貿易自由化と生産性格差の集積に及ぼす影響

Heterogeneous Firms, Trade Liberalization and Agglomeration

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要旨: FTA の増加を受け，貿易自由化に伴う企業の立地選択に焦点を当てた研究が増えている．立地する企業の生産性の違いは地域経済発展に影響を及ぼすことから，本研究では，企業間の生産性格差を新経済地理学の理論に含め，分析を行った．その結果，貿易自由化に伴い，生産性の低い企業は生産性の高い企業との競争を避けるために，後者が立地する都市から，地方へと移転することが明らかになった．また，地方が補助金を用いて，生産性の高い企業を誘致することは困難であることが示された．

Abstract: Firms' location decisions following trade liberalization have received much research attention. For instance, attracting high-paying jobs has become an important strategy in the context of regional economic development. This study incorporates firm heterogeneity in terms of productivity into a new economic geography model. We first show that low-productivity firms tend to locate away from high-productivity counterparts to avoid competition in a closed-economy setting. In the open-economy setting, we find that when trade is liberalized, low-productivity firms relocate from the region where high-productivity firms are concentrated to a less developed region. Narrowing productivity differences among firms within a country fosters agglomeration, while that across countries favors dispersion. Finally, our simulation shows that it is possible for less-developed regions to attract high-productivity firms with a large subsidy, but their urban counterparts hold a distinct advantage in such subsidy competition.

Key words: Firm heterogeneity; New economic geography; Trade openness.

JEL codes: F15, R12, R58

Heterogeneous Firms, Trade Liberalization and Agglomeration

1. Introduction

The effect of trade liberalization on economic growth has been at the core of international economics for decades. However, the recent debate on trade liberalization centers around its effect on income inequality and poverty (Yale Global Forum, 2007). The domestic and international relocation of labor-intensive manufacturing jobs, associated with liberalized trade, and the consequences for low-income households have received much research attention (Feenstra and Hanson 1997; Galiani and Sanguinetti, 2003; Goldberg and Pavcnik, 2005). In some instances, trade liberalization has been accused to increase wage disparities, benefiting higher income groups more than the poor (Feliciano, 2001).

Consideration of relocation decisions of different types of firms in the face of trade and globalization is important from an economic development perspective. Regions in a developing country that are beneficiaries in the relocation process tend to grow faster than others (Hanson, 1998). For example, wages in northern Mexico and coastal regions of China – home to a diverse set of manufacturing activities - are several times higher than that in southern Mexican regions and inland provinces of China (Hanson, 1997).[1] Thus, trade liberalization may influence the spatial distribution of economic activities within an economy, e.g., Ades and Glaeser (1995), where attracting high-wage jobs has become a major development strategy for many local and state governments. To understand how trade liberalization affects income inequality and poverty, it is essential to understand how the location patterns of different types of firms adjust with trade liberalization.

[1] In the context of international income inequality, see Redding and Venables (2004).

The spatial concentration of economic activity has become a major focus of economic research with the seminal contribution of Krugman (1991). The research has led to the development of the new economic geography (NEG), which has greatly increased our understanding of how regions can endogenously become differentiated into an industrialized "core" and an agricultural "periphery" (Fujita et al., 1999; Baldwin et al., 2003). The prototypical NEG model has two regions; two kinds of industries (agriculture and manufactures), and two primary factors of production ("farmers" and "workers"). Agriculture is assumed to be a constant-returns sector tied to land, and the monopolistically-competitive manufacturing sector with increasing-returns can be located in either region. Firms in manufactures produce differentiated products, but have the same production technologies. In equilibrium, all firms produce the same amount of output and receive the same price. Thus, the standard NEG models essentially do not consider firm heterogeneity (Melitz, 2003; Yeaple, 2005).

The impact of trade liberalization on the spatial distribution of economic activities has also been explored in the NEG literature (Krugman and Livas, 1996; Allonso-Villar, 1999). For example, Krugman and Livas (1996) show that even if two regions are not identical at the beginning, as long as they face the same exporting and importing opportunities, trade liberalization will lead to an even distribution of firms between the two regions. The reason is that firms must pay higher wages to urban residents to compensate for their high rents and commuting costs. When urban and rural areas face the same trade costs, benefits from locating in a city decline and firms relocate to rural areas. The enlargement of the European Union is a case in point (Behrens et al., 2003).[2] Mansori (2003) shows that increasing returns to scale in

[2] The literature on EU enlargement is fairly extensive. See also Crozet and Koenig (2004) and Overman and Winters (2006).

transport/trade costs can lead to agglomeration, a result opposite to that of Krugman and Livas (1996). Plauzie (2001) employs immobile workers instead of congestion costs as a dispersion force. Finally, Fujita et al. (1999) extend the model developed by Krugman and Livas (1996) to the case of two monopolistically competitive industries, where trade liberalization leads each region to specialize in one industry. These studies, however, have not considered the agglomeration process of heterogeneous firms with trade liberalization.

The few studies that consider location decisions of heterogeneous firms include Baldwin and Okubo (2006) and Syverson (2004). The former shows that the most productive firms are the first to relocate to a large country from a small country and the last to relocate from a large country, but does not address regional patterns of firm location within a country. The latter is an empirical study of U.S. ready-mixed concrete industry using plant-level data. Syverson (2004) finds that the distribution of productivity in a market shifts toward right, i.e., low-productivity firms disappear, as a market's demand density increases. Overall, there is very limited research on the relocation of different types of firms/jobs with trade liberalization.

The primary objectives of this study are 1) to explore the determinants of firms' location patterns in the presence of firm heterogeneity, in particular, differences in productivity and 2) to examine how heterogeneous firms' location patterns adjust with trade liberalization. For these purposes, we first extend the model of agglomeration developed by Ottaviano et al. (2002) to include different types of manufacturing firms and then use the model to explore how the degree of competition and trade costs affect the location choice of heterogeneous firms in section 2. In section 3, we extend the model to include a foreign market with identical trade costs to different regions in the home economy. We apply the extended model to examine firms' incentives to relocate within the home economy due to the trade liberalization. In section 4, we simulate the effects of regional governments' subsidies to attract firms to a region. Section 5 provides conclusions and policy implications.

2. The Model

Consider an economic space consisting of two regions within a country (henceforth, North and South, indexed N and S, respectively).[3] There are two sectors; sector A produces agricultural goods while the other sector produces manufactured goods. The manufacturing sector consists of two types of firms, i.e., low-productivity (M) and high-productivity (H) firms. The agricultural good is produced using labor (L) as the only input, whereas the manufactured goods are produced using both labor and human capital (K). The two types of firms in the manufacturing sector differ in the marginal labor requirement. There are three types of consumers in the two regions: worker, industrialists, and entrepreneurs. Workers provide labor input for all sectors; industrialists provide human capital for low-productivity firms, and entrepreneurs provide human capital for high-productivity firms. Each worker provides one unit of labor, and each industrialist or entrepreneur provides one unit of human capital. Human capital is not mobile between two types of firms but mobile between regions. Each region is endowed with a given mass of workers, which is mobile between sectors but immobile between regions.[4]

Consider first the demand for goods produced by the two sectors. All consumers have identical preferences, which are defined by the quadratic utility function:

[3]The following results can be recast in the context where a region can be regarded as a country.
[4]Support for the assumption that skilled labor is much more mobile than unskilled labor can be found in Coniglio (2002).

$$U = \alpha\left(\int_0^n c_H(i)di + \int_0^n c_M(i)di\right) - \frac{\beta-\gamma}{2}\left(\int_0^n c_H^2(i)di + \int_0^n c_M^2(i)di\right) \tag{1}$$
$$- \frac{\gamma}{2}\left[\left(\int_0^n c_H(i)di\right)^2 + \left(\int_0^n c_M(i)di\right)^2\right] - \delta\left(\int_0^n c_H(i)di\right)\left(\int_0^n c_M(i)di\right) + c_A,$$

where $c_s(i)$ is the consumption of the *i*-th good produced by type *s* firms, where *s* = *H, M*; c_A is the consumption of the agricultural good; *n* is the total mass of goods, which is assumed to be the same for low-productivity and high-productivity firms to ensure that both types of firms face the same level of competition. Following Ottaviano et al. (2002), we assume that $\alpha > 0$, $\beta > 0$, $\gamma > 0$, $\delta \geq 0$, $\beta > \gamma$ and $\gamma \geq \delta$. Parameter *γ* measures the degree of substitutability within *H* goods or *M* goods, while *δ* measures the degree of substitutability between *H* and *M* goods.[5] In previous studies, it is assumed that $\delta = \gamma$ because type *H* and *M* firms belong to the same industry.[6] However, goods produced by low-productivity firms may be weakly substitutable for goods produced by high-productivity firms and vice versa. For example, a computer sold online by IBM or Apple might be weak substitute for the one assembled by a local computer company. Therefore, we relax this assumption and allow *δ* to take a value other than *γ*.

Each consumer maximizes utility subject to a budget constraint:

$$\max_{c_H(i), c_M(i), c_A} U \quad s.t. \quad \int_0^n p_H(i)c_H(i)di + \int_0^n p_M(i)c_M(i)di + c_A = E \tag{2}$$

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[5]To illustrate, consider the case where there are two high-productivity firms and two low-productivity firms. Then, the inverse demand functions from utility maximization are:

$$p_H(i) = \alpha - \beta c_H(i) - \gamma c_H(j) - \delta(c_M(i) + c_M(j)), \; i, j = 1, 2 \quad i \neq j$$

$$p_M(i) = \alpha - \beta c_M(i) - \gamma c_M(j) - \delta(c_H(i) + c_H(j)), \; i, j = 1, 2 \quad i \neq j$$

[6]When $\delta = \gamma$, the utility function reduces to:

$$U = \alpha\left(\int_0^n c_H(i)di + \int_0^n c_M(i)di\right) - \frac{\beta-\gamma}{2}\left(\int_0^n c_H^2(i)di + \int_0^n c_M^2(i)di\right) - \frac{\gamma}{2}\left(\int_0^n c_H(i)di + \int_0^n c_M(i)di\right)^2 + c_A.$$

where, the agricultural good A is assumed to be a numeraire good, $p_s(i)$ is the price of the i-th good produced by type s firm, and E denotes consumer income which includes the endogenous wage and an exogenously determined endowment of agricultural goods.[7] The first order conditions are:

(3a) $$\alpha-(\beta-\gamma)c_H(i)-\gamma\int_0^n c_H(i)di-\delta\int_0^n c_M(i)di-\lambda p_H(i)=0,$$

(3b) $$\alpha-(\beta-\gamma)c_M(i)-\gamma\int_0^n c_M(i)di-\delta\int_0^n c_H(i)di-\lambda p_M(i)=0,$$

(3c) $$1-\lambda=0.$$

Integrating the equation (3a) and (3b) over i, we obtain:

(4a) $$\alpha n-(\beta-\gamma)\int_0^n c_H(i)di-\gamma n\int_0^n c_H(i)di-\delta n\int_0^n c_M(i)di-P_H=0$$

(4b) $$\alpha n-(\beta-\gamma)\int_0^n c_M(i)di-\gamma n\int_0^n c_M(i)di-\delta n\int_0^n c_H(i)di-P_M=0$$

where, $P_H=\int_0^n p_H(i)di$ and $P_L=\int_0^n p_M(i)di$. Solving (4a) and (4b) for $\int c_H(i)di$ and $\int c_M(i)di$ and substituting these into (3a) and (3b) gives us the demand functions for the goods produced by the two types of firms in the manufacturing sector:

(5a) $$c_H(i)=a-dp_H(i)+bP_H+cP_M$$

(5b) $$c_M(i)=a-dp_M(i)+bP_M+cP_H$$

where,

$$a=\alpha/[\beta\text{-}\gamma+n(\gamma+\delta)],$$

$$b=[\gamma(\beta-\gamma)+n(\gamma^2-\delta^2)]/(\beta-\gamma)[(\beta\text{-}\gamma+\gamma n)^2-n^2\delta^2],$$

$$c=\delta/[(\beta\text{-}\gamma+\gamma n)^2-n^2\delta^2] \text{ and}$$

$$d=1/(\beta-\gamma).$$

[7] We assume that E is sufficiently large so that consumption of agricultural goods is positive.

Given that $\alpha > 0$, $\beta > 0$, $\gamma > 0$, $\delta \geq 0$, $\beta > \gamma$ and $\gamma \geq \delta$, *a*, *b*, *c* and *d* all take positive values. The derivatives of *a*, *b, c* and *d* with respect to *n* and *γ* indicate how the level of competition between firms and the substitutability between goods affect the demand for a manufactured good. For instance, the derivatives of *a*, *b* and *c* with respect to *n* are negative, indicating that as the number of competitors increases, demand for a variety declines. Moreover, the derivative of *d* with respect to *γ* is positive implying that demand for a variety decreases as substitutability between varieties increases. Finally, the demand for agricultural good is given by:

(5c) $$c_A = E - a(P_H + P_M) - b(P_H^2 + P_M^2) - 2cP_H P_M + d\left(\int p_H^2(i)di + \int p_M^2(i)di\right)$$

Substituting (5a)-(5c) into (1) and then simplifying it yields the indirect utility function:

(6) $$V = \frac{na^2}{d - bn - cn} - a\left(P_H + P_M\right) - \frac{b}{2}\left(P_H^2 + P_M^2\right) - cP_H P_M + \frac{d}{2}\left(\int_0^n p_H^2(i)di + \int_0^n p_M^2(i)di\right) + E$$

Now, consider the supply side of the markets. We extend the assumptions of Ottaviano et al. (2002) to the heterogeneous firms' setting for the specification of production technologies. Agriculture requires one unit of labor to produce one unit of output. With free trade in agriculture and zero transport costs, the choice of the agricultural good as the numeraire implies that the wage of labor is equal to one in both regions. Therefore, the supply of workers for the manufacturing sector is perfectly elastic as long as there is no shortage of workers in both regions. Each variety of manufactured goods is produced by a firm, which is owned by the industrialists or entrepreneurs who provide human capital to the firm. The manufacturing firms use human capital as a fixed input and labor as a variable input, and the technology requires k_s units of human capital to produce any amount of type *s* goods. Thus, the total mass of type *s* goods is $n = K_s / k_s$, where K_s is total mass of human capital used for the production of type *s* goods. Let λ_H and λ_M denote, respectively, the shares of the entrepreneurs and industrialists living in the North. The total mass of population in the two regions are $M^N = \lambda_H K_H + \lambda_M K_M + 0.5L$ and $M^S = (1-\lambda_H)K_H + (1-\lambda_M)K_M + 0.5L$, respectively. The problem for each firm is to choose the prices of its product in the two regions to maximize its profit:

$$\max_{p_s^{rr}, p_s^{ro}} \pi_s^r = (p_s^{rr} - x_s)c_s^r M^r + (p_s^{ro} - t - x_s)c_s^r M^o, \quad s = H, M, \quad r, o = N, S, \quad r \neq o, \tag{7}$$

where p_s^{rr} is the price of a type *s* good produced in region *r* and sold in region *r*, p_s^{ro} is the price of a type *s* good produced in region *r* and sold in the other region, c_s^r is the demand by a consumer living in region *r* for a type *s* good, *t* is the cost of transporting one unit of any variety from one region to the other and is assumed to account for all the impediments to trade, and x_s is the amount of labor needed to produce a unit of a type *s* good. Since type *H* (*M*) firms are high (low) productivity, $x_H < x_M$.

The first order conditions of the profit maximization problem in equation (7), after indexing the variety-demand functions in (5a) and (5b) by regions, are:

$$a - 2dp_s^{rr} + bP_s^r + cP_{-s}^r + dx_s = 0, \tag{8a}$$

$$a - 2dp_s^{ro} + bP_s^o + cP_{-s}^o + d(x_s + t_s) = 0, \tag{8b}$$

where, the subscript "-*s*" denotes the other manufacturing sector (i.e., goods other than *s*). Solving (8a) and (8b) gives the prices set by type *s* firm located in region *r*:

$$p_s^{rr} = \frac{a + bP_s^r + cP_{-s}^r + dx_s}{2d} \tag{9a}$$

$$p_s^{ro} = p_s^{rr} + \frac{t}{2} \tag{9b}$$

Since k_s units of human capital are required to set up a type *s* firm, each owner's share of profit in region *r* is π_s^r / k_s, and the corresponding utility for the owner is denoted by V_s^r. We assume that human capital is myopic and migrates to the region where it can get the highest utility.

To analyze the spatial distribution of manufacturing firms between the two regions, we define the concept of spatially stable equilibrium as follows.

Definition: A distribution of resources between the two regions is a spatially stable equilibrium if for each *s* = *H, M*:

(i) $(V_s^N - V_s^S) > 0$ and $\lambda_s = 1$,

(ii) $V_s^N - V_s^S = 0$ and $\dfrac{\partial(V_s^N - V_s^S)}{\partial \lambda_s} < 0$ and $\lambda_s \in [0,1]$, or

(iii) $(V_s^N - V_s^S) < 0$ and $\lambda_s = 0$.

If condition (i) or (iii) holds, then all type *s* firms fully agglomerate in one region. Such a distribution is a spatially stable equilibrium if the owners of the firms cannot achieve a higher utility level by moving to the other region. When condition (ii) holds, the owners of firms are indifferent between the two regions, and the firms could disperse between the two regions or be concentrated in only one of them. Such a distribution is a spatially stable equilibrium if relocation of a firm to the other region would result in lower utility for its owner.

3. Spatial Equilibrium

To analyze the equilibrium distribution of manufacturing firms between the two regions, we assume that the initial dispersion of human capital is symmetric between the two regions. Since both regions are initially identical, the relocation of the first firm is indeterminate. We assume that the first firm relocates to the North.

We first show how the degree of competition (δ) affects firm location and the spatial equilibrium in the two-sector setting. For analytical simplicity, we assume that each manufacturing firm requires one unit of human capital, i.e., $k_s = 1, \ \ s = H, L$. We normalize the unit of human capital so that $K_s = 1, \ \ s = H, L$.[8] Then, both types of manufacturing firms have the same mass of firms (i.e., $K_s / k_s = 1, \ \ s = H, L$). We further assume that $x_H = 0 < \theta_M = x_M$ without loss of generality. Under these assumptions, by substituting (5a), (5b), (7), (9a) and (9b) into (6) and taking a difference, the differences in the levels of utility for the entrepreneurs and industrialists can be derived as:

(10a) $$V_H^N - V_H^S = A_1 t(C_1 - t)\left(\lambda_H - \frac{1}{2}\right) + A_2 t(C_2 - t)\left(\lambda_M - \frac{1}{2}\right)$$

(10b) $$V_M^N - V_M^S = A_2 t(C_3 - t)\left(\lambda_H - \frac{1}{2}\right) + A_1 t(C_4 - t)\left(\lambda_M - \frac{1}{2}\right)$$

where, A_1, A_2, C_1, C_2, C_3 and C_4 are functions of parameters in the utility and profit functions and are presented in Appendix 1. $A_1 \geq A_2 > 0$, $C_1 > C_4$ and $C_2 > C_3$.

Before discussing the spatial equilibrium, we need to ensure inter-regional trade, which may not occur if transport costs are prohibitive. Following Ottaviano et al. (2002), we set $t < t_{\max}$, where $t_{\max} = \min\left\{t : p_s^{ro} - t - x_s \geq 0, \ \ r, o = N, S \ \ s = H, M, \ \ r \neq o\right\}$. To ensure $0 < t_{\max}$, we find that the productivity difference between firms should be bounded from above, $\theta_{M\max}$. The upper bound for transport cost and productivity difference makes C_4 positive. Finally, we set a lower limit for labor, $L_{\min}$, so that $t_{\max} > C_1$, i.e. every type of firms disperses at the initial point.[9] Then, we have the following result.

[8]Suppose there are 1000 industrialists (entrepreneurs) in the economy. Then, our normalization measures industrialists (entrepreneurs) in one-thousand units.

[9]See appendix 2.2 for the reason why $t_{\max} > C_1$ ensures the dispersion of firms at the initial point

<u>Result 1</u>: There exists a $\delta^* \in [0,\gamma]$ such that for any $\delta \in (\delta^*,\gamma]$, $C_1 > C_2$, $C_3 > C_4$, $C_1 > C_3$ and $C_2 > C_4$ hold.

Proof: See Appendix 2.1.

Proposition 1. The equilibrium distribution of manufacturing firms: When transport costs fall below a certain level, all high-productivity firms in the South will move to the North simultaneously. When the substitutability between *H* and *M* goods is sufficiently high, a fraction of low-productivity firms in the North will move to the South. However, with further reduction in transport costs, low-productivity firms in the South will gradually move back to the North and eventually all low-productivity firms will fully agglomerate in the North. When the substitutability between *H* and *M* goods is low, the agglomeration of low-productivity firms in the North begins without some firms moving to the South first.

Proof: See Appendix 2.2.

Proposition 1 is illustrated in figure 1, where panel (a) and (b) correspond to the case of strong and weak substitutability between *H* and *M* goods, respectively. The thick (thin) line in both panels represents the share of the high-productivity (low-productivity) firms located in the North. As shown in the figure, regardless of the substitutability between *M* and *H* goods, all high-productivity firms in the South will move to the North simultaneously when transportation costs fall below a certain threshold. In contrast, the agglomeration process of the low-productivity firms is more gradual and depends on the substitutability between *H* and *M* goods. When goods *H* and *L* are highly substitutable, a fraction of low-productivity firms in the North move to the South first. However, with weak substitutability between goods *H* and *L*, a decline in transport costs causes both types of firms to agglomerate in the North, although low-productivity firms' relocation to the North is not instantaneous.[10]

Agglomeration or dispersion of firms is determined by centripetal forces and centrifugal forces (Fujita et a., 1999; Baldwin et al., 2003). A primary centripetal force is the increased demand for manufacturing goods when firms are located together because of household preferences for varieties (Ottaviano et al., 2002). However, competition between firms acts as a centrifugal force countering agglomeration. When transport costs are high, the latter outweighs the former causing firms to spatially disperse. On the contrary, when transport costs are low, centripetal forces outweigh those that pull firms apart resulting in agglomeration (Baldwin et al., 2003). In our case, competition between H and M goods works as another centrifugal force. In particular, when goods produced by high-productivity firms are strongly substitutable for goods produced by low-productivity firms (i.e., δ is large), competition becomes severe. Even though agglomeration of high-productivity firms in the North increases the demand for manufacturing goods, the severe competition reduces benefits of agglomeration. Since low-productivity firms are less competitive than high-productivity counterparts, low-productivity firms move to the South where high-productivity firms lose their competitiveness due to high transport costs (panel a). However, high-productivity firms become more competitive in the South as transport costs decline. As a result, the benefit of locating in the South falls for low-productivity firms, which begin their agglomeration in the North. When the competition between firms is weak, agglomeration of high-productivity firms benefits low-productivity firms by offering large demand for their goods as well.

[10]At the extreme, i.e., when δ is very small, both high-productivity and low-productivity firms instantaneously move to the North.

Proposition 1 considers a general case where *H* and *M* goods can be weakly substitutable. A more restricted case where any manufacturing good regardless of its type faces the same substitutability is obtained by setting $\delta = \gamma$ (see footnote # 6). Location patterns of firms in this special case is summarized in the following corollary.

Corollary 1. When transportation costs fall below a certain level, all high-productivity firms in the South will move to the North simultaneously, while a fraction of low-productivity firms in the North will move to the South. However, with further reduction in transport costs, some low-productivity firms in the South will move back to the North and eventually all firms will fully agglomerate in the North.

In the presence of productivity difference, we showed that competition between different types of firms works as a dispersion force. As competition becomes severe, i.e., δ is large, low-productivity firms tend to locate away from high-productivity counterparts. We next investigate how the equilibrium distribution will adjust with increasing trade and globalization.

4. Trade Liberalization and Regional Structural Adjustments

In this section, we analyze how trade liberalization affects regional structure by introducing a third region *F*, the rest of the world, into the agglomeration model with firm heterogeneity. For analytical purposes, we assume that only one type of firms exists in region *F*, which use one unit of human capital as a fixed input and labor as a variable input. The marginal labor requirement is $x_F = \theta_F$. In addition, to focus on the effect of trade liberalization, we set $\delta = \gamma$, which implies that goods are equally substitutable both within and across sectors. The region *F* is endowed with K_F units of human capital and L_F units of labor. Since the rest of the world is generally larger than any single economy, we assume that $K_F \geq 2$, which implies that the total mass of differentiated goods is larger in the foreign region F relative to the two home-country regions. Agricultural goods are freely traded between countries, which normalizes the wage rate to one in all three regions. It costs t_F to trade differentiated goods between countries. t_F includes both natural transport costs and artificial trade barriers and is assumed to be the same for the North and the South. With the access to the world market, the utility function becomes:

$$U = \alpha\left(\int_0^n c_H(i)di + \int_0^n c_M(i)di + \int_0^{n_F} c_F(i)di\right) - \frac{\beta-\gamma}{2}\left(\int_0^n c_H^2(i)di + \int_0^n c_M^2(i)di + \int_0^{n_F} c_F^2(i)di\right)$$
$$- \frac{\gamma}{2}\left(\int_0^n c_H(i)di + \int_0^n c_M(i)di + \int_0^{n_F} c_F(i)di\right)^2 + c_A, \tag{11}$$

where, $n_F = K_F$. The demand function for each good can be derived in a similar way as equations (5a)-(5b) are derived. Given the additional region, the domestic firms' profit maximization problem is:

$$\max_{p_l^{rr}, p_l^{ro}, p_l^{rF}} \pi_l^r = (p_l^{rr} - x_l)c_l^r M^r + (p_l^{ro} - t_l - x_l)c_l^s M^s + (p_l^{rF} - t_F - x_l)c_l^F M^F,$$
$$l = H, L, \quad r, o = N, S, \quad r \neq o, \tag{12}$$

where, $M^F = K_F + L_F$. Likewise, foreign firms maximize profits by choosing prices for the three regions:

$$\max_{p_F^{Fr}, p_F^{Fo}, p_F^{FF}} \pi_F = (p_F^{Fr} - t_F - x_F)c_F^r M^r + (p_F^{Fo} - t_F - x_F)c_F^s M^s + (p_F^{FF} - x_F)c_F^F M^F,$$
$$r, o = N, S, \quad r \neq o. \tag{13}$$

Prices for goods produced domestically and by foreign firms can be derived from the first-order conditions of these profit maximization problems. Given the prices, the indirect utility functions for industrialists and entrepreneurs can be derived by maximizing their utility subject to the budget constraint. The difference in utility for each group in the two regions is given by:

(14a) $$V_H^N - V_H^S = q_1(t_F,t)\left(\lambda_H - \frac{1}{2}\right) + q_2(t_F,t)\left(\lambda_L - \frac{1}{2}\right),$$

(14b) $$V_M^N - V_M^S = q_3(t_F,t)\left(\lambda_H - \frac{1}{2}\right) + q_4(t_F,t)\left(\lambda_L - \frac{1}{2}\right),$$

where, $q_i(t_F,t),\ \ i=1,...,4$, are linear in t_F with a positive slope and quadratic in t with a negative sign on t^2. Furthermore, $q_1(t_F,t) > q_2(t_F,t) > q_3(t_F,t) > q_4(t_F,t)$ holds for $t > 0$. Similar to the two-region setting and Ottaviano et al. (2002), there would be no trade among the three regions when t_F and t are high enough. Let $t_{2\max}$ and $t_{F\max}$ denote the highest levels of t and t_F that assure trade among the three regions. Implicit in the derivation of $t_{2\max}$ and $t_{F\max}$ are (i) θ_M and θ_F must be in the space "*pd*" shown in Appendix 1, which assures that maximum transport costs are always positive, and (ii) $q_4(t_F,t) > 0$ for low domestic transport costs. Finally, we set a lower limit for labor, $L_{2\min}$, so that $q_1(t_F,t)$ is negative at $t_{2\max}$, which assures that both types of firms are dispersed when domestic transport costs are high.

From (14a) and (14b), $\partial(V_s^N - V_s^S)/\partial\lambda_k = q_i(t_F,t),\ \ s,k = H,L,\ \ i=1,...,4$. When $q_i(t_F,t) > 0$, agglomeration may occur because as human capital increases in one region, the utility level there will become higher than the other region. As international transport costs decrease, e.g., from t_{F2} to t_{F1} in figure 2, $q_i(t_F,t),\ \ i=1,...,4$ shift downward and the range in which $q_i(t_F,t)$ takes a positive value shrinks. Therefore, international trade opportunity works against agglomeration.[11] All $q_i(t_F,t) = 0$ have one positive solution in terms of t in addition to zero implying that $q_3(t_F,t) + q_4(t_F,t) = 0$ has one positive solution. Let this solution be $t(t_F)$. Then, we have a following proposition.

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[11]When *H* and *M* goods are not substitutable, i.e., $\delta = 0$, $q_i(t_F,t) = 0$ is not a function of t_F. This implies that international trade affects the firm location only when competition between *H* and *M* goods is not weak.

Proposition 2.

When international transport costs are high, both types of firms agglomerate in the North for $t \in (t(0), t(t_{F\max}))$. As international transport costs fall, low-productivity firms relocate to the South, while all high-productivity and some low-productivity firms remain in the North.

Proof: See Appendix 2.3.

The explanation for this result is that large foreign markets become more important than domestic markets when international transport costs are low. Low-productivity firms have to compete with the high-productivity firms if both are located in the North. With the increasing importance of foreign markets, low productivity firms are the first to relocate to the South. When the domestic transport cost *t* is greater than $t(t_{F\max})$, low-productivity firms do not fully agglomerate in the North even when t_F is high. On the other hand, *t* is less than *t*(0), neither type of firms relocate from the North to the South. Figure 3 shows how the two types of firms change their location in response to a change in international transport costs for $t \in (t(0), t(t_{F\max}))$. As in figure 1, the thick (thin) line is the share of high-productivity (low-productivity) firms located in the North. As international transport costs decline, low-productivity firms relocate to the South and the difference in size between the North and the South shrinks with the latter specializing in low-productivity firms.

With regard to a change in productivity difference, we have the following proposition.

Proposition 3

When the domestic productivity difference widens (i.e., θ_M, increases), or when the productivity of foreign firms improves (i.e., θ_F, declines), the level of international transport costs at which domestic low-productivity firms relocate increases. Moreover, when productivity of foreign firms improves, the number of firms relocating to the South also increases.

Proof: See Appendix 2.4.

A narrowing gap in productivity between domestic firms fosters agglomeration of both types of firms. When productivity difference between domestic firms is large, low-productivity firms react to international trade opportunities at higher level of international transport costs because low-productivity firms are not competitive in the North. This result suggests that R&D subsidy for low-productivity firms will increase the regional economic disparity because as productivity gap narrows, trade liberalization will not cause the relocation of low-productivity firms to the South. On the contrary, R&D Subsidy for high-productivity firms will lead to the opposite result.

Productivity improvement of foreign firms leads to dispersion. Alternatively, when productivity of foreign firms improves, competition in the domestic market, which reduces the attractiveness of urban areas, especially for low-productivity firms. At the same time, prices in the South go down due to imports, which increase the utility level and attractiveness of the region. As a result, low-productivity firms move to the South, where they can hire human capital at lower costs.

To further illustrate the role of international trade, figure 4 depicts each region's export value based on a simulation under assumed parameter values.[12] The thick line is the export value of the North, which shows greater export value in this region relative to the South regardless of

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[12]Parameter values are $\alpha = 0.2$, $\beta = 1$, $\gamma = 0.5$, $Lab = 50$, $K_F = 5$, $Lab_F = 100$, $\theta_M = 0.005$, $\theta_F = 0.0025$ and $t = 0.03$.

the level of international transport costs. When international transport costs approach zero, the export value of the North remains greater than the value of the South even though the former loses some exporting firms. This is because all high-productivity exporting firms remain in the North and only low-productivity exporting firms locate in the South, a result consistent with the export decision literature (Bernard and Jensen, 1999).

5. A Policy Simulation: Role of Regional Government Subsidy

In the previous section, the South is shown to attract only low-productivity firms with a fall in international transport costs. Moreover, the export value is always lower in the South than in the North. As a result, wages and incomes, and overall regional welfare including immobile workers' utility are likely to be lower in the South. The parallel to this situation in empirical studies is the case of rural areas, whose economic indicators lag behind their urban counterparts. For example, Glaeser and Mare (2001) report that wages are 33% higher in big cities in the United States. Local governments use various strategies to attract high-productivity firms, whose presence is strongly associated with regional economic development. These strategies include direct governmental subsidies through tax breaks or construction or improvement of local infrastructure. In this section, we use the model to simulate how local government subsidies affect the distribution of firms between the regions. For simplicity, the subsidy takes the form of a lump-sum payment to any firms located in the concerned region.

In the pre-subsidy regime, suppose many low-productivity firms ($1-\lambda_M = 0.79$) locate in the South due to the trade liberalization ($t_F = 0.025$) as shown in the figure 3. The subsidy is financed through a residency tax:

(15) $\left(2-\lambda_H-\lambda_M+\frac{L}{2}\right)tax=(2-\lambda_H-\lambda_M)subsidy$.

The differences in utility for the two groups in the home country are given by:

(16a) $V_H^N-V_H^S=q_1(t_F,t)\left(\lambda_H-\frac{1}{2}\right)+q_2(t_F,t)\left(\lambda_M-\frac{1}{2}\right)-\frac{0.5L\times subsidy}{2-\lambda_H-\lambda_M+0.5L}$,

(16b) $V_M^N-V_M^S=q_3(t_F,t)\left(\lambda_H-\frac{1}{2}\right)+q_4(t_F,t)\left(\lambda_M-\frac{1}{2}\right)-\frac{0.5L\times subsidy}{2-\lambda_H-\lambda_M+0.5Lab}$.

Figure 5 illustrates the reaction of high-productivity and low-productivity firms to such a subsidy.[13] For convenience, we assume that high-productivity firms first react to a subsidy even though the result does not change if low-productivity firms react first. As before, the thick (thin) line is the share of high-productivity (low-productivity) firms in the North. Since all high-productivity firms and some of low-productivity firms locate in the North, $V_H^N-V_H^S>0$ and $V_M^N-V_M^S=0$ when subsidy is zero. When the amount of subsidy is small, only (16b) becomes negative and (16a) remains positive. Thus, only low-productivity firms react to a small subsidy from the South. However, once subsidy exceeds a threshold so that (16a) becomes negative, then all high-productivity firms react and relocate to the South, but, at the same time, many low-productivity firms relocate to the North to avoid competition from high-productivity firms. If the subsidy offered by the local government is large enough, the South would be able to attract all firms, including both high- and low-productivity firms.

Next, we consider a subsidy competition between North and South. It is likely that local government in the North also offers a subsidy to prevent firms from relocating to the South. It is clear from equations 16(a) and 16(b) that even when the South offers a large subsidy to attract high-productivity firms, the North can easily offset those incentives with a lower subsidy.

[13]Parameter values used in this simulation are the same as those used for figure 4.

Therefore, the North holds a distinct advantage in a subsidy competition. Hence, the subsidy instrument is less likely to attract high-productivity firms to rural areas for the purpose of economic development.[14]

6. Summary and Conclusion

In this study, we analyzed the agglomeration process in the presence of firm heterogeneity, i.e., productivity differences. We began with a closed-economy setting, where high- and low-productivity firms exhibit a different path in their location choices and the resulting spatial equilibrium. Similar to other studies, transport costs and the degree of competition are key factors determining firms' location choice and the agglomeration process in our model. However, we demonstrate that low-productivity firms can disperse with a fall in the transport costs when facing severe competition with their high-productivity counterparts. With a reduction in transportation costs, it gets less expensive to ship goods to other regions and the net benefit of agglomeration increases. When the net benefit increases enough to offset the cost of severe competition, low-productivity firms begin to agglomerate with high-productivity ones.

Extending the firm-heterogeneity model of agglomeration to an open-economy setting, we find that trade liberalization acts as a centrifugal force for low-productivity firms. That is, low-productivity firms locate away from their high-productivity counterparts, when both sets of firms face the same set of international trade opportunities. We also find that narrowing productivity differences between domestic firms favors agglomeration, while narrowing productivity differences between domestic and foreign firms favors dispersion.

[14]In Dupont and Martin's (2006) study, with homogeneous firms, a subsidy attracts firms to underdeveloped areas, but, in some cases, it can be an income transfer from a poor to a rich area.

Finally, we carry out two simulations in the open-economy setting: one for the export value in the two domestic regions and the other with a subsidy competition between these regions. Our results show that the gap in export values between the two regions narrows as international transport costs decrease, although it never disappears. When the less developed region with fewer firms attempts to lure firms away from the other region with a subsidy, it tends to attract low-productivity firms initially. However, when its subsidy becomes large enough to attract high-productivity firms, the other region can easily compensate those firms with a lower subsidy and avoid their relocation.

Our results show that trade liberalization is good for rural communities and under-developed regions. When facing the same set of international trade opportunities, less developed rural regions tend to gain less productive firms, which may only provide low-paying jobs relative to those located in more developed areas. Our results are based on a model that allows intra-regional mobility of human capital. However, trade liberalization may accompany foreign direct investment and outsourcing, and low-productivity firms may move to a foreign country rather than a less developed region. How globalization, with outsourcing and international movement of human capital, affects less developed regions remains an important topic for future research.

Appendix 1

In this appendix, we expand on several abbreviations used in this study and provide more detailed explanations how those results are derived.

Derivation of Utility Differences (10a) and (10b)

By substituting equations (5a), (5b), (7), (9a) and (9b) into (6), the difference in the utility level of the entrepreneurs (equation 10a) and industrialists (equation 10b) are derived as a function of their share in the North, transport costs, the parameters A_1, A_2, C_1, C_2, C_3 and C_4 in equations (10a) and (10b) take the following form.

$$A_2 = \frac{(2\beta-\gamma-\delta)\left((6\beta-5\gamma)\beta+(5\beta-3\gamma)\delta+\gamma^2+(2\beta-\gamma+\delta)\delta L\right)}{\left((2\beta-\gamma)^2-\delta^2\right)^2}$$

$$A_1 = A_2 + \frac{(L+2)(\gamma-\delta)}{2(\beta-\gamma)(2\beta-\gamma-\delta)}$$

$$C_1 = \frac{2\left((2\beta-\gamma-\delta)^2(3\beta-\gamma+2\delta)\alpha-2\left(\beta(\gamma-2\beta)+\delta^2\right)\delta\theta_M\right)}{\left((2\beta-\gamma)^2-\delta^2\right)^2 A_1}$$

$$C_2 = \frac{2\left((2\beta-\gamma-\delta)^2(3\beta-\gamma+2\delta)\alpha-\left((2\beta-\gamma)^2\beta-(2\beta-\gamma)^2\delta-(3\beta-2\gamma)\delta^2+\delta^3\right)\theta_M\right)}{\left((2\beta-\gamma)^2-\delta^2\right)^2 A_2}$$

$$C_3 = C_2 - \frac{2(\beta-\gamma)\theta_M}{A_2(2\beta-\gamma-\delta)^2}$$

$$C_4 = C_1 - \frac{2(3\beta-\gamma-2\delta)\theta_M}{A_1(2\beta-\gamma-\delta)^2}$$

Note that $A_1 \geq A_2 > 0$, $C_1 > C_4$ and $C_2 > C_3$ given the parametric assumptions.

Derivation of the Maximum Transport Cost That Assures Trade ($t_{\max}$)

The maximum transport cost that assures trade between the North and the South $t_{\max}$ is defined by $t_{\max} = \min\left\{t : p_s^{ro} - t - x_s \geq 0,\ \ r, o = N, S \ \ s = H, M,\ \ r \neq o\right\}$. Setting the difference between price and marginal costs including transport costs $p_s^{ro} - t - x_s$ to zero, we obtain

$$t_{\max} = \frac{2(\beta-\gamma)\left((2\beta-\gamma-\delta)\alpha - (2\beta-\gamma)\theta_M\right)}{4\beta(\beta-\gamma)+\gamma^2-\delta^2}.$$

Although the denominator of $t_{\max}$ is positive, the numerator can take either sign depending on the productivity difference. Thus, we must set the upper bound, $\theta_{M\max}$, to assure that maximum transport costs are positive:

$$\theta_{M\max} = \frac{\alpha(2\beta-\gamma-\delta)}{2\beta-\gamma}.$$

It can be shown that $C_4 > 0$ when the productivity difference is less than $\theta_{M\max}$. Finally, as shown in the appendix 2, $t_{\max} > C_1$ is necessary so that both types of firms initially disperse between regions and this condition is satisfied when total mass of labor is greater than $L_{\min}$, which is derived as:

$$\begin{aligned} L_{\min} = {} & \frac{1}{(2\beta-\gamma+\delta)(2\beta\gamma-\gamma^2-\delta^2)\left((2\beta-\gamma-\delta)\alpha-(2\beta-\gamma)\theta_M\right)}\Big[2\big\{(2\beta-\gamma-\delta)\alpha \\ & \left(6\beta^3-\gamma^3+2\gamma^2\delta-2\gamma\delta^2-\delta^3-(9\gamma-7\delta)\beta^2+(5\gamma^2-8\gamma\delta+\delta^2)\beta\right)+2(2\beta-\gamma+\delta) \\ & \left((2\beta-\gamma)\beta-\delta^2\right)\delta\theta_M + (2\beta-\gamma)\left(6\beta^3+(3\gamma-\delta)\delta^2-(7\gamma-\delta)\beta^2+2(\gamma^2-2\delta^2)\beta\right)\theta_M\big\}\Big]. \end{aligned}$$

<u>*Derivation of Utility Differences (14a) and (14b)*</u>

Following the same steps as in the derivation of (10a) and (10b), the difference in the utility level of the entrepreneurs (equation 14a) and industrialists (equation 14b) are derived as a function of their share in the North and transport costs. The parameters in the equations, $q_i\left(t_F, t\right),\ \ i = 1, \ldots, 4$, are defined as follows:

$$q_1(t_F,t)=\frac{-1}{4(\beta-\gamma)(2\beta+\gamma K_F)^2}\Big[t\Big\{-8(\beta-\gamma)(3\beta+\gamma+2\gamma K_F)\alpha+\big(12\beta^2+4(3K_F+L)\beta\gamma$$
$$+\big(K_F(3K_F+2L-2)-4\big)\gamma^2\big)t-2(4\beta+2\gamma+3\gamma K_F)\big(K_F(t_F+\theta_F)+\theta_M\big)\gamma\Big\}\Big]$$

$$q_2\left(t_F,t\right)=q_1\left(t_F,t\right)-\frac{t\theta_M}{2\left(\beta-\gamma\right)}$$

$$q_3\left(t_F,t\right)=q_1\left(t_F,t\right)-\frac{t\theta_M}{\beta-\gamma}$$

$$q_4\left(t_F,t\right)=q_1\left(t_F,t\right)-\frac{3t\theta_M}{2\left(\beta-\gamma\right)}$$

For $t>0$, $q_1\left(t_F,t\right)>q_2\left(t_F,t\right)>q_3\left(t_F,t\right)>q_4\left(t_F,t\right)$.

Derivation of the Maximum Transport Cost that Assures Trade in the Open Economy

The parameters $t_{2\max}$ and $t_{F\max}$ are the maximum transport costs which assure trade between the North and the South and between the two countries, respectively. These are obtained in the same way as $t_{\max}$ is derived. Specifically, by setting the difference between price and marginal costs including transports costs to zero, we obtain

$$t_{2\max}=\frac{2(\beta-\gamma)\alpha+(\theta_F-\theta_M)\gamma K_F-(2\beta-\gamma)\theta_M}{2\beta+\gamma K_F}$$

$$t_{F\max}=\min\left\{\frac{2(\beta-\gamma)\alpha+(\theta_F-\theta_M)\gamma K_F-(2\beta-\gamma)\theta_M}{2(\beta-\gamma)+\gamma K_F},\frac{2(\beta-\gamma)\alpha-2\beta\theta_F+\gamma\theta_M}{2\beta}\right\}$$

Although the numerator of $t_{2\max}$ and $t_{F\max}$ can take either sign depending on the productivity difference, they are always positive as long as θ_M and θ_F are in the space "*pd*":

$$pd=\{(\theta_M,\theta_F)\in R^2:2(\beta-\gamma)\alpha+(\theta_F-\theta_M)\gamma K_F-(2\beta-\gamma)\theta_M>0,$$
$$2(\beta-\gamma)\alpha-2\beta\theta_F+\gamma\theta_M>0,\theta_M>0,\theta_F\geq 0\}$$

It can be also shown that $q_4\left(t_F, t\right)=0$ has a positive solution with respect to domestic transport costs when the productivity differences are in the space "*pd*". Finally, as noted in section 4, $q_1\left(t_F, t\right)$ must be less than zero at $t=t_{2\max}$ so that both types of firms initially disperse between regions. This condition is satisfied when total mass of labor is greater than $L_{2\min}$:

$$L_{2\min}=\frac{1}{2\gamma(2\beta+\gamma K_F)\left(2(\beta-\gamma)\alpha+(\theta_F-\theta_M)\gamma K_F-(2\beta-\gamma)\theta_M\right)}\Big[2(\beta-\gamma)\big(12\beta^2 \\ +\left((5K_F+6)K_F+4\right)\gamma^2+8(1+2K_F)\beta\gamma\big)\alpha+\left\{2(2\beta+\gamma K_F)(4\beta+2\gamma+3\gamma K_F)t_{F\max} \\ +\left(4\beta^2+8(K_F+1)\beta\gamma+\left(3(K_F+2)K_F+4\right)\gamma^2\right)\theta_F\right\}\gamma K_F+\Big(24\beta^3+2(9K_F+2)\beta\gamma^2 K_F \\ +\left(4+(3K_F^2+K_F+2)K_F\right)\gamma^3+4(9K_F+1)\beta^2\gamma\Big)\theta_M\Big].$$

Appendix 2

In this appendix, we provide a proof for each of the major results and propositions in this study.

Result 1 in Section 3

First, we prove that $C_3 > C_4$ and $C_2 > C_4$. As shown in Appendix 1, the sign of the difference $C_3 - C_4$ depends on a cubic function of δ and the coefficient on the third-degree term is positive. At $\delta = \gamma$, the difference is positive and the slope is negative. At $\delta = 0$, the difference is positive and the slope is negative. Therefore, for a nonnegative δ, we have $C_3 > C_4$. From $C_2 > C_3$, we have $C_2 > C_4$.

Second, we prove that $C_1 > C_3$. The sign of $C_1 - C_3$ depends on a quadrant function of δ and the coefficient of δ^4 is positive. Thus, $C_1 - C_3$ has at most three local extreme or inflection points. At $\delta = \gamma$, the difference is positive. Since the slope is positive and the second derivative is negative, this point locates to the left of the middle critical point of the three inflection points. At $\delta = 0$, it can be shown that $C_3 > t_{\max}$ which implies $C_3 > C_1$ because $t_{\max} > C_1$ from appendix 1, i.e. the difference is negative. Therefore, there exists a δ^{z1} between zero and γ such that $C_1 = C_3$ at $\delta = \delta^{z1}$ and for any $\delta \in (\delta^{z1}, \gamma]$, $C_1 > C_3$.

Finally, we prove that $C_1 > C_2$. The sign of $C_1 - C_2$ depends on a cubic function of δ and the coefficient of δ^3 is negative. At $\delta = \gamma$, the difference and the slope is positive. At $\delta = \delta^{z1}$, from the above, we know that $C_1 = C_3$. Since $C_2 > C_3$, C_2 must be greater than C_1 at $\delta = \delta^{z1}$. Since at $\delta = 0$ the slope remains positive, there exists a $\delta^{z2} (> \delta^{z1})$ such that for any $\delta \in (\delta^{z2}, \gamma]$, we have $C_1 > C_2$.

Result 1 in section 3 follows if we define δ^* as $\delta^* = \delta^{z2}$.

Proof of Proposition 1

From result 1, we know that for any $\delta \in (\delta^*, \gamma]$, $C_1 > C_2$, $C_3 > C_4$, $C_1 > C_3$ and $C_2 > C_4$ hold. For $t \in (C_1, t_{\max}]$, $C_i - t < 0,\ \ i = 1,...,4$ and $\partial(V_l^N - V_l^S)/\partial\lambda_l < 0$. Thus, a symmetric equilibrium is the stable (initial) equilibrium. For $t \in (C_2, C_1)$, $C_1 - t > 0$ and $C_i - t < 0,\ \ i = 2,3,4$, we have $\partial(V_H^N - V_H^S)/\partial\lambda_H > 0$. In the latter case, symmetric equilibrium is no longer stable and high-productivity firms move to the North. When $\lambda_H > 1/2$, $V_M^N - V_M^S < 0$ and $\partial(V_M^N - V_M^S)/\partial\lambda_M < 0$ hold, causing low-productivity firms to relocate to the South until $V_M^N - V_M^S = 0$ or $\lambda_M = 0$. When $\lambda_H > 1/2$ and $\lambda_M < 1/2$, $V_H^N - V_H^S > 0$ always holds since $C_2 - t < 0$. Therefore, $\lambda_H = 1$. Finally, when $\lambda_H = 1$, $\lambda_M = 0$ is never attained because $A_2(C_3 - t) > A_1(C_4 - t)$ always holds. Consequently, $\lambda_H = 1$ and $\lambda_M \in (0, 1/2)$ is the equilibrium.

Solving $V_M^N - V_M^S = 0$ for λ_M and differentiating it with respect to *t* shows that $d\lambda_M/dt < 0$, which implies that as transport costs decrease, the share of low-productivity firms in the North increases when *t* falls. For $t \in (C_3, C_2)$, when $\lambda_H = 1$, $V_H^N - V_H^S > 0$ holds since $A_1 \geq A_2 > 0$. Thus, entrepreneurs have no incentive to relocate from the North. When $\lambda_H = 1$, $V_M^N - V_M^S = 0$ and $\partial(V_M^N - V_M^S)/\partial\lambda_M < 0$ hold for $\lambda_M \in (0, 1/2)$ and $V_M^N - V_M^S < 0$ holds for $\lambda_M \in [1/2, 1]$ because $C_i - t < 0,\ \ i = 3,4$. Therefore, $\lambda_H = 1$ and $\lambda_M \in (0, 1/2)$ is the equilibrium. Again $d\lambda_M/dt < 0$. After *t* becomes less than C_3, $V_M^N - V_M^S = 0$ and $\partial(V_M^N - V_M^S)/\partial\lambda_M < 0$ hold for $\lambda_M \in [1/2, 1]$ and $V_M^N - V_M^S > 0$ holds for $\lambda_M \in (0, 1/2)$. Hence $\lambda_H = 1$ and $\lambda_M \in [1/2, 1]$ is the equilibrium and $d\lambda_M/dt < 0$.

From Result 1 of section 3, we know that for $\delta < \delta^{z1}$, $C_2 > C_1$ and $C_3 > C_1$ hold. Again, for $t \in (C_1, t_{\max}]$, there exists a symmetric equilibrium Then, for $t < C_1$, sector *H* will relocate to the North because $\partial(V_H^N - V_H^S)/\partial\lambda_H > 0$. Since $C_3 - t > 0$, this relocation makes $d\omega_L > 0$ and low-productivity firms also relocates to the North. Hence, $\lambda_M > 1/2$. When $\lambda_M > 1/2$, $V_H^N - V_H^S > 0$ always holds. As a result, $\lambda_H = 1$ and $\lambda_M \in [1/2, 1]$ is the stable spatial equilibrium. Also, $d\lambda_M / dt < 0$ holds.

Proof of Proposition 2

Since $t(t_F)$ is a linear function of t_F with a positive slope, for any $t_c \in (t(0), t(t_{F\max}))$. there exists a $t_{FC} \in (0, t_{F\max})$ such that $t_c = t(t_{FC})$. As explained in section 3, when t_F decreases, $q_3(t_F, t) + q_4(t_F, t)$ shifts downward when depicted against *t* (figure 2). $q_3(t_F, t) + q_4(t_F, t) > 0$ holds for $t_F \in (t_{FC}, t_{F\max}]$ given $t = t_c$. It can also be shown that $q_1(t_F, t) + q_2(t_F, t) > 0$ because $q_1(t_F, t) > q_2(t_F, t) > q_3(t_F, t) > q_4(t_F, t)$. Therefore, $\lambda_H = 1$ and $\lambda_M = 1$ is a stable equilibrium because $V_H^N - V_H^S > 0$ and $V_M^N - V_M^S > 0$ hold.

After the international transport costs reach t_{FC}, further decline will cause $q_3(t_F, t) + q_4(t_F, t)$ to be negative, but $q_1(t_F, t) + q_2(t_F, t)$ remains positive. Therefore, $V_H^N - V_H^S > 0$, $V_M^N - V_M^S < 0$ and $\partial(V_M^N - V_M^S)/\partial\lambda_M < 0$ hold when $\lambda_H = 1$ and $\lambda_M = 1$. This implies that low-productivity firms are the first to relocate to the South. By solving $V_M^N - V_M^S = 0$ for λ_M and substituting this into (14a), we have $V_H^N - V_H^S = (\lambda_H - 1/2)\left[q_1(t_F, t) q_4(t_F, t) - q_2(t_F, t) q_3(t_F, t)\right]/q_4(t_F, t)$ and it can be shown that $\left[q_1(t_F, t) q_4(t_F, t) - q_2(t_F, t) q_3(t_F, t)\right]/q_4(t_F, t) > 0$ for $t_F \in (0, t_{FC})$. Thus, as long as $\lambda_M \in (0,1)$, i.e. λ_M is determined by $V_M^N - V_M^S = 0$, $\lambda_H = 1$ is always an equilibrium. Note that, with $q_3(t_F, t) > q_4(t_F, t)$, when $\lambda_H = 1$, low-productivity firms do not fully agglomerate in the South, i.e. $V_M^N - V_M^S < 0$ does not occur.

Finally, by setting $\lambda_H = 1$ and solving $V_M^N - V_M^S = 0$ for λ_M and differentiating it with respect to t_F, we have $d\lambda_M / dt_F = \left[q_3(t_F, t) q_4'(t_F, t) - q_4(t_F, t) q_3'(t_F, t)\right]/2q_4(t_F, t)^2 > 0$. Thus, as international transport costs decrease, the share of low-productivity firms in the North decreases as long as it is determined by $V_M^N - V_M^S = 0$.

Proof of Proposition 3

As shown in the proof of proposition 2, at $t_F = t_{FC}$, low-productivity firms begin relocating to the North. By setting $\lambda_H = 1$ and solving $V_M^N - V_M^S = 0$ for λ_M, we obtain the share of low-productivity firms in the North. We can show that $dt_{FC}/d\theta_M > 0$, $dt_{FC}/d\theta_F < 0$ and $d\lambda_M/d\theta_F > 0$.

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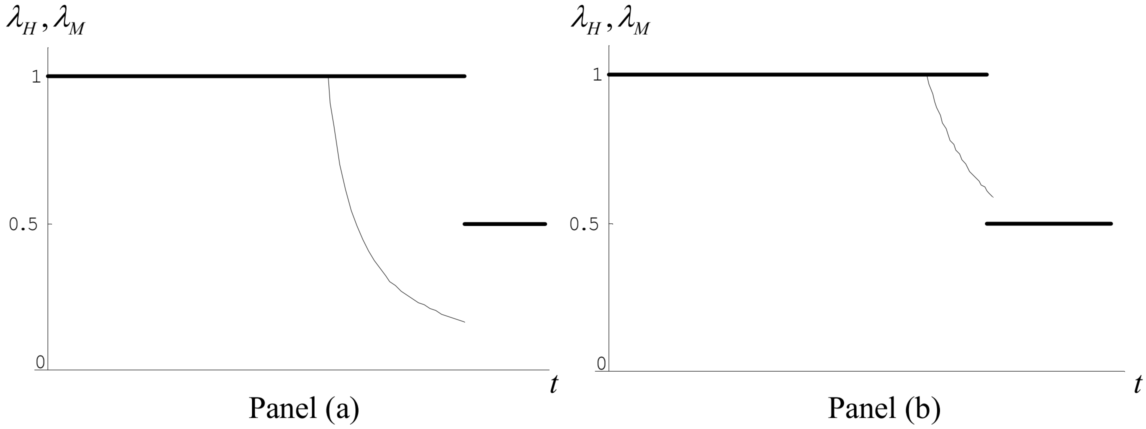

Figure 1: Competition, Transport Costs and Agglomeration of Heterogeneous Firms

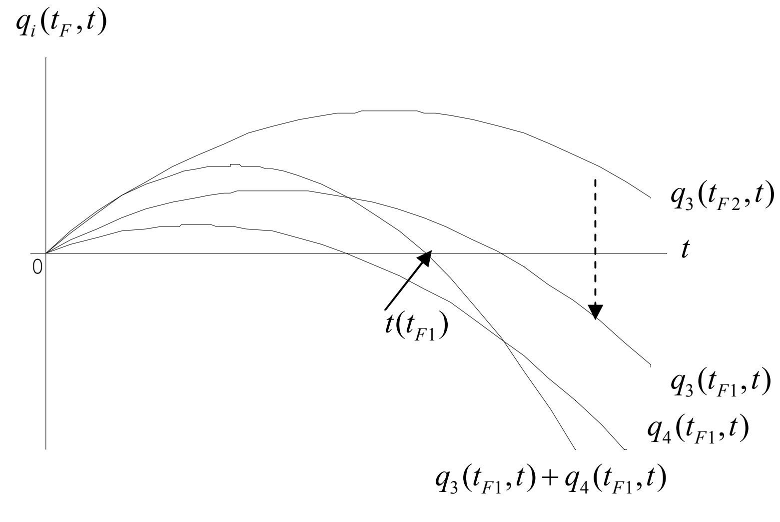

Figure 2: International Trade Opportunity and Agglomeration

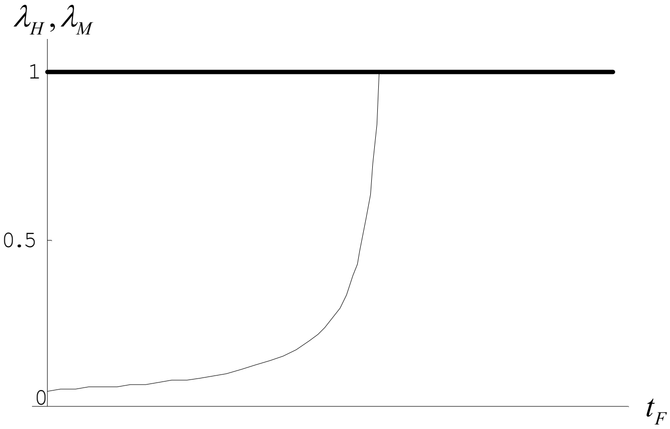

Figure 3: International Transport Costs and Agglomeration of Heterogeneous Firms

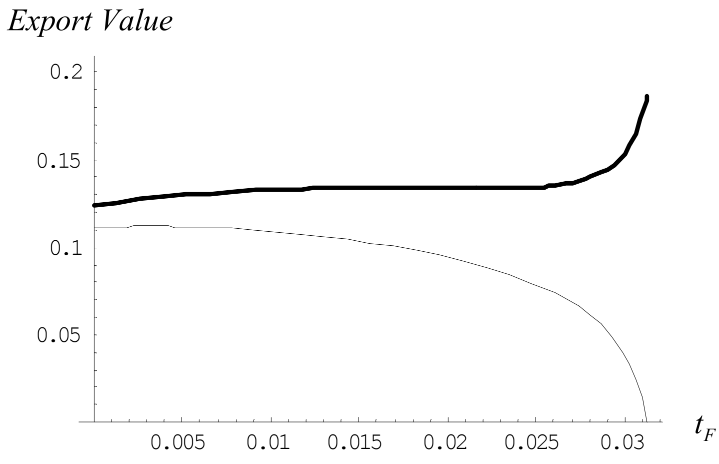

Figure 4: Regional Export Values and International transport

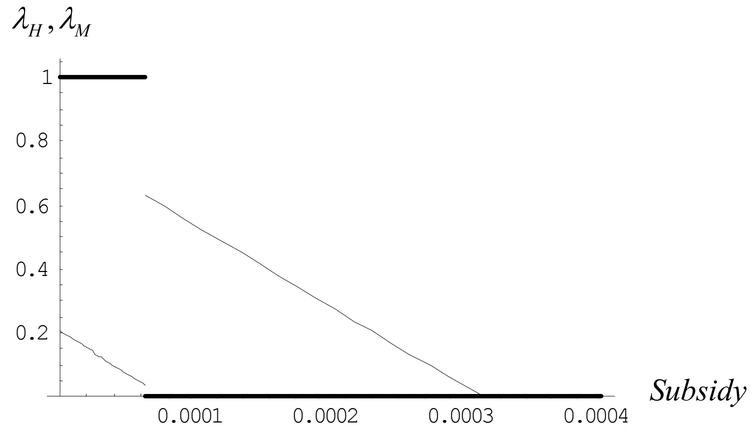

Figure 5: Subsidy and Agglomeration of Heterogeneous Firms