdot c}{2}$.[8] The following proposition is the answer to this question.

Proposition 2 *In a n-home firm model with a quadratic cost function of FDI-spillover prevention, endogenizing spillovers decreases the threshold of the trade cost for FDI.*

Proof $t_c^{n^*} < t_c^n$ is changed to $A+(-1+d-s_0)c > 0$, which holds by the assumption that the output with FDI is positive (equation 16 at $s = s_0$) QED.

Proposition 2 shows that n-home firm case is not different from the duopoly case about home firms' decision on plant location. As shown below, m-foreign firm case has a similar property. However, m-foreign firm case has a different property too.

3.2 m Foreign Firms

Suppose that $m > 1$ identical firms exist in the FDI host country, and that once the home firm performs FDI, the spillovers occur to all m foreign firms equally. Then, the profits of the home firm and the foreign firm j with FDI are as follows.

$$\pi_h = (A-x-\sum_{i=1}^{m}y_i)x-cx-e(s_0-s)^2. \tag{22}$$

$$\pi_{f_j} = (A-x-\sum_{i=1}^{m}y_i)y_j-(1+d-s)cy_j, \quad j=1,\ldots,m. \tag{23}$$

From the first order conditions in period two and the symmetry of the model among the foreign firms, the equilibrium outputs of the home firm and the foreign firm j

[8] t_c^n is derived by equating the outputs of the home firm in cases E and F with assuming that FDI spillovers are exogenous and the level is at s_0.

are as follows.

$$x^F = \frac{A+(-1+md-ms)c}{m+2}. \tag{24}$$

$$y_j^F = \frac{A+(-1-2d+2s)c}{m+2}, \quad j=1,\ldots,m. \tag{25}$$

Substituting the equilibrium outputs (equations 24 and 25) into the profits of the home firm (equation 22) yields its objective function in period one.

$$\pi_h^{Period\ One} = \left[\frac{A+(-1+md-ms)c}{m+2}\right]^2 - e(s_0-s)^2. \tag{26}$$

From the first order condition, the level of FDI spillovers maximizing the profits of the home firm is;

$$s^* = \frac{(m+2)^2 es_0 - mc\{A+(-1+md)c\}}{(m+2)^2 e - m^2c^2}. \tag{27}$$

Assume $e > \frac{m^2}{(m+2)^2}c^2$ for all $m \geq 1$, which is necessary for the second order condition to hold.[9]

Unlike the n-home firm case, the effect of the number of the foreign firms m on s^* depends on the level of m. The derivative of s^* with respect to m is

$$\begin{aligned}\frac{\partial s^*}{\partial m} &= \frac{1}{\{(m+2)^2e-m^2c^2\}^2} \\ &\quad \times[-4m(m+2)c^2e(d-s_0)+c(A-c)\{(m^2-4)e-m^2c^2\}].\end{aligned}$$

The sign of the effect of m is the same as the sign of the value inside the square brackets. The first term is negative. The second term is also negative if $2 \geq m$. However, the second term may be positive if $m \geq 3$, and the overall effect may be positive too. If s_0 is almost equal to d, i.e. FDI erases most of the cost advantage to the home firm unless it invests in spillover prevention, and if e is much larger than c^2, i.e. spillover prevention is very costly, the effect of m on s^* may be positive.

The intuition behind these results is simple. When the number of the foreign firms is small, competition in the foreign market is not severe. The home firm enjoys the oligopoly rent with its cost advantage to the foreign firms. Under such a circumstance, an increase in the number of the foreign firms increases the degree of competition drastically. Although they are low-tech firms, their impact on the home firm is not negligible because of the small number of them. Thus the home firm tries to keep its cost advantage by allowing less spillovers. When the number

[9]The right hand side of this inequality converges to c^2 as m goes to infinity. Therefore, $e > c^2$ is assumed in the rest of this paper in order for the inequality $e > \frac{m^2}{(m+2)^2}c^2$ to hold for all $m \geq 1$.

of the foreign firms is large, the foreign market has one strong home firm and many weak foreign firms. Under this different circumstance, if the spillover prevention is very costly, the home firm allows more spillovers. However, if the spillover prevention is not costly, it is possible that the home firm allows less spillovers.

Figure 1 supports the above intuition. The horizontal axis is the number of the foreign firms, and the vertical axis is the degree of FDI spillovers.[10] Two cases are examined; $e = 3$ and 5. When $e = 3$, as the number of foreign firms increases, the degree of spillovers decreases monotonically. On the other hand, when $e = 5$, the degree of spillovers increases slightly after the number of the foreign firms passes ten. Therefore, higher spillover prevention costs may allow the home firm to give more spillovers to the foreign firms as the number of foreign firms increases. In either cases, however, the effect of changing market structure from duopoly to oligopoly is so large that it works to lower the level of spillovers.

How does the cutoff value of the trade cost change as m increases? The cutoff value is the solution for the following equation;

$$\frac{e}{(m+2)^2e - m^2c^2}\{A+(-1+md-ms_0)c\}^2 = \frac{1}{(m+2)^2}\{A+(-1+md)c-(m+1)t\}^2.$$

The left hand side is the profits of the home firm with FDI, and the right hand side is those with exports. The solution, denoted by $t_c^{m^*}$, is

$$\begin{aligned} t_c^{m^*} &= \sqrt{\frac{(m+2)^2e}{(m+2)^2e - m^2c^2}} \cdot \frac{ms_0 \cdot c}{m+1} \\ &\quad + \left(1 - \sqrt{\frac{(m+2)^2e}{(m+2)^2e - m^2c^2}}\right) \frac{A + (-1+md)c}{m+1}. \end{aligned} \tag{28}$$

The first term is positive and captures the effect of spillover prevention, while the second term is negative and captures the effect of profit opportunity with FDI. One important question is whether extending the model to the m-foreign firms' one makes the cutoff value higher or lower than that with exogenous spillovers s_0. The following proposition is the answer to this question.

Proposition 3 *In a m-foreign firm model with a quadratic cost function of FDI-spillover prevention, endogenizing spillovers decreases the threshold of the trade cost for FDI.*

Proof $t_c^{m^*} < t_c^m$ is changed to $A+(-1+md-ms_0)c > 0$, which holds by the assumption that the output with FDI is positive (equation 24). QED.

[10] To draw the figure, the exogenous variables except for the parameter of spillover prevention cost e and m are set as follows; $s_0 = 1.5,\ c = 1,\ A = 10,$ and $d = 3$.

With Proposition 2, Proposition 3 shows that extending the model from duopoly to oligopoly does not change the property that endogenizing FDI spillovers makes FDI more likely. However, the m-foreign firm case is different from the n-home firm case about the cutoff value of the trade cost with exogenous spillovers. In the former case, it is increased as m increases while in the latter case, it is constant and is the same as in the duopoly case. From this point of view, Figure 2 raises some interesting points.[11] Figure 2 shows how an increase in e, the parameter of spillover-prevention costs, from 2 to 3 affects the effect of m on $t_c^{m^*}$. Figure 2 give two interesting points. First, whatever the level of e is, the cutoff value of the trade cost increases when m increases from one to two. This can be an effect of intensified competition. The second point is that the cutoff value with $e = 2$ decreases as m increases, while the opposite thing occurs with $e = 3$. Therefore, low prevention cost makes FDI more likely while high one makes it less likely.

The above case would be consistent with the observations in Section one; a firm in developed country considering to enter a foreign market where many low-tech firm exists. If the firm does not choose FDI, one reason might be high costs of FDI-spillover prevention and a large number of foreign firms at the same time.

4 Welfare Analysis

One possible interest for the foreign country government is how FDI spillovers affect not just the profits of the foreign firm but the welfare of the country. If the following two conditions are satisfied, the welfare of the FDI host country, defined by the sum of the consumer surplus and the profits of the foreign firm, is higher with FDI than with exports by the home firm.

1. The sum of outputs of the home and foreign firms is larger with FDI than with exports. This condition is for a higher consumer surplus with FDI.

2. The output of foreign firm is larger with FDI than with exports. This condition is for higher profits of the foreign firm with FDI.

Although examining if these two conditions hold is more restrictive than an usual way of analyzing welfare, i.e. comparing the welfare in the two cases, this methodology has two advantages. First, calculation is relatively easy because only the outputs of the two firms are used. Moreover, because of the second condition, any redistributional issue in the foreign country can be avoided. Thus, whether these two conditions hold in the duopoly is examined in this section, first with exogenous spillovers $s = s_0$ and then with endogenous spillovers s^*.

[11] To draw the figure, the exogenous variables except for spillover prevention cost parameter e and m are set as follows; $s_0 = 1,\ c = 1,\ A = 10,$ and $d = 3$.

4.1 Welfare with Exogenous FDI Spillovers

From equations (3) and (4), outputs of the two firms in case of exports (Case E), the total output in Case E, Q^E, is $\frac{2A+(-2-d)c-t}{3}$. On the other hand, from equations (5) and (6), outputs of the two firms in case of FDI (Case F), the total output in Case F, Q^F, is $\frac{2A+(-2-d+s_0)c}{3}$. Because of lower marginal costs for the both firms due to FDI, it is shown that $Q^F > Q^E$. Thus, the first condition holds.

From equations (4) and (6), the output of the foreign firm is higher with FDI than with exports if $t < 2s_0 \cdot c$. This inequality implies that for the foreign firm, the effect of FDI on its marginal cost is larger than that of exports, i.e. the trade cost. Combining this inequality with the condition with which the home firm chooses FDI, the following proposition holds;

Proposition 4 *If the trade cost t is higher than $\frac{s_0 \cdot c}{2}$ and lower than $2s_0 \cdot c$ at the same time, the home firm chooses FDI and the welfare of the foreign country is higher with FDI than with exports.*

4.2 Welfare with Endogenous FDI Spillovers

In Case E, the outputs of the two firms are the same as those in the exogenous case because the degree of spillovers s is not included. Thus, $Q^E = \frac{2A+(-2-d)c-t}{3}$. Inserting the value of s^* (equation 10) into equations (5) and (6) yields the equilibrium outputs of the two firms in Case F, denoted by x^{F^*} and y^{F^*} respectively;

$$x^{F^*} = \frac{3e\{A+(-1+d-s_0)c\}}{9e-c^2}. \tag{29}$$

$$y^{F^*} = \frac{3e\{A+(-1-2d+2s_0)c\}-c^2(A-c)}{9e-c^2}. \tag{30}$$

From equations (29) and (30), the total output in Case F with endogenous FDI spillovers, denoted by Q^{F^*}, is $\frac{3e\{2A+(-2-d+s_0)c\}-c^2(A-c)}{9e-c^2}$. The first condition holds. First, the trade cost t has a negative effect on Q^E while no effect on Q^{F^*}. Second, like the condition with which the home firm chooses FDI, a cutoff value of the trade cost for the total output can be derived. Solving the equation $Q^E = Q^{F^*}$ for t yields the cutoff value, denoted by t_c^Q;

$$t_c^Q = \frac{c^2\{A+(-1+d)c\}-9ces_0}{9e-c^2}. \tag{31}$$

From equation (10), $t_c^Q = -s^*c < 0$. Because t is nonnegative, $Q^{F^*} > Q^E$ and thus the first condition is satisfied. How about the second condition? Solving the equation $y^E = y^{F^*}$ for t yields another cutoff value of the trade cost, t_c^y;

$$t_c^y = \frac{18ces_0-2c^2\{A+(-1+d)c\}}{9e-c^2}. \tag{32}$$

From equation (10), $t_c^y = 2s^*c$. Because t has a positive effect on y^E while no effect on y^{F^*}, if $t < t_c^y = 2s^*c$, $y^{F^*} > y^E$ and thus the second condition holds.

From Proposition 4, in case of the exogenous spillovers, if $\frac{s_0 \cdot c}{2} < t < 2s_0 \cdot c$, the home firm chooses FDI and FDI is desirable for the foreign country. In case of the endogenous spillovers, the corresponding condition is $t_c^* < t < t_c^y = 2s^*c$. Proposition 1 shows that $t_c^* < \frac{s_0 \cdot c}{2}$, and Lemma 1 shows that $s^* < s_0$.

The following proposition summarises the results.

Proposition 5 *In the duopoly model, endogenizing FDI spillovers decreases both the top and the bottom of the range of the trade cost where the home firm chooses FDI and FDI is desirable for the foreign country.*

Proposition 5 is similar with Proposition 1, saying that endogenizing spillovers makes FDI more likely. Proposition 5 implies that for a given trade cost, endogenizing spillovers increases the possibility that FDI is desirable for both the home firm and the foreign government. It also suggests that a trade policy related with the trade cost such as tariff reduction may be affected by the characteristics of FDI spillovers, i.e. how much the home firm may control for it. In the model, parameter e is the key; as mentioned before, the labor market of FDI host country may affect firm's plant location through its impact on FDI spillovers, not through the labor cost of blue collar workers that my argue.

5 Conclusions

With a duopoly and oligopoly models, this paper explores roles of FDI spillovers as a strategic variable for firms entering the foreign market. This paper shows that (1) Endogenizing spillovers make FDI more likely, compared to the exogenous case, (2) n-home firm case may have similar implications with the duopoly case, and (3) m-foreign firm case can be different from others, depending on the parameter of the spillover-prevention costs. Although endogenizing spillovers makes FDI more likely as well as the duopoly case, the effect of m on the level of spillovers and the cutoff value of the trade cost may be positive. (4) In the duopoly model, endogenizing spillovers shift down the range of the trade cost where both the home firm and the foreign country prefer FDI.

In the model, determinants of e, parameter of spillover prevention, are discussed only descriptively. More formal analysis on the local labor market with relating its impact on spillover prevention may be a possible extension of the model.[12]

[12]See Glass and Saggi (2002), for instance.

Appendix: Generalized Oligopoly Model

In this appendix, the oligopoly model is generalized; (1) n home firms and m foreign firms exist, and (2) for demand and cost functions, their functional forms are not specified.[13] To generalize the discussion in Section three, the following general forms of cost functions are assumed.

(i) Reduction of the marginal cost of a foreign firm, c_f, by FDI spillovers:

$$c_f = c_f(s), \ \frac{dc_f}{ds} < 0. \tag{A1}$$

The marginal cost of a home firm is denoted by c_h.
(ii) Spillover prevention costs $e(s)$:

$$e(s_0) = 0, \ 0 \geq \frac{de}{ds}. \tag{A2}$$

$\frac{de}{ds}$ is equal to zero when $s = s_0$. The quadratic cost function used in the text satisfies these properties. The negative sign of the derivative implies that a home firm must pay more to lower the degree of spillovers through its FDI. Then, the profits of the home firm i and the foreign firm j are as follows;

$$\pi_{h_i} = \begin{cases} p(Q)x_i - (c_h + t)x_i, \ Q = \sum_{k=1}^{n} x_k + \sum_{l=1}^{m} y_l & \text{Exports,} \\ p(Q)x_i - c_h x_i - e(s_i) & \text{FDI.} \end{cases} \tag{A3}$$

$$\pi_{f_j} = \begin{cases} p(Q)y_j - c_f(0)y_j & \text{Exports,} \\ p(Q)y_j - c_f(s)y_j, \ s = \frac{1}{n}\sum_{k=1}^{n} s_k. & \text{FDI.} \end{cases} \tag{A4}$$

When the all home firms chooses exports, from equations (A3) and (A4), the first order conditions with symmetry of the model are following.

$$\begin{aligned} p(nx + my) + \left.\frac{dp}{dQ}\right|_{Q=nx+my} \cdot x &= c_h + t \qquad \text{home firm,} \\ p(nx + my) + \left.\frac{dp}{dQ}\right|_{Q=nx+my} \cdot y &= c_f(0) \qquad \text{foreign firm.} \end{aligned}$$

From these equations, the equilibrium outputs of home and foreign firms, $x^E = x(c_f(0), t)$ and $y^E = y(c_f(0), t)$, are derived.

When the all home firms chooses FDI, from equations (A3) and (A4), the first conditions with symmetry of the model are following.

$$\begin{aligned} p(nx + my) + \left.\frac{dp}{dQ}\right|_{Q=nx+my} \cdot x &= c_h \qquad \text{home firm,} \\ p(nx + my) + \left.\frac{dp}{dQ}\right|_{Q=nx+my} \cdot y &= c_f(s) \qquad \text{foreign firm.} \end{aligned}$$

[13]The author thanks Akihiko Yanase for providing the base of the general-case analysis.

From these equations, the equilibrium outputs of home and foreign firms for a given level of FDI spillovers, $x^F = x(c_f(s), 0)$ and $y^F = y(c_f(s), 0)$, are derived. Inserting these outputs in the profits of home firm i yields its objective function in period one;

$$\{p(nx^F + my^F) - c_h\}x^F - e(s_i),\ i = 1, \cdots, n.$$

From the first order conditions for the all home firms with symmetry of the model, the following equation determines the equilibrium level of FDI spillovers;

$$\left(\frac{n-1}{n}\frac{\partial x^F}{\partial c_f} + \frac{m}{n}\frac{\partial y^F}{\partial c_f}\right)\left.\frac{dp}{dq}\right|_{Q=nx^F+my^F} \cdot x^F \cdot \frac{dc_f}{ds} - \frac{de}{ds} = 0.$$

The impact of lower FDI spillovers on the profits of a home firm are twofold. It increases the first term of the above equation while it decreases the second term.

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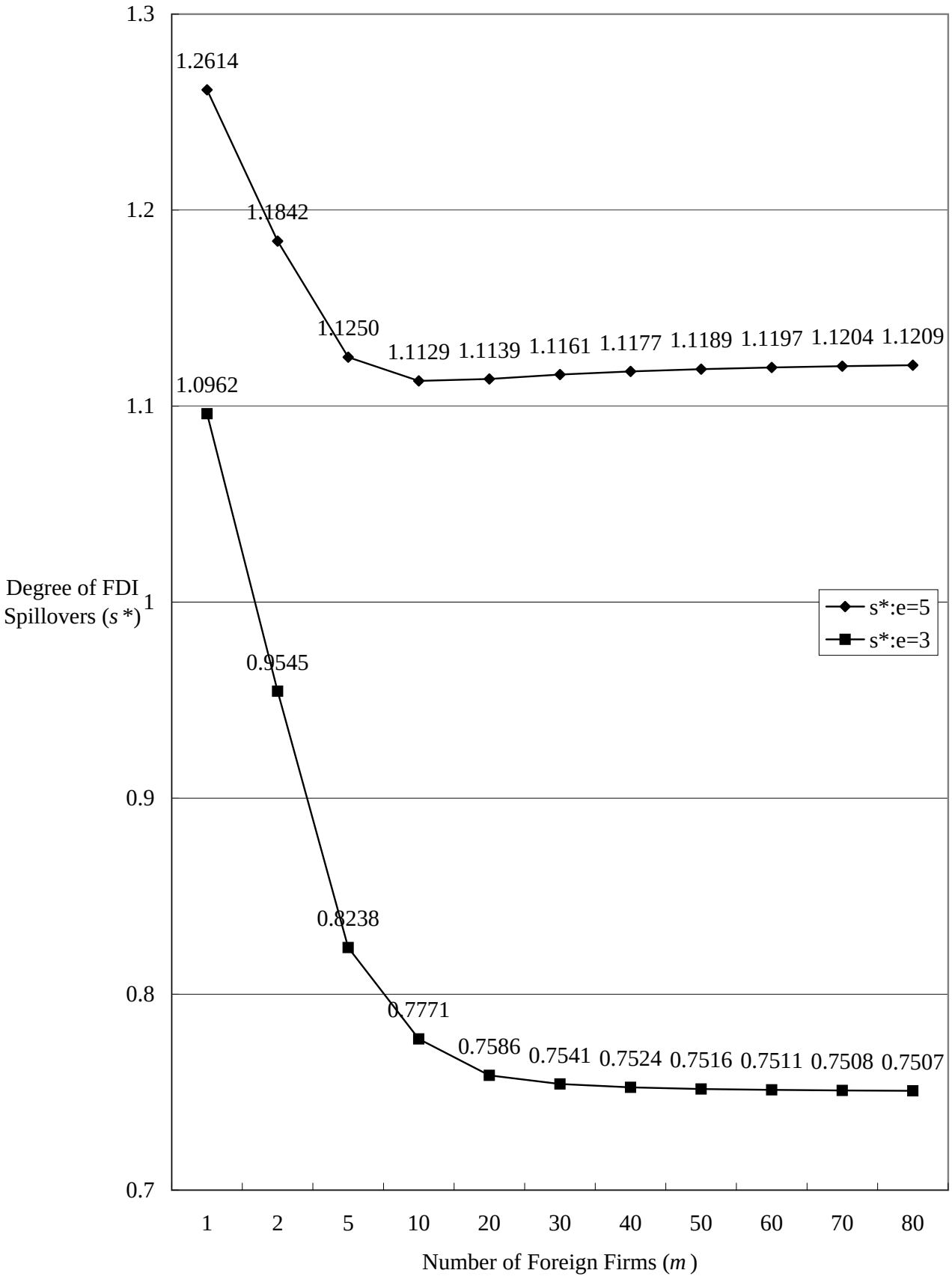

Figure 1. Number of Foreign Firms, Spillover Prevention Cost, and Degree of FDI Spillovers.

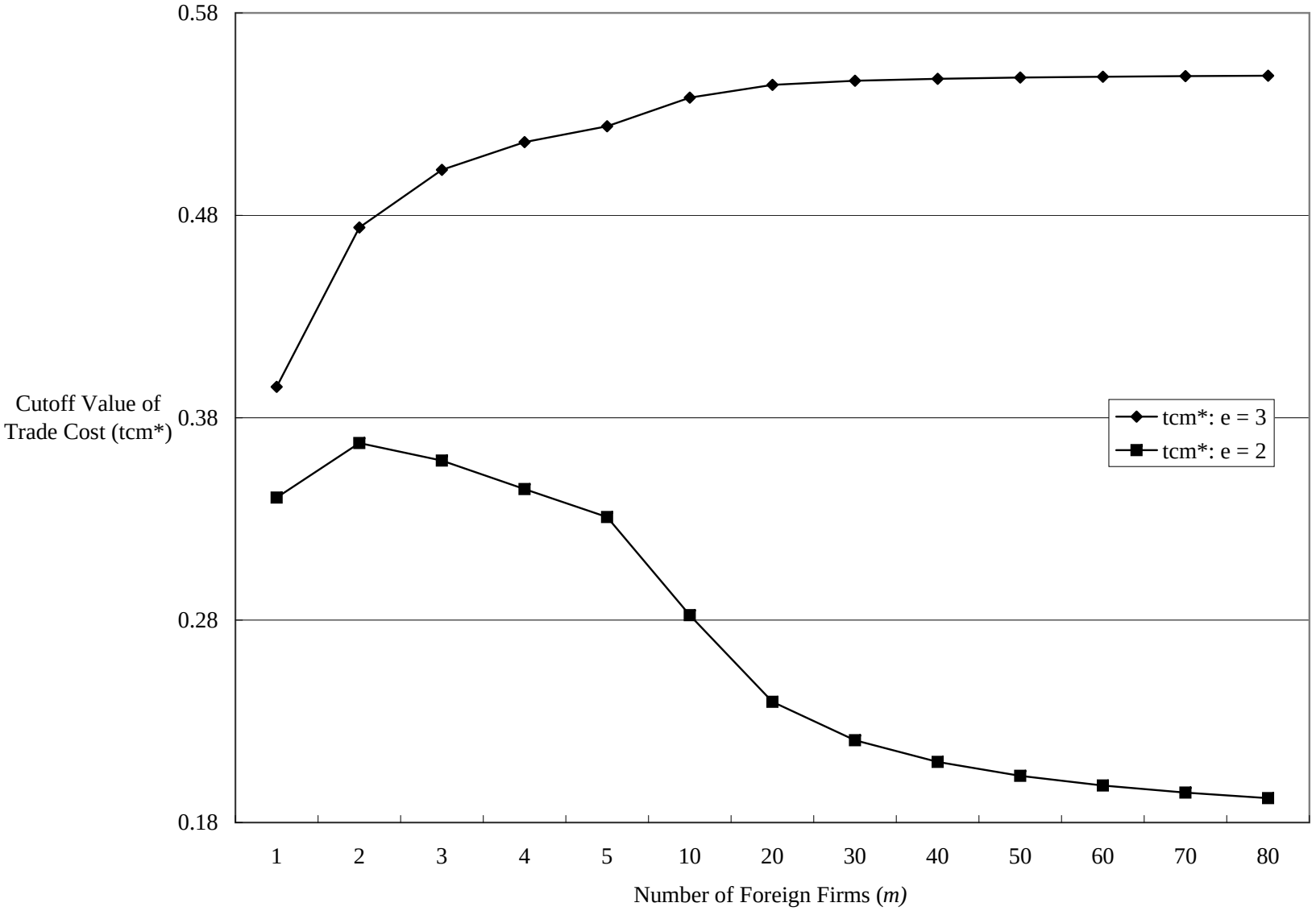

Figure 2. Number of Forieign Firms, Spillover Prevention Cost, and Cutoff Value of Trade Cost.