

# Technology Advantage and Home-market Effects

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## **Abstract**

According to the conventional home-market effect, free trade tends to shrink the market share for a small economy in the differentiated manufacturing goods, and in the extreme leads to a complete hollow-out of the industry from the small economy. This paper considers the technology difference between countries in the standard Helpmand-Krugman model. It is shown that the home-market effects could be offset and even reversed if the smaller economy has better technology. The effect of technology advantage are decomposed into two parts: a direct effect from lower unit cost that leads to higher output level of each firm; an indirect effect through the change of survival firms after trade. Based on the theoretical results we derive the gravity equation to undertake empirical tests on the hypothesis of home-market effects, direct and indirect technology effects, using the US patent stock of 2002 for six industries ranged from the most technology-intensive industry of semiconductor to the most labor-intensive industry of textile and apparel. The empirical results support the technology effects for all the six industries, and the more the technology intensity of an industry, the higher the effect of the technology advantage to offset the home-market effect and more likely to reverse the home-market effects.

**Classification :** F12, F14, F15

**Key Words :** Home-market Effect, Technology Advantage, Gravity Equation

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# 1 Introduction

This paper aims at exploring the effect of technology advantage on the conventional home market effects. In a monopolistic competition model, Krugman (1979, 1980) and Helpman and Krugman (1985) illustrate the home market effects, that is, a country with larger consumers will run a trade surplus in the differentiated products characterized by scale economies.

The illustration of the home market effects in these papers relies on a specific market structure and functional form assumptions, especially on Dixit and Stiglitz's (1977) preferences and 'iceberg' transport costs. Thus, a further development in the literature has been to examine the robustness of the home market effects under different modeling assumptions.

In a model of monopolistic-competition with many industries, Hanson and Xiang (2004) prove that higher transport costs and more differentiated products tend to have more intensive home market effects. Davis (1998) illustrates that if both the homogeneous and differentiated goods face identical transport costs, then the home market effect will vanish. Behrens (2005) shows that the existence of non-traded goods may also offset the home market effect. Head, et al. (2002) find the home market effect may reverse in a Cournot-competition model, in which varieties are linked to nations rather than firms. This result is consistent with those found in Head and Ries (2001) who consider a model featuring perfect competition and national product differentiation. The reversal of home market effect is also found in a 'reciprocal-dumping' model by Feenstra, et al. (2001) considering nation-specific varieties. Yu (2005) shows that if the consumer's preference follows the form of a constant elasticity of substitution between the homogeneous and differentiated goods, then the reverse home market effect may occur depending on the level of elasticity.

More specifically, if the elasticity of substitution is less than one, then the home market effects will reverse.

Under the standard assumption of identical technology in the literature on home market effects, what is ignored is the fact that a better technology for a smaller economy can offset the its market size disadvantage for an increasing return to scale sector. Theoret-

ically, in a monopolistic competition market a firm with better technology, reflected in lower marginal cost or fixed cost, should have higher market share in equilibrium. Similarly, in a two-country monopolistic competition market, the country with technology advantage would not only find each of its firms having higher output, but also support more number of firms to survive under free trade, and consequently run net trade surplus in the underlying industry. Intuitively, if the technology advantage is with the smaller country, then the standard home market effect, that as noted earlier is against the small country, will be counterbalanced to a certain degree depending on the intensity of technology difference. On the contrary, if it is the large country that has the technology advantage, then the home market effect will be enhanced.

To focus on the role of technology advantage for offsetting or even reversing the home market effects, we will employ the same Helpman-Krugman type two-sector model (one homogeneous good with no transport costs, and the other differentiated good with a positive transport cost) in the literature, but allow for technology differences between countries in the differentiated sector. Beginning with a theoretical model, we will prove that the home-market effects can be offset by the technology advantage of the smaller country. In extreme, a smaller but technologically better country can have trade-induced expansion rather than reduction in its manufacturing sector. On the contrary, for a big but technologically poorer country, free trade may end up decreasing rather than increasing its share in the differentiated manufacturing sector. In other words, the technology advantage to the small country may lead to a home market effect reversal, if the technology difference is large enough.

Then, from the theoretical model we derive the gravity equation and three home-market related hypotheses for further testing. By matching the trade data with the amount of each country's industry-specific patent stock registered in the U.S. Patent and Trademark Office (USPTO), which is to proxy country specific the technology level, we establish samples of six different industries, ranging from the most technology-intensive industry of semiconductor (SITC 776) to the conventional labor-intensive apparel and textile (SITC 84). And, as is theoretically predicted, for all the six industries the empirical result does reconfirm the conventional home-market effect, that is, the export country's market size affects more the exports than that of the import country's size. Furthermore

and newly to the literature, the empirical evidence also support significantly the role for technology advantage to offset the home-market effect. However, the degree of the technology effect varies from industry to industry, the more the technology-intensive the more likely that the home-market effect will be reversed due to the technology of the small economy.

The remainder of this paper is organized as follow. Section 2 establishes the theoretical model with technology difference between countries, and solves for free trade equilibrium and derives the corresponding gravity equation and related hypothesis for testing. Section 3 provides empirical tests and simulations for each of the six underlying industries. Section 4 concludes the paper.

## 2 The theoretical model

Suppose that the economy comprises two countries, home and foreign (denoted by an asterisk (\*)), and that they are similar in regard to the consumer's preferences but not necessarily in their production technologies and size. There is only one factor of production, labor, and thus the relative country size is measured by the labor force. Let  $L$  denote the size of the world's total labor force, of which  $\gamma L$  ( $0 < \gamma < 1$ ) belongs to the home country and  $(1 - \gamma)L$  belongs to the foreign. That is,  $\gamma$  denotes the relative home country size. As usual, we assume that there are only two sectors: one a competitive sector which produces a homogeneous goods ( $A$ ), and the other a monopolistically competition sector which produces a large number of varieties of a firm-specific differentiated product ( $X$ ). The homogeneous good, which will be taken as the numeraire, is produced under constant returns to scale technology.

The central assumption is that there is a positive (but not prohibitive) transport cost for the differentiated product under free trade. More specifically, for the differentiated product, the international shipment incurs a "iceberg" effect of transport costs, that is, for  $t$  ( $t > 1$ ) units of the goods shipped, only one unit arrives. Thus, the domestic price of the imported differentiated product will be  $tp^*$ , provided that  $p^*$  is the producer's price for the foreign product. On the other hand, the homogeneous good is assumed to be costlessly to trade, and both countries produce it after trade; with identical technology in this sector, this assumption implies that the wage rates are equal between the countries.

Furthermore, we assume that all consumers share the same Cobb-Douglas preferences, which are represented by the utility function shown below:

$$U = C_A^{1-s} C_X^s, \quad 0 < s < 1, \quad (1)$$

where  $C_A$  is the consumption level of the homogeneous good,  $C_X$  is the quantity index of the differentiated products consumed, and  $s$  is the share of spending devoted to the differentiated products. The quantity index takes the well-known form

$$C_X = \left( \sum_{i=1}^n c_i^\theta + \sum_{i^*=1}^{n^*} c_i'^\theta \right)^{1/\theta}, \quad C_X^* = \left( \sum_{i=1}^{n^*} c_i^{*\theta} + \sum_{i=1}^n c_i'^{*\theta} \right)^{1/\theta}, \quad 0 < \theta < 1, \quad (2)$$

where  $n$  ( $n^*$ ) is the number of products produced in the home (foreign) country,  $c_i$  ( $c_i'$ ) is the quantity of the home (foreign) product  $i$  consumed by the home consumers,  $c_i^*$  ( $c_i'^*$ ) is the quantity of the foreign (home) product  $i$  consumed by the foreign consumers, and  $\varepsilon \equiv 1/(1-\theta)$  is the elasticity of substitution between every pair of differentiated products.

Solving the consumer's utility maximization problem yields the following domestic demand function ( $c_i$ ) for each unit of home product  $i$ .

$$c_i = p_i^{-\varepsilon} P^{\varepsilon-1} s w \gamma L = p_i^{-\varepsilon} P^{\varepsilon-1} s Y, \quad (3)$$

where  $p_i$  denotes the price of home product  $i$ ,  $P$  denotes the price index for the differentiated goods to be shown later,  $w$  denotes the nominal wage, and thus  $w \gamma L$ , which has been rewritten as  $Y$ , represents the income level for the home country. Similarly, the derived demand for foreign product  $i$  on the part of home consumers ( $c_i'$ ) is

$$c_i' = (t p_i)^{-\varepsilon} P^{\varepsilon-1} t s w \gamma L = (t p_i)^{-\varepsilon} P^{\varepsilon-1} t s Y. \quad (4)$$

Correspondingly, we have the foreign consumers' demand for the domestic goods,  $c_i^*$ , and for the imported goods,  $c_i'^*$ , as follow:

$$c_i^* = p_i^{-\varepsilon} P^{*\varepsilon-1} s w^* (1-\gamma) L = p_i^{-\varepsilon} P^{*\varepsilon-1} s Y^*, \quad (3')$$

$$c_i'^* = (t p_i)^{-\varepsilon} P^{*\varepsilon-1} t s w^* (1-\gamma) L = (t p_i)^{-\varepsilon} P^{*\varepsilon-1} t s Y^*. \quad (4')$$

The price index for the differentiated products that is dual to the subutility is represented by

$$P = \left[ \sum_{i=1}^n p_i^{1-\varepsilon} + \sum_{i^*=1}^{n^*} (t p_i^*)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}, \quad P^* = \left[ \sum_{i=1}^n (t p_i)^{1-\varepsilon} + \sum_{i^*=1}^{n^*} (p_i^*)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}. \quad (5)$$

On the other hand, the production technology in the homogenous sector is such that one unit of output requires one unit of labor input. Apart from the traditional setup, we assume that there is a cross-country technological heterogeneity in the monopolistically competitive sector. Let the amount of labor required to produce the quantity  $x_i$  of product  $i$  be given by

$$l_i = a + bx_i, \quad l_i^* = a^* + b^* x_i^*, \quad (6)$$

where  $a > 0$  ( $a^* > 0$ ) is the fixed labor requirement and  $b > 0$  ( $b^* > 0$ ) is the marginal labor requirement for the home (foreign) firm.

Profit maximization and zero profit conditions solve the equilibrium level of each home and foreign firm's output and price,  $x$ ,  $p$  and  $x^*$ ,  $p^*$  respectively, as follows:

$$\begin{aligned} x_i &= \frac{\theta}{1-\theta} \frac{a}{b}, & p &= \frac{b}{\theta}, \\ x_i^* &= \frac{\theta}{1-\theta} \frac{a^*}{b^*}, & p^* &= \frac{b^*}{\theta}. \end{aligned} \quad (7)$$

For simplicity, we will suppress the subscript in what followings. The market clearing condition for each of the differentiated products of the home firms, say,  $x$ , requires that  $x = c + c^*$ . In other words, total supply  $x$  should equal the sum of home and foreign demand,  $c$  and  $c^*$ , respectively. By making use of equations (3), (4') and (7), the market clearing condition for each home goods can be rewritten as:

$$\begin{aligned} \frac{\theta}{(1-\theta)} \frac{a}{b} &= p^{-\varepsilon} P^{\varepsilon-1} sY + (tp^*)^{-\varepsilon} P^{\varepsilon-1} tsY \\ &= \frac{p^{-\varepsilon} sY}{\phi_1} + \frac{\tau p^{-\varepsilon} sY^*}{\phi_2}, \end{aligned} \quad (8)$$

in which we have defined  $\phi_1$ ,  $\phi_2$  and  $\tau$  as follows:

$$\phi_1 \equiv np^{1-\varepsilon} + n^* \tau p^{*1-\varepsilon} \quad \text{and} \quad \phi_2 \equiv n\tau p^{1-\varepsilon} + n^* p^{*1-\varepsilon}, \quad (9)$$

$$\tau \equiv t^{1-\varepsilon}, \quad 0 < \tau < 1.$$

Correspondingly, we have the market clearing condition for each foreign goods,  $x^* = c' + c^*$ , and by making use of equations (3'), (4) and (7) we obtain:

$$\begin{aligned} \frac{\theta}{(1-\theta)} \frac{a^*}{b^*} &= (tp^*)^{-\varepsilon} P^{\varepsilon-1} tsY + p^{*\varepsilon-1} P^{*\varepsilon-1} sY^* \\ &= \frac{p^{*\varepsilon-1} \tau sY}{\phi_1} + \frac{p^{*\varepsilon-1} sY^*}{\phi_2}. \end{aligned} \quad (10)$$

Note that as the homogeneous sector  $A$  remains active in both countries, the identical technology and costless trade in the sector ensure an identical wage rate between the home and foreign countries. In other words, the home wage rate  $w$  should be equal to the foreign wage rate  $w^*$ , i.e.,  $w = w^*$ . By making use of  $w^*/w = 1$ , we can solve equations (8) and (10) to obtain  $n$  and  $n^*$  (see Appendix 1 for the mathematical derivation):

$$n = \frac{(1-\theta)s}{a} \left[ \frac{Y}{1-\tau\Phi} - \frac{\tau Y^*}{\Phi-\tau} \right], \quad (11)$$

$$n^* = \frac{(1-\theta)s}{a^*} \Phi \left[ \frac{Y^*}{\Phi-\tau} - \frac{\tau Y}{1-\tau\Phi} \right] \quad (12)$$

where

$$\Phi \equiv \frac{a^*}{a} \left( \frac{b^*}{b} \right)^{\varepsilon-1} \quad (13)$$

represents the relative technology difference between the countries. As we can see from equation (13), the factors affecting the technology differential include the ratio of fixed labor requirement ( $a^*/a$ ) and ratio of the marginal labor requirement ( $b^*/b$ ). Furthermore, higher values of  $a^*$  and  $b^*$  and/or lower values of  $a$  and  $b$  correspond to a higher  $\Phi$ , indicating higher technology advantage for the home country.

## 2.1 Revised home market effect

The conventional home market effects state that a large country tends to have a more-than-proportional share of differentiated industries, since with increasing returns, transport costs provide an advantage for firms located in a larger market. However, as will be elaborated below, the technology advantage can offset or even reverse the home market effects.

By equation (11) and (12), we can compute the ratio of firms number between home and foreign country as below

$$\frac{n}{n^*} = \frac{a^*}{a} \frac{1}{\Phi} \frac{\frac{\gamma}{1-\gamma} \left( \frac{\Phi-\tau}{1-\tau\Phi} \right) - \tau}{1 - \tau \left( \frac{\Phi-\tau}{1-\tau\Phi} \right) \frac{\gamma}{1-\gamma}}, \quad (14)$$

The total output value of the home product,  $V$  is by definition equal to  $np\bar{x}$ , in which  $p = b/\theta$  and  $\bar{x} = \theta a/(1-\theta)b$  at equilibrium. Similarly, for the foreign country, we have  $V^* = n^*p^*\bar{x}^*$  in which  $p^* = b^*/\theta$  and  $\bar{x}^* = \theta a^*/(1-\theta)b^*$ . Accordingly, the ratio of market

share between home and foreign countries,  $V/V^*$  can be derived as

$$v \equiv \frac{V}{V^*} = \frac{1}{\Phi} \frac{\frac{\gamma}{1-\gamma} \left( \frac{\Phi-\tau}{1-\tau\Phi} \right) - \tau}{1 - \tau \left( \frac{\Phi-\tau}{1-\tau\Phi} \right) \frac{\gamma}{1-\gamma}}. \quad (15)$$

Obviously, the relative market share between home and foreign country is a function of  $\Phi$ ,  $\gamma$  and  $\tau$  implicitly. The relation can be expressed implicitly as  $V/V^* = v(\Phi, \gamma, \tau)$  and depicted as the  $vv$  lines in Figure 1 the properties of the  $v$  function and  $vv$ -line can be listed as below:

- (i)  $\partial v / \partial \gamma > 0$ , i.e., the larger the home country the higher its market share, indicating the positive slope of the  $vv$ -line in Figure 1.
- (ii)  $0 < V/V^* < \infty$  only if  $\underline{\gamma} < \gamma < \bar{\gamma}$ , where  $\underline{\gamma} \equiv \tau / [\tau + (\Phi - \tau) / (1 - \tau\Phi)]$  and  $\bar{\gamma} \equiv 1 / [\tau(\Phi - \tau) / (1 - \tau\Phi) + 1]$ . It states that if the home country is smaller than  $\underline{\gamma}$ , then  $n = 0$ , and  $V = 0$  implying its  $X$  sector will be out of the market under free trade. On the contrary, if the home country is bigger than  $\bar{\gamma}$ , then the other country will find no firm to survive under free trade.
- (iii)  $\partial \underline{\gamma} / \partial \tau > 0$ , and  $\partial \bar{\gamma} / \partial \tau < 0$ , implying the lower the transport cost (that is, higher  $\tau$ ) the smaller the range of size difference between countries for both countries to keep the  $X$  sector survive under free trade.
- (iv)  $\partial \underline{\gamma} / \partial \Phi < 0$ , and  $\partial \bar{\gamma} / \partial \Phi < 0$ , implying that with a better technology not only the home country's  $X$  sector will be less likely to extinct from the world market ( $\partial \underline{\gamma} / \partial \Phi < 0$ ), but also more likely to take up the whole market ( $\partial \bar{\gamma} / \partial \Phi < 0$ ). This also implies that raising  $\Phi$  will move the  $vv$ -line leftward, as shown in Figure 1.
- (v) If  $\Phi = 1$  (identical technology), then

$$\frac{V}{V^*} = \frac{\frac{\gamma}{1-\gamma} - \tau}{1 - \tau \frac{\gamma}{1-\gamma}}.$$

In this case we have

$$\frac{\frac{V}{V^*}}{\frac{\gamma}{1-\gamma}} = \frac{1 - \left( \frac{\tau}{\frac{\gamma}{1-\gamma}} \right)}{1 - \tau \frac{\gamma}{1-\gamma}} \geq 1, \quad \text{if } \gamma \geq 1 - \gamma.$$

Obviously, this special case illustrates the conventional home market effect, which states that a bigger country ( $\gamma > 1 - \gamma$ ) will have more than proportional share of

the world market. The relation between  $V/V^*$  and  $\gamma$  under  $\Phi = 1$  is depicted as  $vv$ -line in Figure 1.

- (vi) Revised home-market effect: with  $\Phi > 1$ , a smaller country ( $\gamma < 1/2$ ) can still have higher market share than the other big country, provided the degree of technology advantage is high enough. The technology effect on the home-market effect can be illustrated in figure 1. In the figure,  $vv$ -line represents the case of identical technology  $\Phi = 1$ , which  $vv$ -line the case of  $\Phi > 1$ . Since higher  $\Phi$  will move  $vv$ -line leftward,  $vv'$ -line is on the left-hand side of  $vv$ -line. We can easily find that with better technology a smaller country  $\gamma < 1/2$ , can still have larger market share than its bigger trade partner, a case against the conventional home-market effect.

[Insert Figure 1]

## 2.2 The gravity equation

To test the effect of technology advantage on the home-market effect, we will adopt the conventional approach of gravity equation. For this purpose, we firstly have to derive the gravity equation from our model. By definition,  $c_i'^*$  is the quantity of export of  $i^{\text{th}}$  firm's output. Under the identical cost assumption,  $c_i'^* = c'^*$  for all  $i$ . For convenience, we shall suppress subscript  $i$  in the followings. Accordingly, the export value for each firm is

$$pc'^* = (tp)^{1-\varepsilon} P^{*1-\varepsilon} s \cdot Y^*.$$

Since there are  $n$  firms in the home country, the export value, denoted as  $X$ , is

$$X \equiv n p \cdot c'^* = n(tp_i)^{1-\varepsilon} P^{*\varepsilon-1} s Y^*. \quad (16)$$

Using equation (11) of  $n$  and replacing  $b/\theta$  for the equilibrium level of  $p$ , we can linearize the gravity equation by taking logs to yield

$$\begin{aligned} \log X &= \alpha + \log \left( \frac{Y}{1 - \tau\Phi} - \frac{\tau Y^*}{\Phi - \tau} \right) + \log Y^* + (1 - \varepsilon) \log t \\ &\quad + (1 - \varepsilon) \log b - \log a + (\varepsilon - 1) \log P^*, \end{aligned} \quad (17)$$

where  $\alpha \equiv 2 \log s + (\varepsilon - 1) \log \theta + \log(1 - \theta)$ . Compared to the conventional gravity equation, equation (17) states that the factors affecting bilateral export value include not only the

conventional gravity variables, such as the national income of both countries ( $Y$ ,  $Y^*$ ), distance (represented by  $t$ ) and the general price level ( $P^*$ ), but also the technology difference as represented by  $\Phi$ ,  $b$  and  $a$ .

### 2.3 Technology effects

The effect of technology advantage on the gravity relation of bilateral trade are two folds as indicated by equation (17): one a direct effect as reflected by the terms of  $(1 - \varepsilon) \log b - \log a$ , the other an indirect effect through the market sizes of  $Y$  and  $Y^*$  as reflected by the term of  $\log(Y/(1 - \tau\Phi) - \tau Y^*/(\Phi - \tau))$ .<sup>1</sup>

#### • Direct technology effect

The direct effect of  $(1 - \varepsilon) \log b - \log a$  clearly indicates that higher marginal cost,  $b$ , and/or higher fixed cost,  $a$ , of the export country will lower its export volume, noting that  $1 - \varepsilon < 0$ .

#### • Indirect technology effect

The term of  $\log(Y/(1 - \tau\Phi) - \tau Y^*/(\Phi - \tau))$  captures the standard home market effect, i.e., the effect of export country's national income ( $Y$ ) v.s. the import country's national income ( $Y^*$ ) on the export level via the firm numbers. Noting that  $\tau < \Phi < 1/\tau$ , we can easily see that the larger the home size of  $Y$  and/or the smaller the foreign size of  $Y^*$ , the higher the level of export from home to the foreign country due to the trade-induced increase in firms number of home country and decrease in the foreign.

A simple algebra yields that the larger the  $\Phi$  (better technology of home), the greater  $Y/(1 - \tau) - \tau Y^*/(\Phi - \tau)$ , keeping in mind the technology index  $\Phi$  lies within the range of  $(\tau, 1/\tau)$  to have meaningful equilibrium. This implies that the technology advantage will enhance the home market effect, no matter whether the home country is bigger or smaller than its trade partner. On the contrary, the technology disadvantage of the export country will weaken the degree of home market effect.

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<sup>1</sup>Term  $\log Y^*$  in equation (17) represents the import demand of the foreign country due to its income change, therefore is not considered as the technology effect.

### 3 Empirical tests

To develop a testable hypothesis, we can base on the above discussion to rewrite equation (17) as below:

$$\begin{aligned} LX_{ij} = \alpha &+ \beta_i(TECH_i)LY_i + \beta_j(TECH_j)LY_j \\ &+ \delta_D LDIST_j + \delta_T LTECH_i + \delta_P LP_j + \mu_{ij}, \end{aligned} \quad (18)$$

where  $LX_{ij} \equiv \log X$ ,  $LTECH_i \equiv \log$  of technology level of country  $i$ ,  $LY_i \equiv \log Y$ ,  $LY_j \equiv \log Y^*$ ,  $LDIST_{ij} \equiv \log$  of geometrical distance,  $LP_j \equiv \log P^*$ ;  $\mu_{ij}$  is the error term.

Clearly, our model predicts  $\beta_i > \beta_j$  (standard home market effect);  $\partial\beta_i/\partial TECH_i > 0$ , and  $\partial\beta_j/\partial TECH_j < 0$  (indirect technology effect);  $\delta_T > 0$  (direct technology effect);  $\delta_D < 0$  (distance effect) and  $\delta_P > 0$  (relative price effect).

To single out the indirect technology effect, we further assume

$$\beta_i(TECH_i) = \beta_i + \beta'_i LTECH_i \quad \text{and} \quad \beta_j(TECH_j) = \beta_j + \beta'_j LTECH_j,$$

where  $\beta'_i > 0$ ,  $\beta'_j < 0$ . Thus, equation (18) can be rewritten as

$$\begin{aligned} LX_{ij} = \alpha &+ \beta_i LY_i + \beta'_i LY_i \cdot LTECH_i + \beta_j LY_j + \beta'_j LY_j \cdot LTECH_j \\ &+ \delta_D LDIST_j + \delta_T LTECH_i + \delta_P LP_j + \mu_{ij}. \end{aligned} \quad (19)$$

In addition to the standard results of  $\delta_D < 0$ ,  $\delta_P > 0$ , the main hypothesis to be tested include the followings:

- (i)  $\beta_i > \beta_j$  (standard home market effect)
- (ii)  $\beta'_i > 0$ , and  $\beta'_j < 0$  (indirect technology effect)
- (iii)  $\delta_T > 0$  (direct technology effect)

#### 3.1 Data

To estimate the gravity equation of (19), we need data on bilateral export flows ( $X_{ij}$ ), geometrical distance between any pair of countries to represent the transport cost ( $DIST_{ij}$ ), general price level of the import countries ( $P_j$ ), and more importantly the technology level of each countries ( $TECH_i, TECH_j$ ). Variables to be used in the regression and their statistics are reported in Table 1 and 2 respectively.

- **General gravity variables**

For  $LX_{ij}$ , we need trade flows, which are extracted from the World Trade Database of Statistics Canada which in turn is derived from United Nations' COMTRADE data. For  $LY_i$  and  $LY_j$ , we need national income, for which we will adopt the gross domestic product of country  $i$  ( $GDP_i$ ) and  $j$  ( $GDP_j$ ) to be extracted from World Development Indicator (WDI), World Bank. Also, from the WDI database, we have the real exchange rate for each country with respect to U.S. (PPP), which in turn is used to compute the real exchange rate between each pair of country  $i$  and  $j$  (denoted as  $RPPP_{ij} = PPP_i/PPP_j$ ) to proxy the corresponding price level  $P_j$  or in log form  $LP_j$  in equation (19).

For  $LDIST_{ij}$ , we need the transport distance between countries, which is basically the sum of sea and inland routes. For the sea route, the distance between major ports is calculated. However, if more than one port is the case, then the average distance of all the navigation routes is adopted. The inland transport distance is measured between the ports and the capital, and an average distance is taken if necessary.

- **Technology**

To measure the industry-specific technology level for each country, we use the NBER Patent Citation Database, described in Hall et al. (2001) which, in turn, draws upon the electronic records of the U. S. Patent and Trademark Office (USPTO). Our sample is confined to the year of 2002, which is the most recently available year for the dataset.<sup>2</sup> From the dataset we are able to count the total number of country and industry specific U.S. patents, denoted as  $PTN_{ki}$  for industry  $k$  country  $i$ .<sup>3</sup> To match the trade data classified by the coding system of SITC Rev. 2, we therefore aggregate the patent data further according to the grouping as shown in the appendix of Table A1. As a result, there are six different industries which can find the matching patent stock for each country, including SITC 75, 76, 776, 78-79 (including SITC 78 and 79), 82 and 84. The gravity equation is estimated for each industry.

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<sup>2</sup>We have also made use the sample of 1999 and found qualitatively the similar results.

<sup>3</sup>See Branstetter (2006) for the references therein.

### 3.2 Empirical strategies

To focus on the role for technology difference on the trade flows and the home market effect, the variable of  $PTN_{k_i}$  (country  $i$ 's total U.S. patent stock in industry  $k$  for 2002) are included in each of the regression in three different models. Taken SITC 75 industry as an example, as is shown in Table 3, in Model 1, in addition to the commonly adopted gravity variables of  $LGDP_i$ ,  $LGDP_j$ ,  $LDIST_{ij}$ , and  $LRPPP_{ij}$ , we consider  $LPTN75_i$  (log of the country  $i$ 's U.S. patent stock for industry SITC75) and  $LPNT75_j$  (for the import country  $j$ ). Keeping in mind the theoretical predictions about the direct technology effect, we expect a positive coefficient for the  $LPTN75_i$  and a negative coefficient for the  $LPNT75_j$ .

In Model 2, we add one more variable of  $DPTN75$ , which is a binary dummy variable and takes value of 1 (0) if the export country's U.S. patent stock in the underlying industry  $PTN75_i$  is greater (smaller) than that of the import country  $j$ ,  $PNT75_j$ . And, obviously, the coefficient of  $DPTN75$  is expected to be positive to reflect the direct technology effect on export.

In Model 3, we keep the dummy for technology difference,  $DPTN75$ , to capture the direct technology effect and include also the cross variable between the income level ( $LGDP_i$ ) its patent stock ( $LPTN_{k_i}$ , denoted as  $LGDP_iPTN_{k_i}$  for the export country  $i$ ; correspondingly  $LGDP_jPTN_{k_j}$  for the import country  $j$ ). Obviously, these two variables match the  $LY_iLTECH_i$  and  $LY_jLTECH_j$  respectively in equation (19). Theoretically, it is expected that the coefficient for  $LGDP_iPTN_{k_i}$  be positive ( $\hat{\beta}'_i > 0$ ), indicating the enhancement of export country's technology on the home market effect and consistently the coefficient for  $LGDP_jPTN_{k_j}$  be negative ( $\hat{\beta}'_j < 0$ ), reflecting the negative impact of import country's technology advantage on the home market effect.

It should also be noted that the sample sizes are different among industries, as can be seen from the corresponding number of observation. This is because that we have deleted the observations with  $X_{ij} + X_{ji} = 0$ , indicating no trade occurs upon the underlying industry between country  $i$  and  $j$ . We can see that industry of SITC 776 has the smallest number of observations of 3,916. This fact should to some extent reflect on one hand the disaggregation of commodity group, and on the other hand its high technology property of the semiconductor devices that makes this commodity only be traded within a small

set of technologically able countries.

### 3.3 Empirical results

The regression results for each industry of SITC 75, 76, 776, 78-79, 82 and 84 are reported in Table 3, 4, 5, 6, 7 and 8 respectively. In general, the commonly-observed empirical results for the gravity equation are reconfirmed in all the three models in each of the underlying industries. That is, the positive coefficient for the  $LGDP_i$ ,  $LGDP_j$  and  $LRPPP_{ij}$ , and the negative coefficient of the  $LDIST_{ij}$ . These results are also consistent with the model predictions.

#### 3.3.1 Home market effect ( $H_0 : \beta_i > \beta_j$ )

The home market effects are empirically supported from the regression results for all the underlying industries, as indicated by a greater coefficient of  $LGDP_i$ ,  $\hat{\beta}_i$ , than that of  $LGDP_j$ ,  $\hat{\beta}_j$ . For example, in the SITC 75 industry, the estimated coefficient  $LGDP_i$  in all the three models are greater than 2, much greater than the estimated coefficient of  $LGDP_j$ , which is less than 1. This result of  $\hat{\beta}_i > 1 > \hat{\beta}_j$  can also be found for all of the other industries, as shown in Table 4, 5, 6, 7 and 8.

Note that Model 1 and 2 consider only the direct technology effect, and thus leave the indirect technology effect be embodied in the home market effect. In Model 3, the indirect technology effect is separated from the  $\hat{\beta}_i$  and  $\hat{\beta}_j$  by considering the cross variables of  $LGDP_iPTN_{k_i}$  and  $LGDP_jPTN_{k_j}$  (with estimated coefficient of  $\hat{\beta}'_i$  and  $\hat{\beta}'_j$  respectively). Consequently, the hypothesis:  $\hat{\beta}_i > \hat{\beta}_j$ , “pure” home market effect, still holds, as reflected by a greater coefficient of  $LGDP_i$  than that of  $LGDP_j$  coefficient in Model 3 in all the industries.

[Insert Table 3, 4, 5, 6, 7 and 8]

#### 3.3.2 Technology effect

##### • Direct technology effect

Theoretically, the direct technology effect states that a country’s export is positively affected by its technology level, but negatively affected by that of the import country. Thus, we would expect a positive efficient for the exporter’s technology level (variable  $LPTN_{k_i}$ ), and negative for the importer’s technology level ( $LPTN_{k_j}$ ). Similarly, we

would also expect a positive coefficient for the dummy variable of  $DPTN_{ij}$ , which takes value one if the export country has more the U.S. patent stock than its counterpart, otherwise zero. The empirical results for all the industries, except the apparel industry (SITC 84), support this hypothesis very consistently.

For the industry of apparel (SITC 84), as reported in Table 8, its direct technology effect appears to be very different from the other industry's. It is readily seen that not only the coefficient of the importer's U.S. patent stock ( $LPTN84_j$ ) is positive as that of the exporter's ( $LPTN84_i$ ), but also greater than the later. The results are also reconfirmed further by the positive estimated coefficient for the technology difference dummy of  $DPTN84$  in Model 2 and 3.

The counter finding for the apparel industry deserves further attention. It seems to imply that the apparel export is more likely to be attracted by the importer's 'technology level' than by the exporter's. Noting that the U.S. patent stock is adopted as the proxy for a country's technology level, the empirical results may simply reflect the fact that a country holding more the U.S. patent of the apparel products, tends to have more expenditure share on the products which in turn indicates a relative larger market size in the particular industry, a situation against our model assumption of the constant expenditure share,  $s$ . In another words, for an industry like apparel, the demand or import side's innovation reflected in the patent stock seems to be more affective on the trade flows than that of the export side.

#### • Indirect technology effect

Indirect technology effect represents the effect on export flows through the home-market effect, which is designed in our empirical model to be captured by the positive coefficient of  $LGDP_iPTN_i$ ,  $\beta'_i$ , and negative coefficient of  $LGDP_jPTN_j$ ,  $\beta'_j$ . As can be seen from Table 3, the regression results in Model 3 for the SITC 75 industry supports this hypothesis, that is, 0.011 for  $LGDP_iPTN75_i$  and 0.0001( not significant) for  $LGDP_jPTN75_j$ . The same pattern of regression results can also be found for the SITC 76 (Table 4) industry. For other industries of SITC 776 (Table 5), SITC 78-79 (Table 6), SITC 82 (Table 7), qualitatively the same pattern is also weakly found, that is, a significantly positive coefficient for the  $LGDP_iPTN_i$ ,  $\beta'_i$ , accompanied with positive but non-significant or

smaller coefficient for  $LGDP_jPTN_j, \beta'_j$ . Again, the apparel industry (SITC 84) presents a different pattern of the indirect technology effect. For the industry, both of the estimated coefficients are significantly positive and almost equal. An economic explanation is probably that the apparel goods is the ‘demand-side determined’ market. Therefore, the import countries’ preference or high propensity to consume imported varieties tends to dominate the trade flows over the export country’s supply-side cost factors.

### 3.3.3 Simulations: Technology advantage and home-market effect reversal

To illustrate the implications of the above empirical results for the likely of home-market effect reversal, we conduct a simulation drawing upon the estimated coefficient. To demonstrate that a small country  $i$  can export more than import from its trade partner  $j$ , we assume country  $i$  is only 90% size of country  $j$ , that is,  $GDP_i = 90\%GDP_j$ . For simplicity and to focus on the size and technology difference, we also assume that both countries have identical real PPP, i.e.  $RPPP=1$ , and therefore  $LRPPP \equiv \log(RPPP) = 0$ . As a result, we can compute the value of  $\log X_{ij} - \log X_{ji}$  with respect to each level of  $\tilde{\Phi} = PTN_i/PTN_j$  based on the estimated coefficient of different model for each industry.

- **Simulation results of Model 1 (direct effect of technology advantage)**

Under the set-up of Model 1, a simple algebra shows that

$$\log \left( \frac{X_{ij}}{X_{ji}} \right) = (\hat{\beta}_i - \hat{\beta}_j) \log 0.9 + (\hat{\delta}_i - \hat{\delta}_j) \log \tilde{\Phi} \quad (20)$$

where as noted before  $\hat{\beta}_i$  and  $\hat{\beta}_j$  are the estimated coefficients of  $LGDP_i$  and  $LGDP_j$  respectively and  $\hat{\delta}_i, \hat{\delta}_j$  are the estimated coefficients of  $LPTN_{k_i}$  and  $LPTN_{k_j}$  for the corresponding  $k$ -industry. The relation between  $\log(X_{ij}/X_{ji})$  and  $\tilde{\Phi}$  for each industry are depicted in Figure 2, in which the vertical axis represent  $\log(X_{ij}/X_{ji})$  and the horizontal axis  $\tilde{\Phi}$  starting from  $\tilde{\Phi} = 1$ .

Obviously, the intercept are all negative for each industry, reflecting that under identical technology ( $\tilde{\Phi} = 1$ ) the smaller country will import more from than export to its trade partner which under the set-up is larger by 11% ( i.e.  $1/0.9 - 1$ ). This is the standard home market effect, without considering the technology difference, and as is readily seen from the figure that for the home-market effect, transport industry (SITC 78-79) ranks the largest, SITC 82 the second, then almost equally ranked as the 3rd of the SITC 84,

76, 75, followed by the smallest of SITC 776. However, along with better and better technology of the smaller country, the home-market effect for the SITC 776 industry becomes firstly reversed (represented by the above zero of  $\log(X_{ij}/X_{ji})$ ) with the smallest degree of technology advantage, indicating the far more important of the technology difference for the semiconductor industry than for other industries. Along with this logic, we can conclude from Figure 2 that the order of technology importance in determining the export are sequentially SITC 776, 76 and then 75. In extreme, the technology advantage for SITC 84 and SITC 78-79 appears not to be an important factor in determining the flow of trade, as is shown in the figure that the home-market effect is never reversed no matter how far is the smaller country's relative technology advantage over its trade partner.

[Insert Figure 2]

• **Simulation results of Model 3 (indirect technology effect)**

By Model 3, a simple algebra yields

$$\log\left(\frac{X_{ij}}{X_{ji}}\right) = (\hat{\beta}_i - \hat{\beta}_j) \log 0.9 + \hat{\delta}_T [DPTN_{k_{ij}} - DPTN_{k_{ji}}] + (\hat{\beta}'_i - \hat{\beta}'_j) [\log 0.9 \cdot \log PTN_{k_j}] + (\hat{\beta}'_i - \hat{\beta}'_j) [\log 0.9 + \log GDP_j] \cdot \tilde{\Phi} \quad (21)$$

To plot the schedule between  $\log(X_{ij}/X_{ji})$  and  $\tilde{\Phi}$ . We have made use the sample's average of  $PTN_k$  to represent  $PTN_{k_j}$ , and also the average of  $GDP$  to represent  $GDP_j$ . Furthermore, to focus on the role of indirect effect of the technology advantage on the export /import ratio through the home-market effect, we suppress the term of  $\hat{\delta}_T [DPTN_{k_{ij}} - DPTN_{k_{ji}}]$  which is to capture the direct technology effect. The results are plotted in Figure 3.

Similar to the results from Model 1, under identical technology level, the ranking of the conventional home-market effect, as indicated by the interrupt at  $\tilde{\Phi}$ , remains the same. The slope of each line represents the corresponding indirect technology effect through the home-market effect, that is, term  $(\hat{\beta}'_i - \hat{\beta}'_j) [\log 0.9 GDP_j]$  in equation (21).

As is shown in the figure, without considering the direct effect, only for the SITC 776, 76 and 75 can the indirect technology effect reverse the conventional home-market effect, making a smaller country to run a positive net export against its big trade partner. In addition, the high-tech semiconductor (SITC 776) appears to have the highest indirect technology effect, followed by the SITC 76, then 75.

On the contrary, the other three conventional sectors of transport (SITC 78-79), furniture (SITC 82) and the apparel (SITC 84) present little strength of the indirect effect of technology advantage to reverse the conventional home-market effect, as is shown in Figure 3 in which the three corresponding lines lie all the way below zero.

In sum, the home-market effect reversal induced by the technology advantage seems more likely to occur to the relatively technology-intensive industries (semi-conductor, consumer's electronic products, computer and automatic data processing) than to other conventional industries (textile, transportation equipment and furniture sectors).

[Insert Figure 3]

## 4 Concluding remarks

As a complement to the literature on conventional home-market effects, we consider the technology difference in a standard Helpman-Krugman model. While the conventional home-market effect is proved to be detrimental to the smaller economy, in the theoretical part, we show that the effect will become smaller provided that the small country has equipped with better technology than its counterpart. Furthermore, if the technology advantage is large enough, then the smaller economy can even hold a more than proportional share of the market, the case of home-market effect reversal.

In the empirical part, the effect of technology advantage on the home-market effect are tested upon six different industries of 2002, ranging from the most technology-intensive industry of SITC 776 (semiconductor), office machine and automatic data-processing equipment of SITC 75, telecommunications and sound recording apparatus of SITC 76 to the conventional labor-intensive industries of furniture SITC 82 and apparel and clothing of SITC 84.

As is theoretically predicted, for all the six industries empirical results reconfirm the conventional home-market effect, that is the export country's market size, represented by its GDP, affects more the exports than the import country's size. Newly to the existing literature, we have also found empirical support for the theoretical findings of the direct and indirect technology effect on the home-market effect. That is, the direct technology effect through lower average cost to improve more exports are significantly supported for all the six industries. And, the indirect technology effect through the home market effects

in terms of firm number change are also significantly confirmed for all the industries, except for the apparel and furniture industries.

In addition, the simulation result based on the estimated coefficients illustrates that the technology advantage for a small economy not only to offset its size disadvantage, but also may lead to export more to than to import from its trade partner, the case of reverse home-market effect. It is also found that the degree of technology effect on offsetting the home-market effects differs from industry to industry. In general, we have found that the home-market effect reversal due to the technology advantage is more likely to occur to the relatively technology-intensive industries than to other conventional labor-intensive manufacturing industries.

## Appendix 1 Derivations of the equilibrium number of firms under free trade ( $n^T$ and $n^{T*}$ )

Instead of solving for  $n$  and  $n^*$  directly from equations (8) and (10), we adopt the following strategy. In the first step,  $1/\phi_1$  and  $1/\phi_2$  are regarded as new variables and are solved from equations (8) and (10) to yield  $1/\phi_1 = \phi'(\cdot)$  and  $1/\phi_2 = \phi'(\cdot)$ . Secondly, the results are substituted into equation (9) to solve for  $n$  and  $n^*$ .

### Step 1: Solving for $1/\phi_1 = \phi'(\cdot)$ and $1/\phi_2 = \phi'(\cdot)$

Equations (8) and (10) can be rewritten in matrix form as

$$\begin{bmatrix} Y & \tau Y^* \\ \tau Y & Y^* \end{bmatrix} \begin{bmatrix} \frac{1}{\phi_1} \\ \frac{1}{\phi_2} \end{bmatrix} = \begin{bmatrix} \frac{\theta}{(1-\theta)} \frac{a}{b} \frac{1}{p^{-\varepsilon} s} \\ \frac{\theta}{(1-\theta)} \frac{a^*}{b^*} \frac{1}{p^{*\varepsilon} s} \end{bmatrix}. \quad (A.1)$$

Denoting the determinant of the matrix as  $\Delta \equiv YY^*(1 - \tau^2)$ , and using Cramer's rule we obtain

$$\begin{aligned} \frac{1}{\phi_1} &= \phi'_1(a, b, w, a^*, b^*, w^*, \tau, \gamma, \theta, s, L) \\ &= \frac{\theta}{(1-\theta)} \frac{1}{sY(1-\tau^2)} \left[ \frac{a}{b} p^\varepsilon - \tau \cdot \frac{a^*}{b^*} \cdot p^{*\varepsilon} \right], \end{aligned} \quad (A.2)$$

$$\frac{1}{\phi_2} = \phi'_2(a, b, w, a^*, b^*, w^*, \tau, \gamma, \theta, s, L)$$

$$= \frac{\theta}{(1-\theta)} \frac{1}{sY^*(1-\tau^2)} \left[ \frac{a^*}{b^*} p^{*\varepsilon} - \tau \cdot \frac{a}{b} \cdot p^\varepsilon \right]. \quad (\text{A.3})$$

### Step 2: Solving for $n$ and $n^*$

By substituting (A.2) and (A.3) into equation (12), we get

$$\begin{bmatrix} p^{1-\varepsilon} & \tau p^{*1-\varepsilon} \\ \tau p^{1-\varepsilon} & p^{*1-\varepsilon} \end{bmatrix} \begin{bmatrix} n \\ n^* \end{bmatrix} = \begin{bmatrix} \frac{1}{\phi_1} \\ \frac{1}{\phi_2} \end{bmatrix}. \quad (\text{A.4})$$

By Cramer's rule,  $n$  and  $n^*$  can be solved as:

$$n = \frac{1}{p^{1-\varepsilon}(1-\tau^2)} \Psi_1, \quad (\text{A.5})$$

$$n^* = \frac{1}{p^{*1-\varepsilon}(1-\tau^2)} \Psi_2, \quad (\text{A.6})$$

where

$$\Psi_1 = \frac{(1-\theta)sY(1-\tau^2)}{\theta \left( \frac{a}{b} p^\varepsilon - \tau \frac{a^*}{b^*} p^{*\varepsilon} \right)} - \frac{(1-\theta)\tau sY^*(1-\tau^2)}{\theta \left( \frac{a^*}{b^*} p^{*\varepsilon} - \tau \frac{a}{b} p^\varepsilon \right)}, \quad (\text{A.7})$$

$$\Psi_2 = \frac{(1-\theta)sY^*(1-\tau^2)}{\theta \left( \frac{a^*}{b^*} p^{*\varepsilon} - \tau \frac{a}{b} p^\varepsilon \right)} - \frac{(1-\theta)\tau sY(1-\tau^2)}{\theta \left( \frac{a}{b} p^\varepsilon - \tau \frac{a^*}{b^*} p^{*\varepsilon} \right)}. \quad (\text{A.8})$$

By using  $w^*/w = 1$ , the results can be simplified further as shown below:

$$n = \frac{(1-\theta)s}{a} \left[ \frac{Y}{1-\tau\Phi} - \frac{\tau Y^*}{\Phi-\tau} \right],$$

$$n^* = \frac{(1-\theta)s}{a^*} \Phi \left[ \frac{Y^*}{\Phi-\tau} - \frac{\tau Y}{1-\tau\Phi} \right],$$

where

$$\Phi \equiv \frac{a^*}{a} \left( \frac{b^*}{b} \right)^{\varepsilon-1},$$

represents the difference in technology between the countries.

## Appendix 2 The 127 countries included in the sample

Albania, Algeria, Angola, Argentina, Australia, Austria, Bahrain, Bangladesh, Barbados, Belgium-Lux., Belize, Benin, Bolivia, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Central Africa Rep., Chad, Chile, China, Colombia, Comoros, Congo, Congo Dem. Rep., Costa Rica, Cote D'Ivoire, Cyprus, Denmark, Djibouti, Dominican Rep., Ecuador, Egypt, El Salvador, Ethiopia, Fiji, Finland, France,

Gabon, Gambia, Germany, Ghana, Greece, Guatemala, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Korea Rep., Kuwait, Laos P.Dem.R, Lebanon, Madagascar, Malawi, Malaysia, Mali, Malta, Mauritania, Mauritius, Mexico, Mongolia, Morocco, Mozambique, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Nigeria, Norway, Oman, Pakistan, Panama, Papua N.Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Rwanda, Saudi Arabia, Senegal, Seychelles, Sierra Leone, Singapore, Solomon Islands, South Africa, Spain, Sri Lanka, St. Kitts Nev, Sudan, Sweden, Switzerland, Syr Arab Rep., Taiwan, Tanzania, Thailand, Togo, Trinidad Tbg, Tunisia, Turkey, Uganda, UK, Uruguay, USA, Venezuela, Vietnam, Yemen, Zambia.

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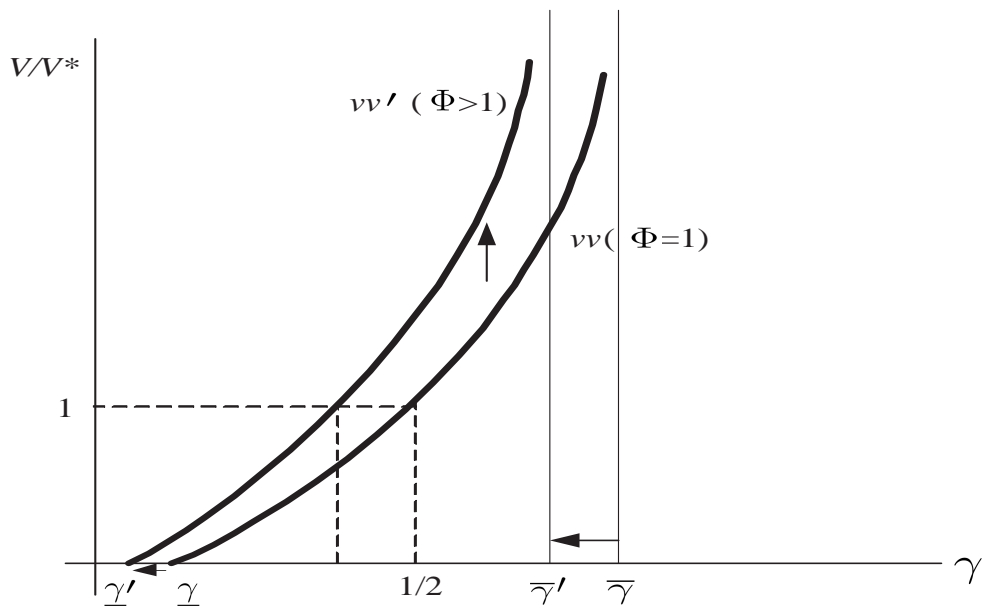


Figure 1: Relative market share and technology advantage

Table 1 List of variables

Variables	Description
$GDP_i$	The export country's gross domestic product, are retrieved from the World Development Indicators, World Bank. $LGDP_i = \log(GDP_i)$ and the same notation applies to other variables.
$GDP_j$	The import country's gross domestic product, retrieved also from the World Development Indicators, World Bank.
$DIST_{ij}$	The transport distance between country i and j, the sum of sea and inland routes that calculated between major ports.
$RPPP_{ij}$	The ratio of country i's real exchange rate and country j's real exchange rate, sourced from the World Development Indicators, World Bank. That is, the relative real exchange rate between country I and j.
$PTN_{k_i}$	Country i's U.S. patent stock registered in the United States Patent and Trademark Office (USPTO) with respect to the industry of SITC k, k=75, 76, 776, 78-79, 82 and 84.
$DPTN_{k_{ij}}$	The dummy-variable that takes value one if $PTN_{k_i} > PTN_{k_j}$ , otherwise zero.
$LGDP_i \cdot LPTN_{k_i}$	$\equiv \log(GDP_i) \cdot \log(PTN_{k_i})$

Table 2 Descriptive statistics of country-specific variables

Variables	N	Avg.	Std. Dev.	Maximum	Minimum
$GDP$	127	2.46E+11	1.02E+12	1.04E+13	2.03E+08
$PPP$	127	0.482	0.288	1.475	2.E-05
$PTN75$	127	3059.929	21509.928	222141	0
$PTN76$	127	3724.472	25753.430	275593	0
$PTN776$	127	632.024	4066.325	38762	0
$PTN7879$	127	803.654	5784.844	63687	0
$PTN82$	127	547.024	4518.353	50726	0
$PTN84$	127	472.984	3067.318	33316	0

Table 3 Estimation of the Gravity Equation (SITC75)

Dependent variable:  $LX_{ij}$  (2002 export value of SITC 75 from country i to j)

Variable	Model 1	Model 2	Model 3
<i>Intercept</i>	-61.28(-17.37)**	-62.899(-18.03)**	-60.261(-17.03)**
<i>LGDP<sub>i</sub></i>	2.415(25.76)**	2.125(22.17)**	2.077(21.37)**
<i>LGDP<sub>j</sub></i>	0.702(7.48)**	0.977(10.23)**	0.916(9.45)**
<i>LDIST</i>	-2.2(-16.73)**	-2.242(-17.25)**	-2.251(-17.33)**
<i>LPTN75<sub>i</sub></i>	0.309(17.01)**	0.257(13.92)**	
<i>LPTN75<sub>j</sub></i>	-0.05(-2.75)**	-0.012(-0.63)	
<i>DPTN75</i>		4.77(11.91)**	4.668(11.54)**
<i>LRPPP<sub>ij</sub></i>	0.76(8.38)**	0.568(6.25)**	0.561(6.17)**
<i>LGDP<sub>i</sub>PTN75<sub>i</sub></i>			0.011(14.15)**
<i>LGDP<sub>j</sub>PTN75<sub>j</sub></i>			0(0.17)
ADJ. R <sup>2</sup>	0.4611	0.4735	0.4741
Number of Obs.	5,976	5,976	5,976

Notes: Numbers in parentheses are t-value. Superscripts '\*' and '\*\*' denote significant levels of 10% and 5% respectively.

Table 4 Estimation of the Gravity Equation (SITC76)

Dependent variable:  $LX_{ij}$  (2002 export value of SITC 76 from country i to j)

Variable	Model 1	Model 2	Model 3
<i>Intercept</i>	-68.408(-21.10)**	-71.141(-22.43)**	-68.158(-20.90)**
<i>LGDP<sub>i</sub></i>	2.543(29.26)**	2.061(23.10)**	2.005(21.88)**
<i>LGDP<sub>j</sub></i>	0.836(9.62)**	1.319(14.77)**	1.251(13.63)**
<i>LDIST</i>	-2.073(-16.47)**	-2.135(-17.34)**	-2.137(-17.37)**
<i>LPTN76<sub>i</sub></i>	0.334(18.38)**	0.282(15.68)**	
<i>LPTN76<sub>j</sub></i>	-0.105(-5.75)**	-0.072(-4.05)**	
<i>DPTN76</i>		6.574(17.58)**	6.431(17.06)**
<i>LRPPP<sub>ij</sub></i>	0.394(4.39)**	0.079(0.89)	0.078(0.87)
<i>LGDP<sub>i</sub>PTN76<sub>i</sub></i>			0.013(15.68)**
<i>LGDP<sub>j</sub>PTN76<sub>j</sub></i>			-0.002(-2.94)**
ADJ. R <sup>2</sup>	0.4704	0.4943	0.4938
Number of Obs.	6,512	6,512	6,512

Notes: Numbers in parentheses are t-value. Superscripts '\*' and '\*\*' denote significant levels of 10% and 5% respectively.

Table 5 Estimation of the Gravity Equation (SITC776)

Dependent variable:  $LX_{ij}$  (2002 export value of SITC 776 from country i to j)

Variable	Model 1	Model 2	Model 3
<i>Intercept</i>	-43.061(-9.55)**	-43.63(-9.66)**	-47.735(-10.76)**
$LGDP_i$	1.36(12.04)**	1.339(11.82)**	1.478(13.28)**
$LGDP_j$	0.993(8.78)**	1.02(8.98)**	1.033(9.26)**
<i>LDIST</i>	-1.958(-12.84)**	-1.982(-12.98)**	-1.995(-13.02)**
$LPTN776_i$	0.562(28.96)**	0.538(24.53)**	
$LPTN776_j$	0.006(0.30)	0.022(1.06)	
<i>DPTN776</i>		1.2(2.36)**	1.066(2.06)*
$LRPPP_{ij}$	0.46(3.99)**	0.432(3.73)**	0.424(3.64)**
$LGDP_iPTN776_i$			0.021(23.87)**
$LGDP_jPTN776_j$			0.001(0.85)
ADJ. R <sup>2</sup>	0.4870	0.4876	0.4840
Number of Obs.	3,916	3,916	3,916

Notes: Numbers in parentheses are t-value. Superscripts '\*' and '\*\*' denote significant levels of 10% and 5% respectively.

Table 6 Estimation of the Gravity Equation (SITC 78 and SITC79)

Dependent variable:  $LX_{ij}$  (2002 export value of SITC 78 and SITC79 from country i to j)

Variable	Model 1	Model 2	Model 3
<i>Intercept</i>	-62.076(-22.26)**	-62.592(-22.50)**	-61.496(-22.10)**
$LGDP_i$	3.068(42.23)**	2.946(39.27)**	2.949(39.40)**
$LGDP_j$	0.243(3.34)**	0.353(4.74)**	0.305(4.10)**
<i>LDIST</i>	-2.476(-20.60)**	-2.513(-20.94)**	-2.524(-21.03)**
$LPTN7879_i$	0.144(9.84)**	0.106(6.72)**	
$LPTN7879_j$	0.006(0.42)	0.028(1.85)*	
<i>DPTN7879</i>		2.341(6.34)**	2.409(6.42)**
$LRPPP_{ij}$	0.639(7.61)**	0.554(6.53)**	0.557(6.56)**
$LGDP_iPTN7879_i$			0.004(6.45)**
$LGDP_jPTN7879_j$			0.002(2.88)**
ADJ. R <sup>2</sup>	0.4352	0.4382	0.4384
Number of Obs.	7,464	7,464	7,464

Notes: Numbers in parentheses are t-value. Superscripts '\*' and '\*\*' denote significant levels of 10% and 5% respectively.

Table 7 Estimation of the Gravity Equation (SITC82)

Dependent variable:  $LX_{ij}$  (2002 export value of SITC 82 from country i to j)

Variable	Model 1	Model 2	Model 3
<i>Intercept</i>	-49.14(-15.57)**	-49.276(-15.61)**	-47.972(-15.23)**
$LGDP_i$	2.641(31.96)**	2.599(30.62)**	2.629(31.07)**
$LGDP_j$	0.147(1.78)*	0.185(2.19)**	0.101(1.20)
<i>LDIST</i>	-2.671(-21.91)**	-2.691(-22.01)**	-2.707(-22.11)**
$LPTN82_i$	0.244(15.22)**	0.23(13.40)**	
$LPTN82_j$	-0.003(-0.21)	0.004(0.24)	
<i>DPTN82</i>		0.81(2.12)**	0.911(2.35)**
$LRPPP_{ij}$	-0.271(-3.16)**	-0.303(-3.48)**	-0.307(-3.53)**
$LGDP_iPTN82_i$			0.009(12.68)**
$LGDP_jPTN82_j$			0.001(1.76)*
ADJ. $R^2$	0.4281	0.4284	0.4274
Number of Obs.	6,448	6,448	6,448

Notes: Numbers in parentheses are t-value. Superscripts '\*' and '\*\*' denote significant levels of 10% and 5% respectively.

Table 8 Estimation of the Gravity Equation (SITC84)

Dependent variable:  $LX_{ij}$  (2002 export value of SITC 84 from country i to j)

Variable	Model 1	Model 2	Model 3
<i>Intercept</i>	-51.165(-13.48)**	-50.914(-13.41)**	-49.602(-13.18)**
$LGDP_i$	2.339(23.43)**	2.39(23.43)**	2.418(23.94)**
$LGDP_j$	0.582(5.83)**	0.533(5.23)**	0.45(4.46)**
<i>LDIST</i>	-2.69(-19.34)**	-2.663(-19.09)**	-2.672(-19.17)**
$LPTN84_i$	0.151(7.88)**	0.169(8.21)**	
$LPTN84_j$	0.05(2.61)**	0.041(2.09)**	
<i>DPTN84</i>		-1.049(-2.40)**	-0.957(-2.16)**
$LRPPP_{ij}$	-1.311(-13.31)**	-1.288(-13.02)**	-1.265(-12.74)**
$LGDP_iPTN84_i$			0.007(7.75)**
$LGDP_jPTN84_j$			0.003(3.28)**
ADJ. $R^2$	0.2658	0.2663	0.2665
Number of Obs.	6,760	6,760	6,760

Notes: Numbers in parentheses are t-value. Superscripts '\*' and '\*\*' denote significant levels of 10% and 5% respectively.

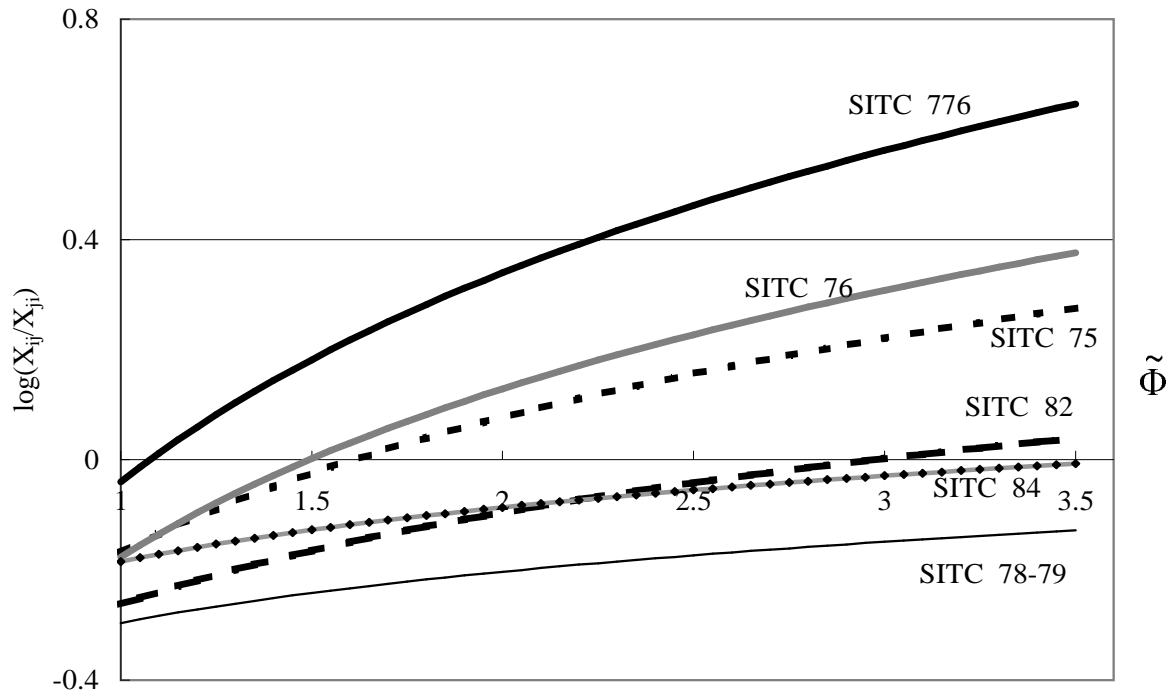


Figure 2 Simulation results of Model 1 ( $GDP_i=0.9*GDP_j$ ,  $\tilde{\Phi}=PTN_i/PTN_j$ )

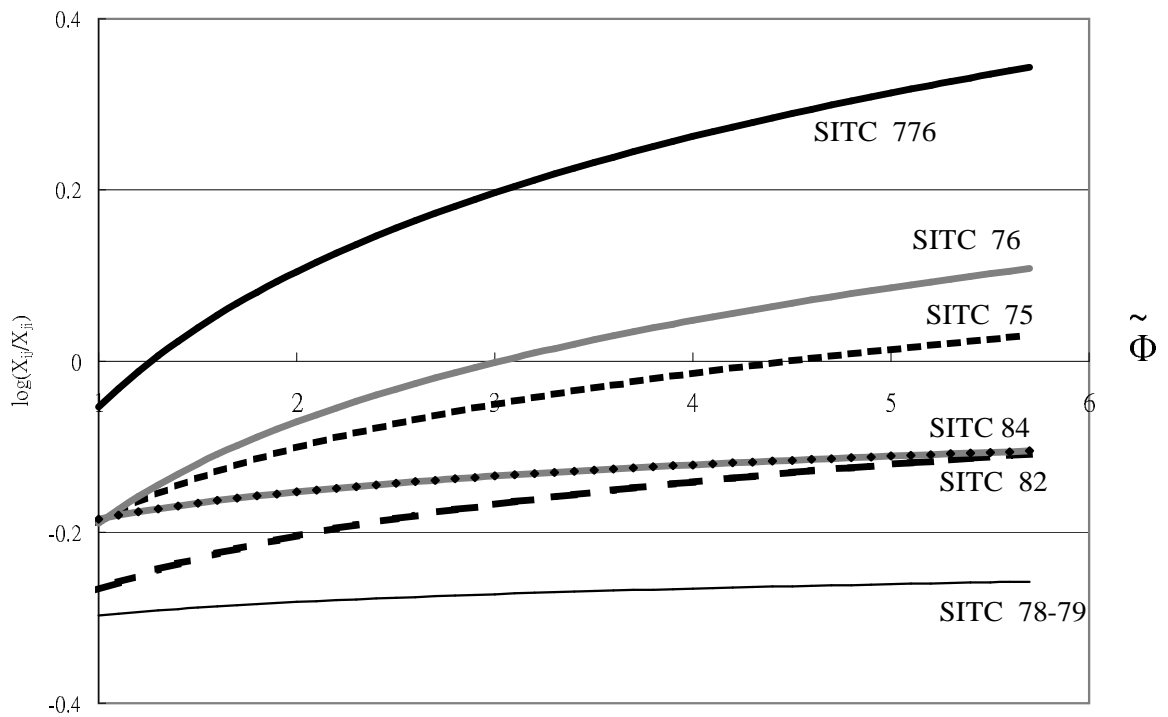


Figure 3 Simulation results of Model 3  
 $GDP_i=0.9*GDP_j$ ,  $\tilde{\Phi}=PTN_i/PTN_j$   
 $GDP_j = \text{average of } GDP_j$ ,  $PTN_j = \text{average of } PTN_j$

Table A1 Industry category

SITC (Rev. 2) <sup>1</sup>		Patent classification	
Code	Description	Patent code <sup>2</sup>	Description
75	Office machines and automatic data processing equipment	21	Communications
		22	Computer hardware and software
		23	Computer peripherals
		24	Information storage
76	Telecommunications and sound recording apparatus	41	Electrical devices
		42	Electrical lighting
		43	Measuring and testing
		45	Power systems
		49	Miscellaneous electrical and electronic
776	Thermionic, cold and photo-cathode valves, tubes, parts	46	Semiconductor devices
78	Road vehicles (include air cushion vehicles)	55	Transportation
79	Other transport equipment		
82	Furniture and parts thereof	65	Furniture, house fixtures
84	Articles of apparel and clothing accessories	63	Apparel and textile

Note: 1. SITC codes represent Standard International Trade Classification Version 2.

2. This is the subcategory of the patent classification described in Hall et al. (2001).