

# Intra-National Regional Heterogeneity in International Trade

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## Abstract

We present a two-country model, specifically with two regions in home country. Each region consists of two types of labor; skilled labor is required to set up a firm, and unskilled labor is used as marginal input for production. Trade cost accrues both intra-nationally and internationally. International trade costs are assumed to be different across regions. Our model produces a region-based gravity model and generates heterogeneity among regional exports in terms of responses with respect to economic size. We also find a home market effect at the regional level. Moreover, we are able to show the relative magnitude of the home market effect among home regions, in terms of a change in the export share. We empirically test our theoretical propositions with an application to the export dataset of Japanese regions. Our empirical results provide strong evidence in support of both a region-based home-market effect and a relative home-market effect.

Keywords: International trade; Quasi-linear preference; Regional exports; Regional heterogeneity; Trade cost.

JEL Classification Codes: F12; F14; R12

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## 1. Introduction

In classical or in (new) new trade models, we assume *heterogeneity* in several features of the economy; namely, factors of production, the productivity of industries, and products within an industry. In a Heckscher-Ohlin type model, factors of production include at least two different factors. In a Ricardian-type model, industries are different in terms of their productivity. In Krugman-type model, consumers' preferences for variety support differentiated products within an industry. Moreover, Melitz (2003) adds another dimension of heterogeneity in terms of the productivity of firms. Of course, furthermore, any trade model consists of at least two different countries. However, with only a few exceptions, trade models do not seriously address geographical features within a country, although cousin models of trade theory in New Economic Geography focus on domestic regions.

It is natural that regional heterogeneity exists within a country. Regional heterogeneity emerges from differences in climate, landscape, and endowments of natural resources. However, heterogeneity can also arise as result from economic activities. When an industry agglomerates in one location, this location may become attractive for another industry that has a close relationship with this agglomerated industry. In such a case, agglomeration itself makes this location very unique in comparison to other regions. For example, automobile makers from the US, Europe, and Japan agglomerate in Shanghai. Consequently, the city has also attracted component suppliers from all over the world. Initially, it might be that automobile makers had an incentive to locate themselves closer to a bigger market to save on transportation costs. Some firms may still decide to remain in the home country but choose to produce in a domestic region with a geographical advantage to foreign markets over other domestic regions.

What is appealing to us with regard to international trade is that exports of regional structures within a country must be affected by their relationship with foreign trading partners. In this paper, we examine the regional heterogeneity that arises from the relationship between domestic regions and foreign countries.

While most international trade studies do not consider regional heterogeneity within a country, Krugman and Elizondo (1996) and Behrens et al. (2006, 2007) are a few exceptions. Krugman and Elizondo (1996) consider three-region models for one foreign and two domestic regions. However, the two domestic regions are homogeneous and symmetric in the sense that the international transportation cost is set equal for both domestic regions<sup>1</sup>. Behrens et al. (2006, 2007) consider a four-region model with two

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<sup>1</sup> Krugman and Elizondo (1996) show that *symmetric* reduction in international trade

foreign and two domestic regions. Behrens et al. (2006) considers the asymmetry with regard to international transportation costs. In their model, however, one region is restricted to export via the other region. Even in Behrens et al. (2007), however, regions within a country are symmetric in terms of international trade costs. In this paper, we present a trade model in which two heterogeneous regions exist within a country, extending the model of Behrens et al. (2007).

In this paper, we introduce a two-country model in which home country consists of two regions and one region for foreign country. The economy has two sectors; a homogeneous good sector under constant returns to scale and a differentiated goods sector under increasing returns to scale. Regions within a country differ in terms of population and international trade costs.

As discussed above, there are international trade models in which a country consists of multiple regions. However, in those papers, international trade costs between the foreign country and each region are assumed to be the same. Symmetric international trade costs among domestic regions also restrict the same effect of the foreign country on each domestic region. Imposing region-specific international trade costs in this paper allows us to describe the heterogeneity in each region that arises from growth in a foreign country.

Regarding the shipment of differentiated goods, there are both international transportation costs and intra-national transportation costs in this model. International transportation costs are the costs that accrue when goods are shipped between countries. Intra-national transportation costs are the costs that accrue when goods are traded between regions within a country. We call the former *trade costs* and the latter just simply *transportation costs*. In our model, we assume that trade costs are region-specific and that any transportation costs are always lower than any trade costs.

Imposing *regional heterogeneity by assumption* with regard to trade costs allows us to derive some *regional heterogeneity as result* for exports of each region within a country. First, the prices of varieties produced in each region depend on the spatial distributions of the firms not only in one's own country but also in the other country. Second, the export of home region also depends on transportation cost of the other region. Third, the exports from regions in a country featuring relatively less skilled labor decrease as the population of skilled laborers in the foreign country increases. Finally, the export share of a region that is further from the foreign country is an increasing function of the population of the foreign country.

The structure of the rest of the paper is as follows. The next section introduces

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cost makes production in a single agglomerated region spread to both domestic regions.

the two-country model with regional heterogeneity in international trade costs. In section 3, we show that the regional version of the home market effect also holds in our model. We further examine the effect of relative change in the labor force in foreign country on the export of home country. It is shown that the relative magnitude of the home market effect among regions matters. Then, section 4 empirically examines predictions of the theoretical model with applications to Japanese regional export data. We find strong support for the home market effect and the export share predictions. The last section discusses the possible extensions of our approach and concludes.

## 2. The model

The economy consists of two countries: home,  $H$ , and foreign,  $F$ . Country  $H$  has two regions labeled 1 and 2. while country  $F$  has only one region. In this economy, there are two factors of production: skilled and unskilled labor. We assume that the amount of skilled and unskilled workers can be different for two countries. We denote the mass of skilled labor in country  $i$  as  $L_i$ . In addition, the number of unskilled workers in  $H$  and  $F$  are denoted by  $A_H$  and  $A_F$ , respectively. Moreover, we assume that the two countries have access to the same technology.

Each individual works and consumes in the region in which she lives. While unskilled workers are assumed to be immobile, skilled workers are mobile between regions but immobile between countries. The share of skilled workers in region 1 in  $H$  is denoted by  $\lambda \in [0,1]$ . We first solve the model in the following subsection by assuming that the share of skilled workers is fixed. Then, in subsection 2-2, we analyze long-run equilibrium by allowing skilled workers to move freely across regions within a country.

### 2-1. Equilibrium when skilled workers are immobile across regions

#### Preference

Each consumer is endowed with one unit of labor, which she supplies inelastically. She has a quasi-linear preference regarding a homogeneous good and a differentiated consumption good. We choose the homogeneous good as numeraire. The sub-utility over the total mass of  $N$  of varieties of the differentiated good is quadratic, as in Ottaviano et al. (2002). An individual consumer solves the following problem:

$$\max_{q(v), \forall v \in [0, N]} \alpha \int_0^N q(v) dv - \frac{\beta - \gamma}{2} \int_0^N [q(v)]^2 dv - \frac{\gamma}{2} \left[ \int_0^N q(v) dv \right]^2 + q_0, \quad (1)$$

$$s.t. \int_0^N p(v)q(v)dv + q_0 = y + \bar{q}_0,$$

where  $\alpha > 0$ ,  $\beta > \gamma > 0$  are parameters;  $p(v)$  is the price of variety  $v$  and  $y$  is the consumer's income, which depends on her skilled/unskilled status. In this expression,  $\alpha$  measures the intensity of preference for the differentiated good with respect to the numeraire. The condition  $\beta > \gamma$  means that workers have a preference for variety. We assume that each worker has, in addition to her wage, sufficiently large endowments  $\bar{q}_0$  of the numeraire.

Solving this optimization problem for consumers, we find the demand function as follows:

$$q_{rs}(v) = a - (b + cN)p_{rs}(v) + cP_s, \quad (2)$$

where  $q_{rs}(v)$  is the demand for variety  $v$  produced in region  $r$  and consumed in region  $s$ , whereas  $p_{rs}(v)$  is the price of variety  $v$  produced in region  $r$  and consumed in region  $s$ . In addition,

$$a \equiv \frac{\alpha}{\beta + (N-1)\gamma}, \quad b \equiv \frac{1}{\beta + (N-1)\gamma}, \quad c \equiv \frac{\gamma}{(\beta - \gamma)[\beta + (N-1)\gamma]},$$

are positive bundles of parameters. If  $\Lambda_{rs}$  denotes the set of varieties produced in region  $r$  and consumed in region  $s$ , the price index in region  $s$  is as follows:

$$P_s \equiv \int_{\Lambda_{1s}} p_{1s}(v)dv + \int_{\Lambda_{2s}} p_{2s}(v)dv + \int_{\Lambda_{Fs}} p_{Fs}(v)dv. \quad (3)$$

## Production

There are two sectors in the economy. One sector produces the homogeneous good under perfect competition using unskilled labor as the only input with constant returns to scale technology. The unit input requirement is set to one. In the other sector, monopolistically competitive firms produce a continuum of varieties of the horizontally differentiated good using both types of labor under increasing returns to scale technology. We assume that the firms can differentiate their products at no cost. Therefore, one firm produces only one variety. Thus, the number of firms is equal to the number of varieties.

Each firm in a monopolistically competitive sector incurs fixed costs of  $\phi (> 0)$  units of skilled labor, whereas its marginal labor requirement is normalized to zero without loss of generality. When  $n_r$  ( $r = 1, 2$ , and  $F$ ) stands for the number of firms in each region, from skilled labor market-clearing conditions in each region for any distribution of skilled workers,  $\lambda_i$  are given by the following forms:

$$n_1 = \frac{\lambda_H L_H}{\phi}, \quad n_2 = \frac{(1 - \lambda_H) L_H}{\phi}, \quad n_F = \frac{L_F}{\phi}. \quad (4)$$

Moreover, when  $n_i (i = H, F)$  and  $N$  denote the number of varieties in each country and that of the economy, respectively, these are represented as follows:

$$n_H = n_1 + n_2 = \frac{L_H}{\phi}, \quad n_F = \frac{L_F}{\phi}, \quad N = n_H + n_F = \frac{L}{\phi}. \quad (5)$$

While  $N$  can vary when the population increases, in our paper,  $N$  is assumed to be fixed for mathematical simplicity. This means that  $L$  is also fixed.

With respect to transportation technology, the shipping of a good incurs a cost. First of all, the shipping of the homogeneous good is assumed to be costless. Because a homogeneous good can be shipped without cost and this good is chosen as the numeraire, the wage of unskilled labor is equal to one in all regions in equilibrium.

Next, regarding transportation technology for the differentiated good, both interregional and international forms of transportation are costly. In addition, international trade costs are region-specific. As for interregional transportation costs within a country, the shipping of a differentiated good between regions 1 and 2 incurs  $\tau_H$  in terms of the numeraire. Henceforth, we refer to the interregional transportation costs as *domestic trade cost*.

Finally, regarding international trade, all regions do not necessarily have equal access to a region in the other country. The international trade costs between region  $r$  and F are denoted by  $\tau_{rF}$  in terms of the numeraire. Moreover, symmetry in trade cost is assumed for any pair of two regions; i.e.,  $\tau_{rF} = \tau_{Fr}$ . We refer to the international transportation costs as *international trade costs*. If we assume that trade cost increases monotonically in distance, geographical distance can be used as a proxy for trade cost in the later analysis. In the following, we assume that one of the regions in country H has a relative advantage in terms of geographical proximity over both regions in the foreign country. Specifically, we assume that the international trade cost between region 2 and country F is smaller than trade cost between region 1 and country F. In addition we assume domestic trade cost is smaller than either international trade costs:  $\tau_{1F} > \tau_{2F} > \tau_H$ . In order to exclude the special case in which region 1 exports by using domestic transportation to region 2 and then ships products from there, we impose another restriction on trade costs:  $\tau_{1F} < \tau_{2F} + \tau_H$ .<sup>2</sup> Figure 1 depicts our

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<sup>2</sup> This restriction is unnecessary in this model because there is no mechanism that region 1 uses region 2 as export-platform. By imposing this restriction, however, there will be only direct export even if export-platform mechanism is explicitly introduced in the model.

assumptions regarding the geography of regions in this paper.

We focus on the case in which transportation costs  $\tau_i$  and trade costs  $\tau_{rs}$  are sufficiently low that interregional and international bilateral trades occur. We will show the conditions under which both international and intra-national trade between any two regions at the equilibrium prices occur.

### Product and labor market

We make three crucial assumptions: the product market is segmented, the labor market is local, and entry and exit are free.

Under these assumptions, the profit of the firm in region 1 is as follows.

$$\begin{aligned} \pi_1 = & q_{11} \left( \frac{A}{2} + \lambda_H L_H \right) p_{11} + q_{12} \left( \frac{A}{2} + (1 - \lambda_H) L_H \right) (p_{12} - \tau_H) \\ & + q_{1F} (A_F + L_F) (p_{1F} - \tau_{1F}) - w_1 \phi. \end{aligned} \quad (6)$$

The firm in region 1 maximizes this profit with respect to prices  $p_{11}$ ,  $p_{12}$ , and  $p_{1F}$ , separately.

### The market outcome

Solving the optimization problem for producers that produce differentiated good yields the profit-maximizing price as a function of the price aggregate. These are as follows:

Intraregional prices:

$$p_{11}(P_1) = \frac{a + cP_1}{2(b + cN)}, \quad (7)$$

Interregional prices:

$$p_{21}(P_1) = \frac{a + cP_1}{2(b + cN)} + \frac{\tau_H}{2} = p_{11} + \frac{\tau_H}{2}, \quad (8)$$

International prices:

$$p_{F1}(P_1) = \frac{a + cP_1}{2(b + cN)} + \frac{\tau_{1F}}{2} = p_{11} + \frac{\tau_{1F}}{2}. \quad (9)$$

Note that the prices in one region depend on the price aggregate in this region, which is determined by the price set there by all firms. Because there is a continuum of firms, each firm is negligible and chooses its optimal price, taking aggregate market conditions as given. At the same time, these aggregate market conditions must be consistent with firms' optimal pricing decisions. Therefore, the (Nash) equilibrium price aggregate  $P_1^*$  must satisfy the following condition:

$$P_1^* = n_1 p_{11}^*(P_1^*) + n_2 p_{21}^*(P_1^*) + n_F p_{F1}^*(P_1^*). \quad (10)$$

Similar conditions hold for the other regions. Using the profit-maximizing prices leads to  $P_1^*$ :

$$P_1^* = \frac{aN + (b + cN)[(n_H - n_1)\tau_H + n_F\tau_{1F}]}{2b + cN}. \quad (11)$$

Substituting this equation into the profit-maximizing prices, we find the equilibrium prices,

$$p_{11}^* = \frac{2a + c[(n_H - n_1)\tau_H + n_F\tau_{1F}]}{2(2b + cN)}, \quad (12)$$

$$p_{21}^* = p_{11}^* + \frac{\tau_H}{2}, \quad (13)$$

and

$$p_{F1}^* = p_{11}^* + \frac{\tau_{1F}}{2}. \quad (14)$$

Note that each of equilibrium prices decreases with the number of firms located in the corresponding region. In addition, prices increase with transportation and trade costs. These two effects are referred to as the *pro-competitive effect* in Behrens et al. (2007). Furthermore, the prices of the varieties traded internationally depend on the number of firms in the other country. The novel feature of our paper is that each price of the varieties traded internationally is region specific. This is due to that we assume that trade costs are region-specific.

Substituting these equilibrium prices into the demand and using the price aggregate, the equilibrium consumption level can be derived as follows:

Intra-regional demands:

$$q_{11}^* = a - bp_{11}^* + \frac{c}{2}(n_H - n_1)\tau_H + \frac{c}{2}n_F\tau_{1F}, \quad (15)$$

Interregional demands:

$$q_{21}^* = q_{11}^* - (b + cN)\frac{\tau_H}{2}, \quad (16)$$

International demands:

$$q_{F1}^* = q_{11}^* - (b + cN)\frac{\tau_{1F}}{2}. \quad (17)$$

Note that high trade costs raise the domestic demand for each national variety at the expense of varieties produced abroad. This is the substitution effect. This effect decreases when varieties become more differentiated (when  $c$  decreases). Similarly, the intra-regional demand for each locally produced variety and the international

demand increases at the expense of the variety produced in the other region within a country when the transportation costs of one's own country rise.

After solving for equilibrium prices and quantities for a given set of model parameters, we can derive equilibrium export functions for two regions in home country. We define the export of each region as  $E_1$  and  $E_2$  which are aggregated values of variety exports from each region:

$$\begin{aligned} E_1 &= n_1 p_{1F} q_{1F} (A_F + L_F) \\ E_2 &= n_2 p_{2F} q_{2F} (A_F + L_F) \end{aligned} \quad (18)$$

With explicit expressions of model parameters, export can be represented as the function of skilled worker share and the model parameters.

$$\begin{aligned} E_1 &= E_1(\lambda|\alpha, \beta, \gamma, \phi, L_F, L_H, A_F, A_H, \tau_{1F}, \tau_{2F}, \tau_H) \\ E_2 &= E_2(\lambda|\alpha, \beta, \gamma, \phi, L_F, L_H, A_F, A_H, \tau_{1F}, \tau_{2F}, \tau_H) \end{aligned} \quad (19)$$

With these export functions, we can analyze the effect of transportation costs and the size of economy on international trade to derive a variant type of Gravity model. With the assumption of fixed skilled worker share in home country; however, comparative statics analysis is just that of a three country model. In the following subsection, we investigate equilibrium when skilled workers are free to move across regions in home country.

## 2-2. Long-run Equilibrium

Now, we consider about local labor market. Firms compete for workers by offering higher wages. This process continues until no firm can profitably enter or exit the market. As a result, all operating profit are absorbed by the wage bill, and become zero at equilibrium. From (7), the following equation holds at the equilibrium;

$$\begin{aligned} \pi_1^* &= q_{11}^* \left( \frac{A}{2} + \lambda_H L_H \right) p_{11}^* + q_{12}^* \left( \frac{A}{2} + (1 - \lambda_H) L_H \right) (p_{12}^* - \tau_H) \\ &\quad + q_{1F}^* (A_F + L_F) (p_{1F}^* - \tau_{1F}) - w_1^* \phi = 0. \end{aligned} \quad (20)$$

The equilibrium wages in region 1 is as follows;

$$\begin{aligned} w_1^* &= \frac{A}{2\phi} (p_{11}^* q_{11}^* + p_{12}^* q_{12}^*) + \frac{A_F}{\phi} p_{1F}^* q_{1F}^* + n_1 p_{11}^* q_{11}^* + n_2 p_{12}^* q_{12}^* + n_F p_{1F}^* q_{1F}^* \\ &\quad - q_{12} \tau_H \left( \frac{A}{2} + (1 - \lambda) L_H \right) - q_{1F} \tau_{1F} (A_F + L_F) \end{aligned} \quad (21)$$

The market equilibrium, given a spatial distribution of the skilled in  $H$ , is determined by using (12) through (17).

Because skilled workers can migrate between regions, they move to the region in which they can acquire the higher indirect utility level. The indirect utility level in region  $r$  ( $r=1,2$ ) is obtained by substituting equilibrium prices and demands in (12) through (17) and equilibrium wage in (21) into utility function in (1) as follows;

$$\begin{aligned}
V_r = & \alpha(n_1 q_{1r}^* + n_2 q_{2r}^* + n_F q_{Fr}^*) - \frac{\beta - \gamma}{2} \left[ n_1 (q_{1r}^*)^2 + n_2 (q_{2r}^*)^2 + n_F (q_{Fr}^*)^2 \right] \\
& - \frac{\gamma}{2} (n_1 q_{1r}^* + n_2 q_{2r}^* + n_F q_{Fr}^*)^2 \\
& + w_r^* + \bar{q}_0 - (n_1 p_{1r}^* q_{1r}^* + n_2 p_{2r}^* q_{2r}^* + n_F p_{Fr}^* q_{Fr}^*), \quad r = 1, 2.
\end{aligned} \tag{22}$$

By noting that  $n_1$  and  $n_2$  are determined by the share of skilled worker,  $\lambda$ , the indirect utility differential between the two regions in  $H$  is defined as function of  $\lambda$  as follows,

$$\Delta V(\lambda) = V_1(\lambda) - V_2(\lambda). \tag{23}$$

At equilibrium, the skilled workers have no incentive to move between regions. Formally, the equilibrium arises at:

$$\begin{cases} \lambda^* \in (0,1) & \text{when } \Delta V(\lambda^*) = 0, \\ \lambda^* = 0 & \text{if } \Delta V(\lambda^*) \leq 0, \\ \lambda^* = 1 & \text{if } \Delta V(\lambda^*) \geq 0. \end{cases}$$

An interior equilibrium is stable if and only if the slope of the indirect utility differential is negative in a neighborhood of the equilibrium, while the equilibrium such that full agglomeration of the skilled in one region is always stable whenever it exists. Investigating the indirect utility differential, we show that the differential is liner function of  $\lambda$ . Therefore, we state that the interior solution of is stable if and only if the coefficient of  $\lambda$  of the differential is negative.

For studies intended to provide theoretical explanations for regional agglomerations, equilibrium at two extremes is interest in itself. The model in this paper; however, is to provide an analytical foundation for exports of multi-regions within a country. We restrict our equilibrium concept to stable existence of multi-regional exports. We restate all parameter restrictions imposed in this paper so far as the following assumptions before our formal definition of equilibrium concept. All eleven parameters in this model are denoted by

$$\theta = (\alpha, \beta, \gamma, \phi, L_F, L_H, A_F, A_H, \tau_{1F}, \tau_{2F}, \tau_H).$$

**Assumptions:**

(A1) All parameters are non-negative. (A2)  $\beta > \gamma$ . (A3)  $\tau_{1F} > \tau_{2F} > \tau_H$ . (A4)  $\tau_{1F} < \tau_{2F} + \tau_H$ .

**Definition (Long-run Stable Heterogeneous Export Equilibrium):**

The parameters  $\theta = (\alpha, \beta, \gamma, \phi, L_F, L_H, A_F, A_H, \tau_{1F}, \tau_{2F}, \tau_H)$  satisfying assumptions

(A1) through (A4) and  $\lambda^*$  is defined to be at a long-run stable heterogeneous export (LSHE) equilibrium if (i)  $\lambda^*$  is strictly within the range between 0 and 1, (ii)  $\Delta V(\lambda^*) = 0$  (iii)  $d\Delta V(\lambda^*)/d\lambda \leq 0$  and (iv) both  $E_1$  and  $E_2$  are strictly positive.

The first condition implies that some of skilled workers always remain in each home region. We need to be careful that this condition assures that there will be production of differentiated products in each region but not exports of these products. The second and third conditions require that the share of skilled workers is endogenously determined and stable. The fourth condition requires that both regions actually export. The random choice of numerical values for eleven parameters guarantees condition (ii) holds for some  $\lambda$  but not other three conditions. The fourth equation can be met if  $\tau_{1F}$  is smaller than the threshold value which is a function of  $\alpha, \beta, \gamma, \phi, L_F$ , and  $L_H$ . This condition is provided in the Appendix A1.

**3. Home market effect and relative home market effect**

In this section, we investigate the effect of the decline in trade costs and the increase in the population of the foreign country on the exports in one region. We therefore aim to investigate the regional version of the gravity model. The theoretical foundation for the traditional gravity model with the effect of trade cost and income of two countries on bilateral trade is given in Anderson (1979).

**3-1. Analytical results**

Now, we define the value of export of region 1 as  $E_1$  represented as follows:

$$E_{1F} = n_1^* p_{1F}^* q_{1F}^* (A_F + L_F). \quad (24)$$

First, we show the effect of the change in trade costs on the value of export. Then, we present the effect of the change in the size of skilled workers in foreign country on the value of export.

### Trade Cost Effect

First of all, we examine the effect of the decreases in trade costs on exports. Note that price and demand depend on trade costs.

$$\frac{\partial E_{1F}}{\partial \tau_{1F}} = (A_F + L_F) \left[ p_{1F}^* q_{1F}^* \frac{\partial n_1^*}{\partial \tau_{1F}} + n_1^* \frac{\partial p_{1F}^* q_{1F}^*}{\partial \tau_{1F}} \right]. \quad (25)$$

Since  $n_1 = \lambda^* L_H / \phi$ , the number of firms in region 1 is affected through the migration of skilled workers between regions 1 and 2 which caused by the change in trade costs. This is shown as follows:

$$\frac{\partial n_1^*}{\partial \tau_{1F}} = n_H \frac{\partial \lambda^*}{\partial \tau_{1F}}. \quad (26)$$

The first term of the bracket of (25) expresses the indirect effect through the change of the firms in region 1 due to the migration of skilled workers. The second term of the bracket in RHS of (25) states the effect on the value of export, which consists of two parts as follows:

$$\frac{\partial p_{1F}^* q_{1F}^*}{\partial \tau_{1F}} = q_{1F}^* \frac{\partial p_{1F}^*}{\partial \tau_{1F}} + p_{1F}^* \frac{\partial q_{1F}^*}{\partial \tau_{1F}}. \quad (27)$$

Since both the price and demand depend on the share of skilled workers in each region in H, each part is affected through the migration of skilled workers.

$$\frac{\partial p_{1F}^*}{\partial \tau_{1F}} = \frac{\partial p_{FF}^*}{\partial \tau_{1F}} + \frac{1}{2} = \left( \frac{cn_1^*}{2b + cN} + \frac{1}{2} \right) + \frac{cn_H(\tau_{1F} - \tau_{2F})}{2b + cN} \frac{\partial \lambda^*}{\partial \tau_{1F}}. \quad (28)$$

The first term in RHS of (28) is the direct effect on the price, which is always positive. The second term in RHS of (28) is the indirect effect through the migration of skilled workers. The coefficient of  $\partial \lambda^* / \partial \tau_{1F}$  is positive from the assumption with regard to trade costs. The sign of the second term is ambiguous.

$$\frac{\partial q_{1F}^*}{\partial \tau_{1F}} = \frac{\partial q_{FF}^*}{\partial \tau_{1F}} - \frac{b + cN}{2} = \left[ \frac{c^2 n_1^* N}{2(2b + cN)} - \frac{(b + cN)}{2} \right] + \frac{c^2 n_H N (\tau_{1F} - \tau_{2F})}{2(2b + cN)} \frac{\partial \lambda^*}{\partial \tau_{1F}}. \quad (29)$$

The first term in RHS of (29) is the direct effect, which is always negative. The second term in RHS of (29) is the indirect effect through migration of skilled workers. The coefficient of  $\partial \lambda^* / \partial \tau_{1F}$  is positive as stated above. However, the sign of the second term in ambiguous since the sign of  $\partial \lambda^* / \partial \tau_{1F}$  might be derived analytically.

The overall effect of the value of export is determined by the magnitude the direct effect on the price and demand, and the indirect effect through the migration. Using above equations, (27) is written as follows,

$$\begin{aligned} \frac{\partial p_{1F}^* q_{1F}^*}{\partial \tau_{1F}} = & \frac{(2b + cN + 2cn_1^*)q_{1F}^* - [c^2 n_1^* N - (b + cN)(2b + cN)]p_{1F}^*}{2(2b + cN)} \\ & + \frac{cn_H (\tau_{1F} - \tau_{2F})(2q_{1F}^* + cNp_{1F}^*)}{2(2b + cN)} \frac{\partial \lambda^*}{\partial \tau_{1F}}. \end{aligned} \quad (30)$$

It is clear that the coefficient of  $\partial \lambda^* / \partial \tau_{1F}$  is positive due to the assumption of trade costs. Therefore, the sign of the second term in RHS of (30) is determined by the sign of  $\partial \lambda^* / \partial \tau_{1F}$ . Using above results, we find the effect of the change in trade costs on the value of export. The value of export of region 1 is affected by not only  $\tau_{1F}$  but also  $\tau_{2F}$ .<sup>3</sup>

### Labor Force Effect

Next, we derive the effect of the increase in the population of the foreign country on the value of export of region 1. It is found that this overall effect consists of three effects as follows:

$$\frac{\partial E_{1F}}{\partial L_F} = p_{1F}^* q_{1F}^* (A_F + L_F) \frac{\partial n_1^*}{\partial L_F} + n_1^* (A_F + L_F) \frac{\partial p_{1F}^* q_{1F}^*}{\partial L_F} + n_1^* p_{1F}^* q_{1F}^*. \quad (31)$$

The first term of RHS in (31) provides the indirect effect through the migration behavior of the skilled to region 1. Given the value of foreign demand for each variety, a change in the number of variety in region 1 affects total export of region 1. The second term of RHS in (31) states the indirect effect through the change in the individual demand for a variety. The last term of RHS in (31) demonstrates the direct effect on the export due to the change in the population of foreign country. Here, we investigate each term.

The effect of the change in the population of F on the firm in region 1 is as follows:

$$\frac{\partial n_1^*}{\partial L_F} = n_H \frac{\partial \lambda^*}{\partial L_F} \quad (32)$$

The change of the population of foreign country affect through the change in the share of the skilled in H due to migration of skilled workers. It is noteworthy to mention that the sign of this first term in export of region2 should be opposite because  $\partial n_2^* / \partial L_F = -n_H (\partial \lambda^* / \partial L_F)$ . This can result in increase in export for one region and decrease in export for the other region if the effect on the share of skilled workers in home country of a change in foreign labor overwhelms the net of other effects.

<sup>3</sup> The cross effect of trade cost on regional export is derived in the appendix A2.

Then, the second term of RHS in (31) presents the effect of the change in the population of F on the value of export per capita is presented as shown below:

$$\frac{\partial p_{1F}^* q_{1F}^*}{\partial L_F} = 2(b + cN) p_{FF}^* \frac{\partial p_{FF}^*(n_1, n_2, N)}{\partial L_F}. \quad (33)$$

From this equation, it is clear that the sign of this derivation depend on that of  $\partial p_{FF}^* / \partial L_F$ . This cannot be derived analytically, since the change in  $L_F$  affects through  $n_1$ ,  $n_2$  and  $N$ . The signs of  $\partial p_{FF}^* / \partial L_F$  might not be found by using numerical method.

The third term of RHS in (31) indicates the change the aggregate demand from foreign country due to the change of the size of population, which is obviously positive.

We find the overall effect of export function by substituting these two derivations into (31). We need numerical method in order to find the sign of comparative statistics with regard to export function. After we show the results derived from numerical method, we summarize our results as proposition.

Next, we derive the effect of the increase in the population of the home country on the value of export of region 1. It is found that this overall effect consists of two effects as follows:

$$\frac{\partial E_{1F}}{\partial L_H} = p_{1F}^* q_{1F}^* (A_F + L_F) \frac{\partial n_1^*}{\partial L_H} + n_1^* (A_F + L_F) \frac{\partial p_{1F}^* q_{1F}^*}{\partial L_H}. \quad (34)$$

The effect of the change in the number of skilled workers on the value of export from region 1 has two channels. The first term of RHS in this equation provides the indirect effect through the migration behavior of the skilled to region 1. The second term of RHS in this equation presents the indirect effect through the change in the individual demand for a variety.

$$\frac{\partial n_1^*}{\partial L_H} = \frac{\lambda^*}{\phi} + n_H \frac{\partial \lambda^*}{\partial L_H}. \quad (35)$$

The change in the population of the skilled in H has two effects. The first term of RHS in this equation presents the change in the number of firms in H, which is positive. The second term of RHS in this equation states the indirect effect through the migration of the skilled, which cannot be derived analytically.

Then, we investigate the effect of the change in the number of unskilled workers in both countries on the value of export of region 1. First, we show the effect of the change in the population of unskilled workers in F, which is presented as follows:

$$\frac{\partial E_{1F}}{\partial A_F} = p_{1F}^* q_{1F}^* (A_F + L_F) \frac{\partial n_1^*}{\partial A_F} + n_1^* (A_F + L_F) \frac{\partial p_{1F}^* q_{1F}^*}{\partial A_F} + n_1^* p_{1F}^* q_{1F}^*. \quad (36)$$

The first term of RHS in this equation provides the indirect effect through the migration

behavior of the skilled to region 1. Given the value of foreign demand for each variety, a change in the number of variety in region 1 affects total export of region 1. The second term of RHS in this equation states the indirect effect through the change in the individual demand for a variety. The last term of RHS in this equation demonstrates the direct effect on the export due to the change in the population of foreign country.

Finally, the effect of the change in the unskilled in H on the value of export of region 1 is provided as follows:

$$\frac{\partial E_{1F}}{\partial A_H} = p_{1F}^* q_{1F}^* (A_F + L_F) \frac{\partial n_1^*}{\partial A_H} + n_1^* (A_F + L_F) \frac{\partial p_{1F}^* q_{1F}^* (n_1, n_2)}{\partial A_H}. \quad (37)$$

The change in the number of unskilled workers in H affects the value of export from region 1 through two channels. The first term of RHS in this equation provides the indirect effect through the migration behavior of the skilled to region 1. The second term of RHS in this equation presents the indirect effect through the change in the individual demand for a variety, which is depend on only the share of the skilled on H.

### 3-2. Numerical Calibration Example

Because of high nonlinearity in solution of the model, usefulness of analytical approach is limited. In this subsection, we find a set of parameter values to satisfy our equilibrium concept by using numerical methods.

First, we start by choosing numerical values for preference parameters:  $\alpha$ ,  $\beta$ , and  $\gamma$ . We set  $\gamma$  equal to unity as a numeral. Assumption (A2) requires  $\beta$  needs to be greater than  $\gamma$ . A larger value for  $\alpha$  is likely to support equilibrium for positive exports when transportation costs incur because it leads to a greater demand. We set  $\alpha = 5$  and  $\beta = 2$ .

Second, we move to set numerical values for both type of labors:  $A_F$ ,  $A_H$ ,  $L_F$ , and  $L_H$ . We retained that the sizes of unskilled labor in both countries are equal. After numerous attempts for the wide range of values, we found out that (i) unskilled labor needs to be much larger than skilled labor and (ii) skilled labor in foreign country is necessary to be relatively smaller than that of home country. We set  $L_F=0.15$ ,  $L_H=1.5$ , and  $A_F=A_H=200$ .

Third, we set the skilled labor requirement as fixed cost,  $\phi$ , equal to 10. It is important to remember that both countries share the technology so that the change in this parameter has similar effect as simultaneous change in the skilled labor in both countries. With numerical examinations, we confirm that this parameter and skilled labor are closely related.

At last, we need to determine the appropriate values for transportation costs:

$\tau_H, \tau_{1F},$  and  $\tau_{2F}$ . These parameters need to satisfy two assumptions: (A3)  $\tau_{1F} > \tau_{2F} > \tau_H$  and (A4)  $\tau_{1F} < \tau_{2F} + \tau_H$ . Moreover, these parameters cannot exceed the threshold values in order to have strictly positive value of trade. The conditions for positive export are derived in the Appendix A1. We set  $\tau_{1F}=4.9$ ,  $\tau_{2F}=4.8$ , and  $\tau_H=2$ .

With these parameter values, we obtain **LSHE** equilibrium in which the share of skilled worker in region 1 is 0.409634. It is important to note that the only regional heterogeneity by assumption is the difference in international transportation cost and about two percent difference in transportation cost results in 20 percent difference in the share of skilled workers. The effect of difference in international transportation costs on regional export is more pronounced: export values are 1.64636 for region 1 and 6.67087 for region 2. We confirm that distance effect in general gravity model still holds for our intra-national regional model.

With regard to the effect of size of economy on regional exports, the results from numerical simulations are shown in Figure 2 and then are summarized in Table 1. We obtain three noteworthy features from the numerical simulations. First, the most important result is that the well-documented economy size effect in gravity model does not necessarily hold in our intra-national regions model. An increase in foreign labor may decrease regional exports. Second, the effect of foreign labor size on regional exports may be opposite in the sign. For an increase in unskilled workers in foreign country, the export of region 1 decreases while the export of region 2 increases. Third, the effect of labor size on regional export may differ depending on the type of labor. For region 2, an increase in foreign skilled labor lowers export while an increase in foreign unskilled labor raises export.

By comparing the signs of effects on regional export in Table 1, predictions for home market effect in regional export is summarized in the following Proposition 1.

**Proposition 1 (home market effect):**

Home market effect (*HME*) holds for exports for region 1 with regardless of labor type. *HME* holds for exports for region 2 when size of economy is measured with skilled labor. For region 2, it is ambiguous whether *HME* holds with regard to unskilled labor.

The original version of home market effect is constructed on the basis of greater response of export with respect to home market expansion than with respect to foreign market expansion. Home market effect in this model is more straightforward because only home market expansion raises regional export while exporting functions in these

previous models increase with respect to the growth of both economies. It should be noted for the effect of unskilled labor on region 2 export that we did not rely on comparing the magnitudes of labor expansion effect from numerical simulation. The result from the numerical calibration may be subtle to different parameter values.

Next, we consider the share of exports of each region in one region. Because the studies on international economics have focused on aggregate variables, this share has been neglected. Our setting allows us to examine the share of exports of various regions.

The proportion of exports of region 1 is defined as follows.

$$S_1 \equiv \frac{E_1}{E_1 + E_2}. \quad (38)$$

We would like to investigate the effect of the increase in the population of the foreign country on this proportion. Differentiating this proportion with respect to the population of the foreign country, we find that

$$\frac{\partial S_1}{\partial L_F} = \frac{1}{(E_1 + E_2)^2} \left( E_1 \frac{\partial E_2}{\partial L_F} - E_2 \frac{\partial E_1}{\partial L_F} \right). \quad (39)$$

The sign of this derivation is determined by that of the equation in parenthesis. Using demand functions, price functions, and the derivation of exports with regard to the population of the foreign country, we obtain the following relationship.

$$\frac{\partial S_1}{\partial L_F} = \left( \frac{A}{2} + L_F \right)^2 \frac{\lambda_H (1 - \lambda_H) L_H^2}{(E_1 + E_2)^2} \left( p_{2F}^* q_{2F}^* \frac{\partial p_{1F}^* q_{1F}^*}{\partial L_F} - p_{1F}^* q_{1F}^* \frac{\partial p_{2F}^* q_{2F}^*}{\partial L_F} \right). \quad (40)$$

It is clear that the sign of (40) is determined by that of the equation in parentheses. For drawing predictions of the effect of labor on export share, we resort to simulated signs in numerical calibration in Table 1. This result is summarized as the following proposition 2.

**Proposition 2 (export share)**

Export share of region 1 decreases with an increase in foreign labor of both types and increases with an increase in home unskilled labor. The effect on export share is ambiguous with an increase in home skilled labor.

Previous empirical studies on home market effect focuses on whether home market effect can be found with international dataset. In this study we can take a further step to compare the degree of home market effect across regions because we

explicitly model two regions in home country. With this proposition we resort to additional numerical simulation at the calibrated values of model parameters in addition to Proposition 1 and 2. We call this result as *relative home market effect* for convenience.

### **Proposition 3 (relative home market effect)**

The degree of home market effect is stronger in region 1 such that export share increases (decreases) with respect to home (foreign) unskilled labor.

This proposition is interpreted as indicating that when the population of the foreign country and home country simultaneously increases in the same degree, the difference in the effect on export is larger for region 1. It is obvious that the effect of foreign unskilled labor on export share is smaller for region 1 because the effect is negative for region 1 while the effect is positive for region 2. However, simulated exercise further reveals that the share of region 1 becomes larger with home unskilled labor expansion.

Given the result of proposition 1, we can test for home market effect by comparing estimated coefficients of foreign economy and regional economy in gravity model regression. With proposition 2, we estimate gravity-type regression with export share as dependent variable. With proposition 3, we test relative home market effect by comparing estimated coefficients of foreign economy and regional economy in an export share gravity model regression.

## **4. An Application to Japanese Exports**

Figures 3 show how the production of industry can be sparsely distributed across the nation. Figure 3 shows production in 2005 for industrial robot and medical equipment. This figure can provide the intuition that production is relatively dispersed across regions within a country; however, it falls short in telling us what exports from these regions may look like. We use port-level export data of Japan in this section to address the region-based propositions provided in the previous section.

### **Data**

Export data are taken from the database of the Japanese Customs, the Ministry of Finance. Japanese Customs provides finely disaggregated export data for each international port/airport in addition to national aggregate export data. The original annual export series is provided at a Harmonized System (HS) 9-digit level and by each destination country. Our aggregation process takes three steps. In the first step,

HS 9-digit commodities are aggregated over HS 2-digit industries. For the second step, we aggregated these port-level exports at the HS 2-digit level for each prefecture. At this point, we decided to further aggregate these prefecture exports for two reasons. Some prefectures do not report any exports due to a lack of international ports in their prefectures. Firms in these prefectures, however, export from ports in another prefecture. Similarly, there exist some firms, especially near at the border, that use international ports in adjacent prefectures. To minimize this cross-border export's effect on our estimates, we decided to group 47 prefectures into nine regions. In the last step, we constructed the export series at the HS 2-digit level for nine regions in Japan. The details of these regions are given in Appendix A3. Eight importing countries were selected: China, Hong Kong, Indonesia, Korea, Malaysia, the Philippines, Singapore, and Thailand.

Regional GDP is constructed based on the Japanese Prefecture Income. For the years between 1990 and 2004, continuous series are readily available. We added two additional years prior to 1990 and after 2004 from different report files. Regional employment data is taken from the Census in Japan. GDP and employment data for nine Asian countries are taken from the World Development Indicators, the World Bank. The original GDP series in terms of current US dollars are converted to Japanese yen values by period average foreign exchange rates. All series are adjusted to be expressed in terms of one unit of Japanese yen.

The distance between the Japanese regions and Asian countries is measured in two steps. First, the distance to each Asian country is measured from each prefecture. Then, the distance between an Asian country and a region is defined as the shortest distance between the country and the prefectures in the region.

#### 4-1. Estimation Model for Regional Exports

For each HS 2-digit industry, we estimate the following export equation in a panel framework:

$$E_{ijt} = \mathbf{X}_t \boldsymbol{\beta} + \varepsilon_{ijt} = \beta^i + \beta^j + \beta_1 L_{it} + \beta_2 L_{jt} + \beta_3 \tau_{ij} + \varepsilon_{ijt} \quad (41)$$

where  $\mathbf{X}_t$  is a row vector of explanatory variables and  $\boldsymbol{\beta}$  is a column vector of coefficients.  $\beta^i$  and  $\beta^j$  are fixed effects for Asian country ( $i$ ) and Japanese region ( $j$ ), respectively;  $L_{it}$  and  $L_{jt}$  are the size of the economy for Asian country ( $i$ ) and Japanese region ( $j$ ); and  $\tau_{ij}$  is the trade cost between the Asian country ( $i$ ) and the Japanese region ( $j$ ). For the size of the economy,  $L_{it}$  and  $L_{jt}$ , the gross domestic product and

population, are used alternatively. As a proxy to trade cost, we use distance between an importing country and a region.

Table 2 provides estimated coefficients for the gross domestic product of importing countries and Japanese regions, as well as for distance. In conformity with the results of other trade models, the expected signs of both economy size variables are positive:  $\beta_1 > 0$  and  $\beta_2 > 0$ . The estimated coefficients in the first and second columns show that the income effect of both the importing country and the region is positive for all industries. The third column in Table 2 indicates that estimators for distance are negative for all industries. Thus, the result achieved using our region-based gravity model is quite consistent with previous empirical studies using country-based gravity models.

However, this result is not quite consistent with predictions of our theoretical model. Our theoretical model is consistent for the effect of foreign labor with empirical results only if unskilled labor is considered for region 2. In Table 1, the effect of foreign labor is negative for other cases. We will come back to this issue in next subsection.

Next, we turn to home market effect. Our intra-national regional theoretical model predicts the relative size of these coefficients as the home-market effect:  $\beta_2 > \beta_1$ . We test this hypothesis formally using a one-sided test with the null hypothesis of  $H_0: \beta_2 - \beta_1 = 0$  against the alternative  $H_1: \beta_2 - \beta_1 > 0$ .

$$\text{HME} = \frac{\beta_2 - \beta_1}{\sqrt{\text{Var}(\beta_1) + \text{Var}(\beta_2) - 2\text{Cov}(\beta_1, \beta_2)}} \quad (42)$$

We use the statistics in equation (42) as HME test statistics of which the distribution is asymptotically normal under regular conditions.

Table 2 also provides HME test statistics along estimated coefficients for economic size and trade costs. The HME, surprisingly, holds for almost all industries when the statistical significance level is at ten percent. There were only 4 out of 96 industries for which the null hypothesis could not be rejected: HS1 (live animals), HS50 (silk), HS75 (nickel and nickel products), and HS93 (arms and ammunition). Even for the five-percent statistical significance level, there were only 15 industries for which the null hypothesis could not be rejected. However, at the one-percent statistical significance level, industries with home market effects became a smaller portion of the entire body of industries; 33 industries still allowed the rejection of the null hypothesis and therefore demonstrate home market effects.

The noteworthy element here is that there seems to be no relationship between

the degree of HME and industry characteristics. Industries with the highest HME statistics are HS2 (meat), HS8 (fruits and nuts), HS10 (cereals), HS11 (products of cereals), HS24 (tobacco), and HS79 (zinc and zinc products). The most highly differentiated product industries, such as HS84 (general machinery), HS85 (electrical appliances), HS87 (vehicles), and HS90 (precision machinery), do not appear as in the extreme cases.

We also replaced population with gross domestic product in estimation equation (41) and obtained qualitatively similar results for all coefficients. For all industries,  $\beta_1$  and  $\beta_2$  are positive and  $\beta_3$  is negative. The size of  $\beta_1$  is larger than that of  $\beta_2$ . However, HME statistics could not reject the null hypothesis of there being no home-market effect<sup>4</sup>. This inconsistency with our theoretical predictions when the population variable is used could be related to the assumption of a Ricardian type of production in the model versus the use of many factors of production in the real world. For theoretical tractability and expositional purposes, we assumed that production uses only two types of labor. Labor is simultaneously the only factor of production and of consumers in the model. However, using labor as the explanatory variable in an empirical model may undermine the effect of economy size on exports.

#### 4-2. Robust Estimation Addressing Zero Trade

Given the well-known fact that trade data can contain many zeros, especially when disaggregated data is used, the ordinary least squares method may not produce efficient estimators.<sup>5</sup> We therefore estimated the same empirical model using probit estimation.

$$\Pr ob(E_{ijt} > 0 | X_t) = \Phi(\mathbf{X}_t\boldsymbol{\beta}) \quad (43)$$

where  $\Phi$  denotes the standard normal distribution function and  $\mathbf{X}_t\boldsymbol{\beta}$  is given in equation (41).

The result of the probit estimation is given in Table 2. The coefficients for Japanese regional income are positive and large in magnitude for all industries, while the signs of the coefficients for the income of importing countries are negative for 44 industries. The estimated negative effect of size of foreign economy on export is not

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<sup>4</sup> The regression results when population is used to indicate the size of economy can be made available upon request to the authors.

<sup>5</sup> Helpman et al. (2008) addresses this issue by using probit estimation in two stage estimation.

standard in empirical studies; however, these are consistent with theoretical findings summarized in Table 1.

With regard to the home market effect, in comparing the size of coefficients  $\beta_1$  and  $\beta_2$ , we obtained even stronger support for home market effects than in the previous subsection. Even at a one-percent statistical significance level, only two industries indicate no evidence of the home market effect. Table 3 also reworks the order of industries according to the value of HME statistics. More interestingly, the order of industries is very different from the ones in Table 2. The top three industries with the highest HME statistics are HS37 (photographic products), HS30 (pharmaceutical products), and HS92 (musical instruments). These industries may be categorized as differentiated-product industries. We should not take these three samples as representative of the entire sample because we also find homogenous product industries with very high HME statistics. On the other hand, the lowest three industries are HS47 (pulp), HS6 (trees and plants), and HS41 (hide and leather). At the lower end of the HME statistics, homogenous product industries seem to be appropriately representative for probit estimation.

Our strong support of the home-market effect on a wide range of industries is consistent with the findings of Davis and Weinstein (2003) for OECD countries, although their approach involves relative changes in productions and demand. They find strong evidence of home-market effects for a broad segment of manufacturing industries.<sup>6</sup> It is also important to mention the work of Davis and Weinstein (1999), which uses the same approach as do Davis and Weinstein (2003) for Japanese prefectures. Their findings are less strong than ours; they find evidence of the home-market effect for eight of 19 manufacturing industries. Feenstra et al. (2001) separate differentiated goods from homogeneous goods using Rauch's (1999) measures. They find evidence of a home-market effect in differentiated goods but not in homogeneous goods.

#### **4-3. Estimation Model for Export Share**

Proposition 2 in the theoretical section proposes another empirical prediction. The export share of region 1, located further from the foreign country, declines with respect to an increase in foreign labor. In this subsection, we empirically test this prediction of proposition 2.

For proposition 2, we need to construct the dependent variable as the export

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<sup>6</sup> Head and Ries (2001), on the other hand, find evidence against home market effect, using sector level trade between the US and Canada.

share of the region in total export. We divided regional export by the sum of exports from all regions. To determine the effect of foreign labor force, we need to classify each region as the region-1 type (located relatively further from the foreign country) and the region-2 type (located closer to the foreign country) because the effect has the opposite sign for the two regions. We introduce an indicator function,  $f(\tau_{ij})$ , which takes a positive value for the region-1 type and a negative value for the region-2 type. Specifically, we implement the specification for an indicator function in which region-specific distance is subtracted from the average distance between two countries. This indicator function is multiplied by the figure for foreign labor. The net effect of foreign labor is then measured by multiplying the estimated coefficient and the indicator function. With this function, proposition 2 implies that the coefficient,  $\gamma_1$  is negative, indicating the effect of foreign labor increase to be negative for the region-1 type.

In addition, we need to control for the relative size of regions because a larger region is likely to have a larger export share. Our estimation model for testing proposition 2 is given in equation (43),

$$\left( \frac{E_{ijt}}{\sum_{i=1}^9 E_{ijt}} \right) = \bar{\gamma}_1 f(\tau_{ij}) \times L_{jt} + \bar{\gamma}_2 f(\tau_{ij}) \times L_{it} + \bar{\gamma}^{ij} + \varepsilon_{ijt} \quad (44)$$

where the second term is also interaction term of the local region labor variable with the indicator function. In addition, fixed-effect dummy  $\bar{\gamma}_{ij}$  for the control variable is introduced.

Table 4 provides estimated coefficients in the regression equation (44). Empirical results overwhelmingly support proposition 2. For 85 industries the coefficients of foreign labor is estimated to be negative. Refreshing on the detailed results of numerical simulation, the effect of foreign labor is quite distinct between skilled and unskilled labor force. For an increase in skilled worker, numerical simulation indicates that exports of both regions decline. Proposition 2 only states that decline in region 2 is less severe. For foreign unskilled labor, it is more intuitive that export from region 2 increases while export from region 1 declines. An increase in foreign demand promotes firms to relocate across regions and shifts export from region 1 to region 2.

Now, we move onto testing Proposition 3. The correctly measured statistics for the export share effect of proposition 3 are  $\bar{\gamma}_1 - \bar{\gamma}_2 > 0$ . We test this hypothesis formally using a one-sided test with the null hypothesis of  $H_0: \bar{\gamma}_1 - \bar{\gamma}_2 = 0$  against the

alternative H1:  $\bar{\gamma}_1 - \bar{\gamma}_2 > 0$ .

$$\frac{\bar{\gamma}_1 - \bar{\gamma}_2}{\sqrt{\text{Var}(\bar{\gamma}_1) + \text{Var}(\bar{\gamma}_2) - 2\text{Cov}(\bar{\gamma}_1, \bar{\gamma}_2)}} \quad (45)$$

We use as export share test statistics, of which the distribution is asymptotically normal under regular conditions.

Table 4 also provides export share statistics and p-values for the test statistics. At the ten-percent statistical significance level, the export share test is positive for 46 industries and negative for 24 industries. At the one-percent statistical significance, the test statistics for 37 industries support proposition 2, while the statistics are negative for only 18 industries. Overall, the test statistics are in favor of proposition 2.

This empirical result suggests that regions with a geographical proximity advantage gain a higher export share as the size of foreign country increases. This result is more appealing to our intuition than proposition 2. However, we need to be careful with our underlying assumptions in deriving the results for proposition 2. We maintained the world population to be constant for mathematical convenience when we derived our results from the comparative statistics. Thus, the appropriate measurement to take in empirically testing proposition 2 is an adjustment of  $\gamma_1$  based on the effects of simultaneous decline in regional economies. This leads us to use a similar approach in testing proposition 1: export share is regressed simultaneously on labor forces of foreign countries and domestic regions.

It is noteworthy that we obtained the negative coefficient for interaction term between foreign labor,  $L_{jt}$ , and adjusted distance,  $f(\tau_{ij})$ . Since adjusted distance term is negative for a Japanese region with geographical advantage, i.e., region 1 in our theoretical model, our result implies that the growth in foreign country will raise the export ratio of this region.

Our approach shares some resemblance with the approach taken in Hanson and Xiang (2004). They use the difference-in-difference approach for treatment industries and control industries and find strong evidence of a home-market effect in a panel of 107 exporting countries and 58 importing countries. Their test of home-market effects is whether larger countries export relatively more high-transportation-cost, low-substitution-elasticity goods. Our test of the export share effect is whether larger regions export relatively more when regions possess geographical advantage.

## 5. Discussions and conclusions

In this paper, we introduced a two-region, two-country trade model. Our

crucial assumptions are that regions are heterogeneous in terms of trade cost with regard to foreign countries and population shares of regions are fixed in our analytical period. With this model, we are able to establish a foundation for region-based gravity predictions in which trade between a region in the home country and a region in the foreign country depends on the incomes of both regions and the trade cost between them. More specifically regarding the relative size of income coefficients, our region-based trade model predicts the home market effect. More interestingly, our theoretical model is explicitly for the first time able to predict a change in the relative share of regional exports in the home country when foreign market grows.

With Japanese trade data disaggregated in regions, we applied a region-based gravity model for exports of 97 industries from nine Japanese regions to eight Asian countries. First, we found strong support for a region-based home market effect. For most of industries, income coefficient of Japanese region is found to be larger than the income coefficient of importing countries. Second, empirical evidence is also in favor for export ratio hypothesis, or relative home market effect. Our empirical results suggest that proximity to trade partner countries and the recent rapid growth of Asian economies have led regions with relative advantage in geographical location to become export platforms for some industries.

There are several trade models that consider regions within a country besides Krugman and Elizondo (1996) and Behrens et al. (2007). Rossi-Hansberg (2005) considers a continuum segmented line model in which countries are intervals on the line. This approach is flexible enough to allow for various types of regional production patterns within a county. Marjit and Beladi (2009) also consider a Ricardian model with a continuum region within a country. However, international (or intra-national) trade in these models is only necessitated by specialization in one of two products, so its direct application to empirical excise is limited. Our model is also capable of making predictions regarding regional productions, regional export ratios, and export tendencies with industry characteristics, among other issues. These will remain tasks for our future research.

## Appendix:

### A1. The conditions on trade and transportation costs

In this Appendix, we show the conditions of trade and transportation costs such that trade occurs between any two regions at equilibrium prices. That trade occurs means that  $q_{rs}^* > 0$  ( $r, s = 1, 2, \text{ and } F, r \neq s$ ). Using this, we can derive the conditions.

First of all, we show the conditions under which intra-national trade emerges. When intra-national trade occurs in any county,  $q_{12}^* > 0$ , and  $q_{21}^* > 0$ . Using demand functions, we find that in order for intra-national and international trades to occur at any distribution of skilled workers, the following condition must hold:

$$\tau_H < \tau_{intra} = \frac{2a}{2b + cN}. \quad (\text{A-1})$$

Then, we show the conditions under which international trade occurs in the same way. In this way, we find the following conditions:

$$\max\{\tau_{1F}, \tau_{2F}\} < \tau_{inter} \equiv \frac{2a}{2b + cN}. \quad (\text{A-2})$$

In our paper, we focus on the situation in which intra-national and international trade occurs. Therefore, we impose these conditions on trade and transportation costs.

### A2. The cross effect of trade cost on regional export

The effect of the change in trade costs between region 2 and foreign country of the price and the amount of export of variety from region 1 to foreign country is represented as follows:

$$\frac{\partial p_{1F}^*}{\partial \tau_{2F}} = \frac{\partial p_{FF}^*}{\partial \tau_{2F}} = \frac{cn_2^*}{2b + cN} + \frac{cn_H(\tau_{1F} - \tau_{2F})}{2b + cN} \frac{\partial \lambda^*}{\partial \tau_{2F}}, \quad (\text{A-3})$$

and

$$\frac{\partial q_{1F}^*}{\partial \tau_{2F}} = \frac{\partial q_{FF}^*}{\partial \tau_{2F}} = \frac{c^2 n_2^* N}{2(2b + cN)} + \frac{c^2 n_H N(\tau_{1F} - \tau_{2F})}{2(2b + cN)} \frac{\partial \lambda^*}{\partial \tau_{2F}}. \quad (\text{A-4})$$

Note that both the price and the export have direct and indirect effects. The individual value of export is therefore represented as follows:

$$\frac{\partial p_{1F}^* q_{1F}^*}{\partial \tau_{2F}} = \frac{cn_1^*(2q_{1F}^* + cNp_{1F}^*)}{2(2b + cN)} + \frac{cn_H(\tau_{1F} - \tau_{2F})(2q_{1F}^* + cNp_{1F}^*)}{2(2b + cN)} \frac{\partial \lambda^*}{\partial \tau_{2F}}. \quad (\text{A-4})$$

When trade costs between region 2 and F increase, the prices of variety exported to F rise. In addition to increase in the prices, the amount of export from region 1 to F increases since the consumers in F decrease the demand for the varieties that they have

to accrue higher trade costs than before.

From above investigation, it is shown that the effect of the change in trade costs on the export of region 1 has direct and indirect effects. It is clear that the direct effects the changes of trade costs between region 1 and F and between region 2 and F on the value of export from region 1 are positive. Moreover, the coefficients of  $\partial\lambda^*/\partial\tau_{1F}$  and  $\partial\lambda^*/\partial\tau_{2F}$  are positive. However, the sign of the indirect effects cannot be derived analytically, since it might be impossible for the sign of  $\partial E_{1F}/\partial\tau_{1F}$  and  $\partial E_{1F}/\partial\tau_{2F}$  to be found analytically. What we state is that if the indirect effects are negative and the magnitudes of these effects are sufficiently large, the increase in both trade costs between region 1 and F and between region 2 and F leads to decreases the value of export from region 1. Note that the value of export from one region is affected by trade costs between the other region and foreign country, which is derived from introducing region specific trade costs. This result is new feature.

### **A3. Classification of Regions**

(1)Hokkaido, (2)Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima, (3)Ibaragi, Tochigi, Gunma, Saitama, Chiba, Tokyo, Kanagawa, (4)Niigata, Toyama, Ishikawa, Fukui, Yamanashi, Nagano, Gifu, Shizuoka, Aichi, (5)Mie, Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama, (6)Tottori, Shimane, Okayama, Hiroshima, Yamaguchi, (7)Tokushima, Kagawa, Ehime, Kochi, (8)Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima, (9)Okinawa.

## A4. Descriptions of Chapters (Two-digit HS classification codes)

- |   |   |
|---|---|
| <p>1 Live animals.<br/> 2 Meat and edible meat offal.<br/> 3 Fish &amp; crustacean, mollusc &amp; other aquatic invertebrate<br/> 4 Dairy prod; birds' eggs; natural honey; edible prod nes<br/> 5 Products of animal origin, nes or included.<br/> 6 Live tree &amp; other plant; bulb, root; cut flowers etc<br/> 7 Edible vegetables and certain roots and tubers.<br/> 8 Edible fruit and nuts; peel of citrus fruit or melons.<br/> 9 Coffee, tea, mat* and spices.<br/> 10 Cereals.<br/> 11 Prod mill indust; malt; starches; inulin; wheat gluten<br/> 12 oil seed, oleagi fruits; miscell grain, seed, fruit etc<br/> 13 Lac; gums, resins &amp; other vegetable saps &amp; extracts.<br/> 14 Vegetable plaiting materials; vegetable products nes<br/> 15 Animal/veg fats &amp; oils &amp; their cleavage products; etc<br/> 16 Prep of meat, fish or crustaceans, molluscs etc<br/> 17 Sugars and sugar confectionery.<br/> 18 Cocoa and cocoa preparations.<br/> 19 Prep of cereal, flour, starch/milk; pastrycooks' prod<br/> 20 Prep of vegetable, fruit, nuts or other parts of plants<br/> 21 Miscellaneous edible preparations.<br/> 22 Beverages, spirits and vinegar.<br/> 23 Residues &amp; waste from the food indust; prepr ani fodder<br/> 24 Tobacco and manufactured tobacco substitutes.<br/> 25 Salt; sulphur; earth &amp; ston; plastering mat; lime &amp; cem<br/> 26 ores, slag and ash.<br/> 27 Mineral fuels, oils &amp; product of their distillation; etc<br/> 28 Inorgn chem; compds of prec met, radioact elements etc<br/> 29 organic chemicals.<br/> 30 Pharmaceutical products.<br/> 31 Fertilizers.<br/> 32 Tanning/dyeing extract; tannins &amp; derivs; pigm etc<br/> 33 Essential oils &amp; resinoids; perf, cosmetic/toilet prep<br/> 34 Soap, organic surface-active agents, washing prep, etc<br/> 35 Albuminoid subs; modified starches; glues; enzymes.<br/> 36 Explosives; pyrotechnic prod; matches; pyrop alloy; etc<br/> 37 Photographic or cinematographic goods.<br/> 38 Miscellaneous chemical products.<br/> 39 Plastics and articles thereof.<br/> 40 Rubber and articles thereof.<br/> 41 Raw hides and skins (other than furskins) and leather.<br/> 42 Articles of leather; saddlery/harness; travel goods etc<br/> 43 Furskins and artificial fur; manufactures thereof.<br/> 44 Wood and articles of wood; wood charcoal.<br/> 45 Cork and articles of cork.<br/> 46 Manufactures of straw, esparto/other plaiting mat; etc<br/> 47 Pulp of wood/of other fibrous cellulosic mat; waste etc<br/> 48 Paper &amp; paperboard; art of paper pulp, paper/paperboard<br/> 49 Printed books, newspapers, pictures &amp; other product etc<br/> 50 Silk.<br/> 51 Wool, fine/coarse animal hair, horsehair yarn &amp; fabric<br/> 52 Cotton.<br/> 53 other vegetable textile fibres; paper yarn &amp; woven fab<br/> 54 Man-made filaments.<br/> 55 Man-made staple fibres.</p> | <p>56 Wadding, felt &amp; nonwoven; yarns; twine, cordage, etc<br/> 57 Carpets and other textile floor coverings.<br/> 58 Special woven fab; tufted tex fab; lace; tapestries etc<br/> 59 Impregnated, coated, cover/laminated textile fabric etc<br/> 60 Knitted or crocheted fabrics.<br/> 61 Art of apparel &amp; clothing access, knitted or crocheted.<br/> 62 Art of apparel &amp; clothing access, not knitted/crocheted<br/> 63 other made up textile articles; sets; worn clothing etc<br/> 64 Footwear, gaiters and the like; parts of such articles.<br/> 65 Headgear and parts thereof.<br/> 66 Umbrellas, walking-sticks, seat-sticks, whips, etc<br/> 67 Prepr feathers &amp; down; arti flower; articles human hair<br/> 68 Art of stone, plaster, cement, asbestos, mica/sim mat<br/> 69 Ceramic products.<br/> 70 Glass and glassware.<br/> 71 Natural/cultured pearls, prec stones &amp; metals, coin etc<br/> 72 Iron and steel.<br/> 73 Articles of iron or steel.<br/> 74 Copper and articles thereof.<br/> 75 Nickel and articles thereof.<br/> 76 Aluminium and articles thereof.<br/> 78 Lead and articles thereof.<br/> 79 Zinc and articles thereof.<br/> 80 Tin and articles thereof.<br/> 81 other base metals; cermets; articles thereof.<br/> 82 Tool, implement, cutlery, spoon &amp; fork, of base met etc<br/> 83 Miscellaneous articles of base metal.<br/> 84 Nuclear reactors, boilers, mchy &amp; mech appliance; parts<br/> 85 Electrical mchy equip parts thereof; sound recorder etc<br/> 86 Railw/tramw locom, rolling-stock &amp; parts thereof; etc<br/> 87 Vehicles o/t railw/tramw roll-stock, pts &amp; accessories<br/> 88 Aircraft, spacecraft, and parts thereof.<br/> 89 Ships, boats and floating structures.<br/> 90 optical, photo, cine, meas, checking, precision, etc<br/> 91 Clocks and watches and parts thereof.<br/> 92 Musical instruments; parts and access of such articles<br/> 93 Arms and ammunition; parts and accessories thereof.<br/> 94 Furniture; bedding, mattress, matt support, cushion etc<br/> 95 Toys, games &amp; sports requisites; parts &amp; access thereof<br/> 96 Miscellaneous manufactured articles.<br/> 97 Works of art, collectors' pieces and antiques.<br/> 98 Special Classification Provisions<br/> 99 Special Transaction Trade.</p> |
|---|---|

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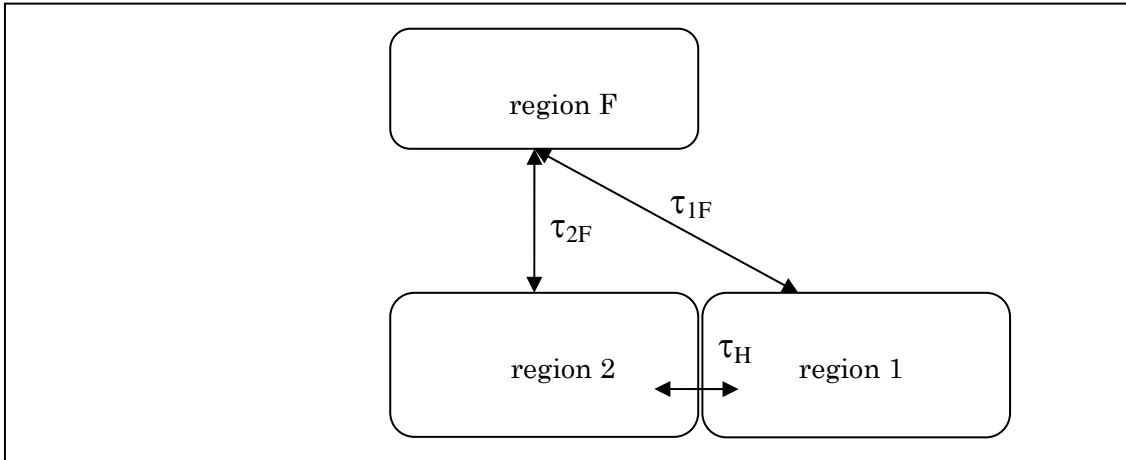
Note: Descriptions are from OECD International Trade by Commodity Statistics

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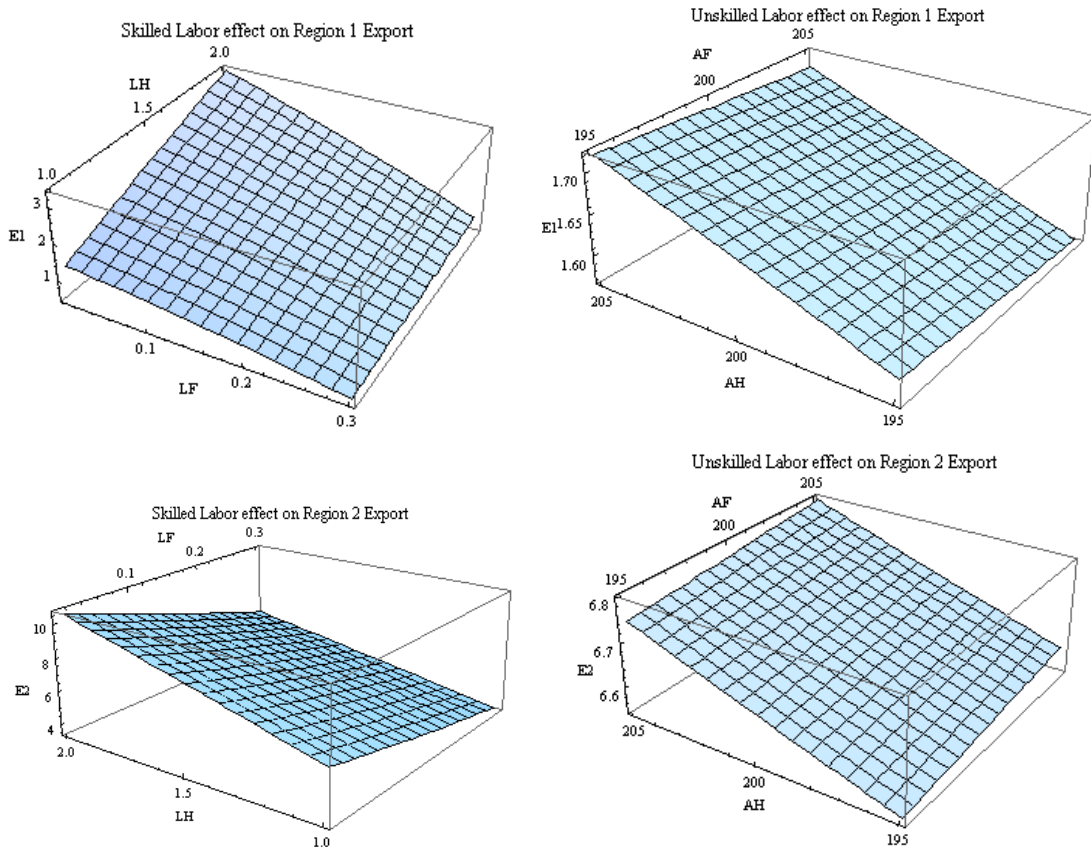
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**Figure 1. The geography of the two home region and one foreign region model**



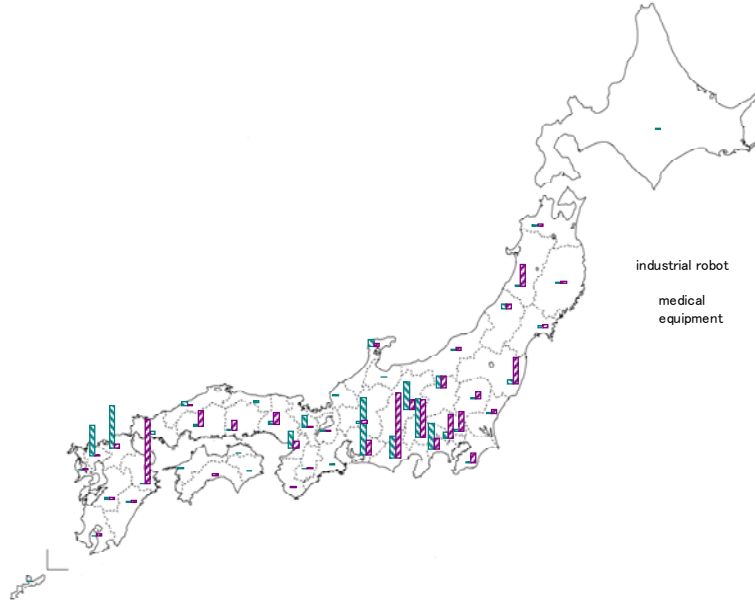
Note: Region 1 and 2 represents the Home country and region F is foreign country. International trade costs are represented by the length of arrows between two regions.

**Figure 2. The Effect of Labor Expansion on Regional Exports**



Note: Baseline parameter values of  $\theta = (\alpha, \beta, \gamma, \phi, L_F, L_H, A_F, A_H, \tau_{1F}, \tau_{2F}, \tau_H)$  are (5, 2, 1, 0.15, 1.5, 200, 200, 4.9, 4.8, 2).

**Figure 3. Regional production in 2005:  
Industrial robot [JSIC2698] and medical equipment [JSIC3131]**



Note: The value of production for each industry in prefectures are represented in a relative height of bar. Figures are calculated by authors, using the *Census of Manufactures*.

**Table 1. The Effect of Labor Force on Regional Exports**

<u>type of labor</u>	<u>Region1 export</u>	<u>Region 2 export</u>
$L_F$	-	-
$A_F$	-	+
$L_H$	+	+
$A_H$	+	+

Note: Baseline parameter values of  $\theta = (\alpha, \beta, \gamma, \phi, L_F, L_H, A_F, A_H, \tau_{1F}, \tau_{2F}, \tau_H)$  are (5, 2, 1, 0.15, 1.5, 200, 200, 4.9, 4.8, 2).

**Table 2. Least Square Estimates and HME Test Statistics**

(HS2) Industry	GDPIM	GDPGR	Distance	HMEtest	adj. R2	(HS2) Industry	GDPIM	GDPGR	Distance	HMEtest	adj. R2
(10)Cereals.	0.28992 (0.34676)	4.352*** (0.91652)	-102760*** (25626)	3.77	0.047	(63)other made up textile articles; sets; worn clothing etc	23.913*** (9.2648)	96.372*** (24.488)	-2800400*** (684680)	2.52	0.028
(8)Edible fruit and nuts; peel of citrus fruit or melons.	4.8458 (6.9921)	78.68*** (18.48)	-1914500*** (516720)	3.40	0.023	(96)Miscellaneous manufactured articles.	161.8*** (61.802)	642.67*** (163.35)	-18953000*** (4567200)	2.51	0.027
(24)Tobacco and manufactured tobacco substitutes.	19.851 (24.635)	278.71*** (65.113)	-6630200*** (1820600)	3.38	0.022	(60)Knitted or crocheted fabrics.	155.49*** (57.432)	593.64*** (151.8)	-17925000*** (4244300)	2.46	0.027
(2)Meat and edible meat offal.	0.37708 (0.40095)	4.2912*** (1.0597)	-107050*** (29630)	3.14	0.024	(20)Prep of vegetable, fruit, nuts or other parts of plants	6.9094*** (2.2931)	24.281*** (6.0607)	-714040*** (169460)	2.44	0.029
(11)Prod mill indust; malt; starches; inulin; wheat gluten	5.4295 (6.1244)	64.961*** (16.187)	-1630900*** (452600)	3.13	0.023	(56)Wadding, felt & nonwoven; yarns; twine, cordage, etc	139.04*** (49.132)	507.31*** (129.86)	-15145000*** (3630900)	2.41	0.028
(79)Zinc and articles thereof.	27.201 (17.642)	192.25*** (46.628)	-5067900*** (1303700)	3.01	0.025	(59)Impregnated, coated, cover/laminated textile fabric etc	150.6*** (52.853)	546.51*** (139.69)	-16469000*** (3905900)	2.41	0.028
(16)Prep of meat, fish or crustaceans, molluscs etc	48.623 (32.384)	344.39*** (85.592)	-9049300*** (2393200)	2.94	0.024	(5)Products of animal origin, nes or included.	4.8498*** (1.8003)	18.31*** (4.7584)	-536750*** (133040)	2.41	0.026
(42)Articles of leather; saddlery/harness; travel goods etc	6.9859* (4.1145)	44.107*** (10.875)	-1179000*** (304060)	2.91	0.024	(36)Explosives; pyrotechnic prod; matches; pyrop alloy; etc	1.0009** (0.45054)	4.3653*** (1.1908)	-126790*** (33295)	2.40	0.026
(86)Railw/tramw locom, rolling-stock & parts thereof; etc	138.02* (78.261)	834.33*** (206.85)	-22773000*** (5783500)	2.87	0.023	(85)Electrical mchgy equip parts thereof; sound recorder etc	22826*** (7413.8)	76495*** (19595)	-2328100000*** (547880000)	2.33	0.029
(19)Prep of cereal, flour, starch/milk; pastrycooks' prod	20.987* (11.636)	124.03*** (30.755)	-3358300*** (859910)	2.85	0.025	(48)Paper & paperboard; art of paper pulp, paper/paperboard	460.27*** (152.42)	1560.9*** (402.86)	-47270000*** (11264000)	2.33	0.029
(22)Beverages, spirits and vinegar.	19.139** (9.5717)	103.56*** (25.299)	-2830700*** (707350)	2.84	0.025	(54)Man-made filaments.	431.82*** (141.39)	1448.1*** (373.71)	-44623000*** (10449000)	2.31	0.029
(89)Ships, boats and floating structures.	256.55* (155.05)	1619.7*** (409.82)	-43209000*** (11459000)	2.83	0.027	(52)Cotton.	242.63*** (83.009)	836.51*** (219.4)	-26105000*** (6134400)	2.30	0.029
(7)Edible vegetables and certain roots and tubers.	2.809 (2.5474)	25.106*** (6.7329)	-664040*** (188250)	2.82	0.022	(78)Lead and articles thereof.	7.3745*** (2.2181)	23.165*** (5.8626)	-703460*** (163920)	2.29	0.030
(91)Clocks and watches and parts thereof.	111.15 (84.176)	847.44*** (222.48)	-22437000*** (6220700)	2.82	0.024	(95)Toys, games & sports requisites; parts & access thereof	309.77*** (93.595)	974.31*** (247.38)	-29680000*** (6916700)	2.29	0.031
(45)Cork and articles of cork.	0.26866* (0.14931)	1.5552*** (0.39464)	-42070*** (11034)	2.77	0.026	(9)Coffee, tea, mat & spices.	5.0514*** (1.5997)	16.362*** (4.2282)	-503650*** (118220)	2.28	0.030
(71)Natural/cultured pearls, prec stones & metals, coin etc	613.23** (304.7)	3217*** (805.34)	-88744000*** (22517000)	2.75	0.026	(81)other base metals; cermets; articles thereof.	293.24*** (88.549)	915.06*** (234.04)	-28077000*** (6543800)	2.26	0.030
(41)Raw hides and skins (other than furskins) and leather.	43.52** (21.495)	227.05*** (56.813)	-6163700*** (1588500)	2.75	0.024	(57)Carpets and other textile floor coverings.	5.5005*** (1.8425)	18.39*** (4.8698)	-569270*** (136160)	2.25	0.028
(4)Dairy prod; birds' eggs; natural honey; edible prod nes	2.0074** (0.9581)	10.15*** (2.5323)	-282740*** (70804)	2.74	0.025	(76)Aluminium and articles thereof.	586.21*** (177.42)	1825.7*** (468.94)	-56568000*** (13112000)	2.25	0.031
(88)Aircraft, spacecraft, and parts thereof.	5.6849** (2.6369)	28.079*** (6.9696)	-778410*** (194870)	2.73	0.027	(68)Art of stone, plaster, cement, asbestos, mica/sim mat	264.13*** (77.678)	803.54*** (205.31)	-24559000*** (5740500)	2.24	0.031
(18)Cocoa and cocoa preparations.	9.2962** (3.9059)	42.143*** (10.323)	-1167800*** (288640)	2.71	0.026	(83)Miscellaneous articles of base metal.	155.39*** (48.016)	488.36*** (126.91)	-15319000*** (3548400)	2.23	0.030
(64)Footwear, gaiters and the like; parts of such articles.	12.16** (5.1928)	55.487*** (13.725)	-1552900*** (383750)	2.69	0.027	(58)Special woven fab; tufted tex fab; lace; tapestries etc	77.87*** (23.68)	241.5*** (62.587)	-7690500*** (1749900)	2.23	0.030
(80)Tin and articles thereof.	22.606** (8.9199)	95.175*** (23.576)	-2723200*** (659180)	2.62	0.028	(51)Wool, fine/coarse animal hair, horsehair yarn & fabric	110.95*** (34.744)	350.68*** (91.831)	-11240000*** (2567600)	2.22	0.030
(62)Art of apparel & clothing access, not knitted/crocheted	35.01*** (13.276)	141.47*** (35.089)	-4093300*** (981080)	2.58	0.027	(55)Man-made staple fibres.	275.96*** (86.363)	868.16*** (228.26)	-27536000*** (6382300)	2.21	0.030
(61)Art of apparel & clothing access, knitted or crocheted.	33.537*** (12.658)	133.81*** (33.455)	-3852700*** (935400)	2.55	0.027	(35)Albuminoidal subs; modified starches; glues; enzymes.	159.44*** (45.017)	468.08*** (118.98)	-14472000*** (3326800)	2.21	0.032

Note: For expository purpose, coefficients for GDPIM and GDPGR are presented after original estimated coefficients are multiplied by 1,000,000. Figures in parenthesis are heteroskedastic consistent standard errors. \*, \*\*, \*\*\* denote statistical significance at ten, five, and one percent level, respectively. HME test represents statistics given in equation (31) and critical value for ten percent significance level is 1.282.

**Table 2(continued). Least Square Estimates and HME Test Statistics**

(HS2) Industry	GDPIM	GDPR	Distance	HMEtest	adj. R <sup>2</sup>	(HS2) Industry	GDPIM	GDPR	Distance	HMEtest	adj. R <sup>2</sup>
(21)Miscellaneous edible preparations.	106.62*** (29.95)	311.07*** (79.159)	-9671700*** (2213300)	2.20	0.032	(28)Inorgn chem; compts of prec met, radioact elements etc	975.12*** (244.43)	2440.7*** (646.04)	-79473000*** (18063000)	1.93	0.034
(46)Manufactures of straw, esparto/other plaiting mat; etc	0.18253*** (0.060437)	0.59473*** (0.15974)	-18462*** (4466.3)	2.20	0.028	(92)Musical instruments; parts and access of such articles	43.935*** (11.397)	112.19*** (30.123)	-3696400*** (842250)	1.93	0.036
(47)Pulp of wood/of other fibrous cellulosic mat; waste etc	205.11*** (60.299)	611.07*** (159.38)	-1963000*** (4456200)	2.17	0.030	(3)Fish & crustacean, mollusc & other aquatic invertebrate	306.07*** (73.908)	745.45*** (195.34)	-24033000*** (5461900)	1.91	0.034
(53)other vegetable textile fibres; paper yarn & woven fab	11.288*** (3.5495)	34.945*** (9.3816)	-1121200*** (262310)	2.15	0.028	(97)Works of art, collectors' pieces and antiques.	6.7409*** (1.5894)	15.971*** (4.2009)	-521230*** (117460)	1.87	0.035
(17)Sugars and sugar confectionery.	20.465*** (5.4645)	56.778*** (14.443)	-1746000*** (403830)	2.14	0.033	(30)Pharmaceutical products.	199.99*** (46.291)	461.49*** (122.35)	-15421000*** (3420900)	1.82	0.036
(37)Photographic or cinematographic goods.	904.41*** (247.71)	2546.6*** (654.7)	-79822000*** (18306000)	2.13	0.032	(12)oil seed, oleagi fruits; miscell grain, seed, fruit etc	25.359*** (5.8747)	57.943*** (15.527)	-1926000*** (434140)	1.79	0.035
(6)Live tree & other plant; bulb, root; cut flowers etc	6.231*** (1.8902)	18.732*** (4.9958)	-601200*** (139680)	2.13	0.029	(70)Glass and glassware.	1507.4*** (338.73)	3359.3*** (895.3)	-113110000*** (25033000)	1.76	0.036
(65)Headgear and parts thereof.	2.8447*** (0.77654)	7.9682*** (2.0525)	-248670*** (57387)	2.12	0.032	(15)Animal/veg fats & oils & their cleavage products; etc	15.468*** (3.4402)	33.747*** (9.0926)	-1108500*** (254230)	1.71	0.037
(33)Essential oils & resinoids; perf, cosmetic/toilet prep	285.3*** (76.623)	790.05*** (202.52)	-24639000*** (5662500)	2.12	0.032	(67)Prepr feathers & down; arti flower; articles human hair	1.3066*** (0.28416)	2.7818*** (0.75105)	-97075*** (20999)	1.67	0.038
(40)Rubber and articles thereof.	820.59*** (230.71)	2332.9*** (609.77)	-74354000*** (17049000)	2.11	0.032	(49)Printed books, newspapers, pictures & other product etc	160.49*** (35.71)	341.64*** (94.385)	-11954000*** (2639000)	1.63	0.036
(66)Umbrellas, walking-sticks, seat-sticks, whips, etc	0.25997*** (0.099362)	0.90868*** (0.26262)	-26142*** (7342.9)	2.10	0.027	(26)ores, slag and ash.	38.783*** (8.212)	80.209*** (21.705)	-2740300*** (606870)	1.62	0.038
(82)Tool, implement, cutlery, spoon & fork, of base met etc	497.21*** (138.25)	1395.5*** (365.4)	-44793000*** (10217000)	2.09	0.032	(13)Lac; gums, resins & other vegetable saps & extracts.	8.8347*** (1.734)	17.543*** (4.583)	-578940*** (128140)	1.62	0.042
(73)Articles of iron or steel.	1460.5*** (426.56)	4223.4*** (1127.4)	-135010000*** (31523000)	2.09	0.031	(94)Furniture; bedding, mattress, matt support, cushion etc	196.21*** (43.388)	405.68*** (114.68)	-14674000*** (3206400)	1.55	0.037
(32)Tanning/dyeing extract; tannins & derivs; pigm etc	888.73*** (240.42)	2445.1*** (635.45)	-77985000*** (17767000)	2.08	0.032	(14)Vegetable plaiting materials; vegetable products nes	0.34279*** (0.083889)	0.74172*** (0.22172)	-21482*** (6199.4)	1.53	0.029
(74)Copper and articles thereof.	2126*** (591.53)	5941.4*** (1563.5)	-191150000*** (43715000)	2.08	0.031	(29)organic chemicals.	6345.2*** (1315.2)	12583*** (3476.1)	-446910000*** (97193000)	1.53	0.038
(39)Plastics and articles thereof.	5573.3*** (1504.1)	15244*** (3975.5)	-489940000*** (111150000)	2.07	0.032	(27)Mineral fuels, oils & product of their distillation; etc	1740.5*** (358.9)	3430.4*** (948.59)	-122130000*** (26523000)	1.52	0.038
(84)Nuclear reactors, boilers, mchy & mech appliance; parts	20329*** (5480.1)	55327*** (14484)	-	2.06	0.032	(25)Salt; sulphur; earth & ston; plastering mat; lime & cem	173.56*** (35.454)	339.17*** (93.707)	-11976000*** (2620100)	1.50	0.040
(69)Ceramic products.	199.37*** (52.363)	532.1*** (138.4)	-16594000*** (3869700)	2.05	0.034	(72)Iron and steel.	10715*** (2149.2)	20593*** (5680.4)	-726050000*** (158830000)	1.48	0.040
(90)optical, photo, cine, meas, checking, precision, etc	7858.8*** (2062)	20930*** (5450)	-674600000*** (152380000)	2.04	0.033	(23)Residues & waste from the food indust; prepr ani fodder	26.072*** (4.8963)	46.72*** (12.941)	-1592300*** (361840)	1.36	0.042
(87)Vehicles o/t railw/tramw roll-stock, pts & accessories	4998.1*** (1383.9)	13732*** (3657.7)	-447160000*** (102270000)	2.03	0.032	(43)Furskins and artificial fur; manufactures thereof.	0.35125*** (0.12551)	0.86631*** (0.33173)	-31225*** (9275.1)	1.32	0.029
(44)Wood and articles of wood; wood charcoal.	20.207*** (5.2833)	53.149*** (13.964)	-1685000*** (390440)	2.01	0.033	(93)Arms and ammunition; parts and accessories thereof.	0.063405*** (0.014129)	0.11457*** (0.037344)	-3955.4*** (1044.1)	1.17	0.045
(31)Fertilizers.	11.354*** (4.0793)	36.346*** (10.782)	-1127300*** (301470)	1.97	0.034	(75)Nickel and articles thereof.	198.4*** (33.074)	313.38*** (87.416)	-11619000*** (2444200)	1.12	0.049
(38)Miscellaneous chemical products.	2743.2*** (677.58)	6832.5*** (1790.9)	-222580000*** (50074000)	1.94	0.034	(50)Silk.	30.363*** (5.7777)	49.987*** (15.271)	-2022100*** (426970)	1.09	0.041
(34)Soap, organic surface-active agents, washing prep, etc	408.74*** (101.68)	1019*** (268.74)	-3325000*** (7514000)	1.93	0.034	(1)Live animals.	3.1794*** (0.46937)	4.367*** (1.2406)	-165880*** (34686)	0.81	0.056

Note: For expository purpose, coefficients for GDPIM and GDPR are presented after original estimated coefficients are multiplied by 1,000,000. Figures in parenthesis are heteroskedastic consistent standard errors. \*, \*\*, \*\*\* denote statistical significance at ten, five, and one percent level, respectively. HME test represents statistics given in equation (31) and critical value for ten percent significance level is 1.282.

**Table 3. Probit Estimates and HME Test Statistics**

(HS2) Industry	GDPI	GDPR	Distance	HMEtest adj. R2	(HS2) Industry	GDPI	GDPR	Distance	HMEtest adj. R2
(37)Photographic or cinematographic goods.	-4.3001*** (0.88003)	23.628*** (1.275)	-0.00045945*** (0.000024016)	16.07 0.640	(45)Cork and articles of cork.	-4.6389*** (0.73257)	7.527*** (0.41996)	-0.00036374*** (0.000017928)	13.11 0.239
(30)Pharmaceutical products.	-4.258*** (0.81153)	17.009*** (0.87524)	-0.00035491*** (0.000019823)	15.90 0.529	(62)Art of apparel & clothing access, not knitted/crocheted	1.8177* (0.96632)	24.56*** (1.3342)	-0.00050805*** (0.000025812)	12.90 0.665
(92)Musical instruments; parts and access of such articles	-2.9717*** (0.80554)	18.701*** (0.96419)	-0.00044946*** (0.000022335)	15.65 0.593	(59)Impregnated, coated, cover/laminated textile fabric etc	-0.91034 (0.92925)	24.623*** (1.512)	-0.0003715*** (0.000022567)	12.84 0.567
(78)Lead and articles thereof.	-3.101*** (0.8089)	16.127*** (0.82622)	-0.00041647*** (0.000020819)	15.01 0.548	(38)Miscellaneous chemical products.	-0.2149 (1.1972)	41.226*** (2.7178)	-0.00031403*** (0.000026944)	12.84 0.498
(33)Essential oils & resinoids; perf, cosmetic/toilet prep	-1.9281** (0.83562)	18.837*** (0.99857)	-0.0004045*** (0.000021508)	14.45 0.568	(28)Inorgn chem; compds of prec met, radioact elements etc	-0.53682 (1.1598)	39.01*** (2.5806)	-0.00029091*** (0.000026113)	12.78 0.460
(88)Aircraft, spacecraft, and parts thereof.	-5.0418*** (0.76868)	9.8337*** (0.52288)	-0.00039148*** (0.000019211)	14.42 0.364	(52)Cotton.	1.767* (0.91861)	21.485*** (1.1315)	-0.00050175*** (0.000025091)	12.77 0.644
(91)Clocks and watches and parts thereof.	-2.0723** (0.88085)	21.942*** (1.2189)	-0.00041144*** (0.000022327)	14.39 0.594	(96)Miscellaneous manufactured articles.	-0.086412 (1.0334)	30.445*** (1.9487)	-0.00036904*** (0.00002437)	12.40 0.554
(13)Lac; gums, resins & other vegetable saps & extracts.	-1.8917** (0.80079)	15.647*** (0.79369)	-0.00047145*** (0.000023098)	14.32 0.557	(40)Rubber and articles thereof.	-0.72882 (1.1765)	39.547*** (2.7465)	-0.00024245*** (0.000026409)	12.31 0.428
(69)Ceramic products.	-3.5949*** (0.94939)	29.663*** (1.8488)	-0.00041071*** (0.00002499)	14.12 0.605	(15)Animal/veg fats & oils & their cleavage products; etc	0.2166 (0.83035)	15.975*** (0.85006)	-0.00038606*** (0.000020067)	12.23 0.533
(75)Nickel and articles thereof.	-1.5122* (0.84708)	18.116*** (0.96301)	-0.00035778*** (0.000019751)	13.86 0.541	(49)Printed books, newspapers, pictures & other product etc	0.27345 (1.0251)	29.04*** (1.8849)	-0.00035394*** (0.00002389)	12.08 0.541
(81)Other base metals; cermet; articles thereof.	-0.31972 (0.91547)	23.573*** (1.2933)	-0.0004231*** (0.000022963)	13.77 0.614	(61)Art of apparel & clothing access, knitted or crocheted.	1.9053** (0.90353)	19.028*** (0.99414)	-0.00044532*** (0.000022724)	11.99 0.599
(79)Zinc and articles thereof.	-1.8517** (0.81074)	16.452*** (0.88216)	-0.00032594*** (0.000018887)	13.74 0.504	(64)Footwear, gaiters and the like; parts of such articles.	0.84711 (0.87576)	17.335*** (0.92539)	-0.00036122*** (0.000019901)	11.98 0.532
(71)Natural/cultured pearls, prec stones & metals, coin etc	-1.9401** (0.88916)	22.737*** (1.3348)	-0.00036437*** (0.000021482)	13.74 0.568	(74)Copper and articles thereof.	3.3585** (1.3731)	40.16*** (2.551)	-0.00038463*** (0.000027562)	11.81 0.548
(42)Articles of leather; saddlery/harness; travel goods etc	-0.38199 (0.84591)	18.376*** (0.94986)	-0.00043028*** (0.000021998)	13.65 0.583	(18)Cocoa and cocoa preparations.	-3.2571*** (0.72947)	7.5488*** (0.42788)	-0.00034786*** (0.000017372)	11.74 0.273
(58)Special woven fab; tufted tex fab; lace; tapestries etc	0.34696 (0.89848)	22.42*** (1.1971)	-0.00049319*** (0.000024896)	13.64 0.644	(29)organic chemicals.	0.43959 (1.1419)	33.05*** (2.279)	-0.00025775*** (0.000024394)	11.61 0.426
(80)Tin and articles thereof.	-2.1859*** (0.78109)	13.355*** (0.68789)	-0.00040313*** (0.000020183)	13.56 0.496	(32)Tanning/dyeing extract; tannins & derivs; pigm etc	0.23254 (1.0715)	29.746*** (2.0635)	-0.00026926*** (0.000023366)	11.41 0.459
(68)Art of stone, plaster, cement, asbestos, mica/sim mat	-0.9717 (1.1664)	42.805*** (2.7172)	-0.00035987*** (0.000027484)	13.54 0.530	(9)Coffee, tea, mat * and spices.	-1.0878 (0.75622)	10.397*** (0.5531)	-0.0003688*** (0.000018373)	11.29 0.412
(65)Headgear and parts thereof.	-2.8619*** (0.75975)	11.391*** (0.59285)	-0.00040712*** (0.000019964)	13.50 0.447	(34)Soap, organic surface-active agents, washing prep, etc	1.1045 (1.0718)	27.951*** (1.8456)	-0.00032318*** (0.000023134)	11.28 0.511
(82)Tool, implement, cutlery, spoon & fork, of base met etc	-0.63069 (1.2013)	43.837*** (2.793)	-0.00035015*** (0.000027761)	13.43 0.527	(35)Albuminoidal subs; modified starches; glues; enzymes.	0.87845 (1.0499)	26.883*** (1.8208)	-0.00031129*** (0.000022813)	11.14 0.508
(60)Knitted or crocheted fabrics.	0.98801 (0.90343)	21.657*** (1.13)	-0.00051202*** (0.000024931)	13.37 0.655	(90)optical, photo, cine, meas, checking, precision, etc	4.0725** (1.6343)	48.826*** (3.4903)	-0.00033087*** (0.000031017)	11.12 0.471
(70)Glass and glassware.	-1.5544 (0.98102)	32.094*** (2.0415)	-0.00032427*** (0.000023952)	13.36 0.527	(94)Furniture; bedding, mattress, matt support, cushion etc	1.3897 (1.0992)	28.806*** (1.9525)	-0.00031654*** (0.00002347)	11.04 0.503
(11)Prod mill indust; malt; starches; inulin; wheat gluten	-1.3641* (0.7843)	14.22*** (0.72116)	-0.00037645*** (0.000019425)	13.34 0.515	(17)Sugars and sugar confectionery.	-0.14816 (0.80472)	12.829*** (0.71585)	-0.00031491*** (0.000017614)	10.99 0.446
(57)Carpets and other textile floor coverings.	-1.8325** (0.76588)	13.19*** (0.689)	-0.00038493*** (0.000019598)	13.27 0.481	(73)Articles of iron or steel.	1.7948 (1.4917)	48.578*** (3.778)	-0.00022446*** (0.000031521)	10.97 0.380
(83)Miscellaneous articles of base metal.	-0.71507 (1.0571)	34.746*** (2.1822)	-0.00036449*** (0.000025362)	13.18 0.549	(19)Prep of cereal, flour, starch/milk; pastrycooks' prod	0.2689 (0.8337)	14.199*** (0.79884)	-0.00030644*** (0.000017936)	10.96 0.460

Note: For expository purpose, coefficients for GDPI and GDPR are presented after original estimated coefficients are multiplied by 1,000,000,000,000. Figures in parenthesis are heteroskedastic consistent standard errors. \*, \*\*, \*\*\* denote statistical significance at ten, five, and one percent level, respectively. HME test represents statistics given in equation (31) and critical value for ten percent significance level is 1.282.

**Table 3(continued). Probit Estimates and HME Test Statistics**

(HS2) Industry	GDPIM	GDPR	Distance	HMEtest adj. R2	(HS2) Industry	GDPIM	GDPR	Distance	HMEtest adj. R2
(86)Railw/tramw locom, rolling-stock & parts thereof; etc	-0.26789 (0.77684)	11.627*** (0.63556)	-0.00033356*** (0.000017952)	10.93 0.435	(7)Edible vegetables and certain roots and tubers.	0.34206 (0.73573)	8.0321*** (0.45777)	-0.00032475*** (0.000016812)	8.28 0.320
(36)Explosives; pyrotechnic prod; matches; pyrop alloy; etc	-3.7785*** (0.73131)	6.0788*** (0.39077)	-0.00036283*** (0.000017718)	10.87 0.166	(23)Residues & waste from the food indust; prepr ani fodder	1.6735* (0.88876)	12.834*** (0.84378)	-0.00017965*** (0.000016365)	8.22 0.363
(55)Man-made staple fibres.	1.0581 (0.92843)	19.171*** (1.1959)	-0.00029291*** (0.000019529)	10.85 0.482	(14)Vegetable plaiting materials; vegetable products nes	-0.44256 (0.71773)	6.8178*** (0.40893)	-0.00038545*** (0.0000184)	8.22 0.263
(67)Prepr feathers & down; arti flower; articless human hair	-2.0372*** (0.71794)	7.7787*** (0.44283)	-0.00039179*** (0.000018786)	10.79 0.295	(50)Silk.	1.5283** (0.76794)	9.2415*** (0.49386)	-0.00043352*** (0.000020397)	8.11 0.415
(76)Aluminium and articles thereof.	3.3421*** (1.278)	33.04*** (2.1911)	-0.00035278*** (0.000025399)	10.73 0.538	(21)Miscellaneous edible preparations.	5.1303*** (1.1214)	18.742*** (1.1148)	-0.0003505*** (0.000020398)	7.99 0.537
(56)Wadding, felt & nonwoven; yarns; twine, cordage, etc	2.764** (1.1502)	28.406*** (1.9116)	-0.00035069*** (0.0000239)	10.48 0.529	(12)oil seed, oleagi fruits; miscell grain, seed, fruit etc	5.5245*** (1.0248)	16.37*** (0.87536)	-0.00048471*** (0.000023991)	7.83 0.602
(54)Man-made filaments.	2.6639*** (1.0304)	22.646*** (1.4329)	-0.00035401*** (0.000021857)	10.37 0.541	(84)Nuclear reactors, boilers, mchy & mech appliance; parts	3.3846 (2.1999)	63.684*** (7.1282)	-0.000081686** (0.000041665)	7.74 0.269
(48)Paper & paperboard; art of paper pulp, paper/paperboard	1.7699 (1.3829)	37.525*** (2.8994)	-0.00015482*** (0.000027425)	10.35 0.358	(25)Salt; sulphur; earth & ston; plastering mat; lime & cem	5.5551*** (1.3798)	25.345*** (1.8813)	-0.00025223*** (0.000022611)	7.71 0.424
(95)Toys, games & sports requisites; parts & access thereof	3.4949*** (1.0977)	25.048*** (1.5816)	-0.00040034*** (0.000023587)	10.26 0.583	(66)Umbrellas, walking-sticks, seat-sticks, whips, etc	-0.81307 (0.7125)	5.9734*** (0.40456)	-0.00043025 (0.000019967)	7.70 0.232
(24)Tobacco and manufactured tobacco substitutes.	-3.072*** (0.72791)	6.2188*** (0.4054)	-0.00042684 (0.000019989)	10.21 0.197	(3)Fish & crustacean, mollusc & other aquatic invertebrate	3.6447*** (1.1203)	17.348*** (1.1922)	-0.00014119*** (0.000018191)	7.62 0.347
(20)Prep of vegetable, fruit, nuts or other parts of plants	0.98811 (0.81658)	12.697*** (0.69928)	-0.00034613*** (0.000018606)	10.03 0.464	(44)Wood and articles of wood; wood charcoal.	5.0932*** (1.1912)	19.63*** (1.3012)	-0.00028206*** (0.000019645)	7.56 0.481
(39)Plastics and articles thereof.	3.8287** (1.6629)	44.065*** (3.4438)	-0.00022313*** (0.000030007)	9.91 0.378	(10)Cereals.	-3.872*** (0.72428)	2.6261*** (0.34585)	-0.00028794*** (0.000015918)	7.35 0.412
(63)other made up textile articles; sets; worn clothing etc	2.2054** (1.018)	20.454*** (1.3569)	-0.00027285*** (0.000019839)	9.72 0.473	(51)Wool, fine/coarse animal hair, horsehair yarn & fabric	3.4013*** (0.83693)	10.844*** (0.55547)	-0.0004421*** (0.000021057)	7.23 0.490
(46)Manufactures of straw, esparto/other plaiting mat; etc	-1.2726* (0.72293)	7.4905*** (0.42901)	-0.00039797*** (0.00001882)	9.72 0.295	(72)Iron and steel.	7.3268*** (1.9992)	32.146*** (2.7081)	-0.00015189*** (0.000026988)	6.87 0.345
(4)Dairy prod; birds' eggs; natural honey; edible prod nes	-1.4667** (0.71125)	6.9827*** (0.40966)	-0.00034636*** (0.00001715)	9.53 0.253	(89)Ships, boats and floating structures.	3.9627*** (1.1007)	15.213*** (1.1167)	-0.00011243*** (0.000017758)	6.50 0.281
(85)Electrical mchy equip parts thereof; sound recorder etc	3.0625 (1.8663)	63.494*** (5.9518)	-0.00019981*** (0.000038992)	9.39 0.323	(27)Mineral fuels, oils & product of their distillation; etc	7.3128*** (1.5119)	23.69*** (1.7376)	-0.0002663*** (0.000022011)	6.47 0.442
(97)Works of art, collectors' pieces and antiques.	-0.52926 (0.72872)	7.818*** (0.44319)	-0.00041116 (0.000019245)	9.19 0.327	(43)Furskins and artificial fur; manufactures thereof.	0.8091 (0.72146)	6.3416*** (0.40825)	-0.00042196 (0.000019531)	6.29 0.283
(31)Fertilizers.	-0.94913 (0.73858)	7.9491*** (0.5038)	-0.00014432*** (0.00001435)	9.06 0.255	(53)other vegetable textile fibres; paper yarn & woven fab	3.2606*** (0.80682)	9.3454*** (0.50295)	-0.00043642*** (0.000020539)	6.22 0.437
(22)Beverages, spirits and vinegar.	2.227*** (0.85469)	13.048*** (0.72846)	-0.00033819*** (0.000018542)	8.97 0.469	(1)Live animals.	0.59372 (0.71572)	6.0334*** (0.40734)	-0.00044556 (0.00002048)	6.19 0.257
(2)Meat and edible meat offal.	-2.5829*** (0.70819)	5.2189*** (0.37598)	-0.00035161*** (0.000017337)	8.90 0.162	(26)ores, slag and ash.	1.367* (0.74417)	5.7226*** (0.38966)	-0.00019256*** (0.000014126)	4.81 0.208
(16)Prep of meat, fish or crustaceans, molluscs etc	1.0021 (0.8107)	10.923*** (0.64347)	-0.00026377*** (0.00001655)	8.74 0.385	(5)Products of animal origin, nes or included.	4.1217*** (0.82363)	8.8039*** (0.4825)	-0.00039176*** (0.000018797)	4.74 0.433
(93)Arms and ammunition; parts and accessories thereof.	-3.9767*** (0.73491)	3.5374*** (0.36121)	-0.00034411*** (0.00001756)	8.35 0.030	(41)Raw hides and skins (other than furskins) and leather.	6.8762*** (1.0708)	11.858*** (0.70188)	-0.00034621*** (0.000018903)	3.73 0.471
(87)Vehicles o/t railw/tramw roll-stock, pts & accessories	2.0429 (1.2771)	26.512*** (2.297)	- (0.000067858**	8.35 0.233	(6)Live tree & other plant; bulb, root; cut flowers etc	4.2697*** (0.77858)	6.0453*** (0.39919)	-0.00037593*** (0.000018057)	1.95 0.330
(8)Edible fruit and nuts; peel of citrus fruit or melons.	-1.8716*** (0.68099)	5.1478*** (0.35889)	-0.00026252*** (0.000015089)	8.34 0.162	(47)Pulp of wood/of other fibrous cellulosic mat; waste etc	7.885*** (1.0648)	6.7691*** (0.44477)	-0.00028072*** (0.000015933)	-0.93 0.339

Note: For expository purpose, coefficients for GDPIM and GDPR are presented after original estimated coefficients are multiplied by 1,000,000,000,000,000. Figures in parenthesis are heteroskedastic consistent standard errors. \*, \*\*, \*\*\* denote statistical significance at ten, five, and one percent level, respectively. HME test represents statistics given in equation (31) and critical value for ten percent significance level is 1.282.

**Table 4. Export Ratio Regression**

Industry	f(dist)*L_im	f(dist)*L_reg	NOB	Adj. R <sup>2</sup>	ER Stat	ER test	Industry	f(dist)*L_im	f(dist)*L_reg	NOB	Adj. R <sup>2</sup>	ER Stat	ER test
(1)Live animals.	-0.00019907 (0.00074648)	-0.017564*** (0.004276)	1044	0.526	0.017	3.821	(25)Salt; sulphur; earth & ston; plastering mat; lime & cem	-0.00053577 (0.00037448)	0.00079151 (0.0016267)	1368	0.621	-0.001	-0.754
(2)Meat and edible meat offal.	-0.0019576*** (0.00071162)	-0.01361*** (0.0036141)	1044	0.545	0.012	3.013	(26)ores, slag and ash.	-0.00024748 (0.00065431)	0.0081626*** (0.0029013)	1332	0.446	-0.008	-2.683
(3)Fish & crustacean, mollusc & other aquatic invertebrate	-0.00026839 (0.00042042)	-0.0027221 (0.0018262)	1368	0.626	0.002	1.241	(27)Mineral fuels, oils & product of their distillation; etc	0.000019927 (0.00039957)	0.0055058*** (0.0017357)	1368	0.595	-0.005	-2.920
(4)Dairy prod; birds' eggs; natural honey; edible prod nes	-0.0016424** (0.00068054)	-0.021584*** (0.0031392)	1269	0.538	0.020	5.898	(28)Inorgn chem; compds of prec met, radioact elements etc	-0.0002247 (0.00025442)	-0.0045849*** (0.0011052)	1368	0.824	0.004	3.645
(5)Products of animal origin, nes or included.	0.00051734 (0.00066906)	-0.0053671* (0.00313)	1323	0.459	0.006	1.747	(29)organic chemicals.	-0.00044785*** (0.00022022)	-0.0032023*** (0.0009566)	1368	0.780	0.003	2.661
(6)Live tree & other plant; bulb, root; cut flowers etc	-0.00073101 (0.00076819)	-0.0086128** (0.0035533)	1179	0.309	0.008	2.059	(30)Pharmaceutical products.	-0.00053374* (0.00029796)	-0.00040396 (0.0012943)	1368	0.863	0.000	-0.093
(7)Edible vegetables and certain roots and tubers.	-0.00043406 (0.00059926)	-0.0074432*** (0.0025972)	1314	0.606	0.007	2.504	(31)Fertilizers.	-0.00010134 (0.00050561)	-0.00073933 (0.0021963)	1368	0.490	0.001	0.268
(8)Edible fruit and nuts; peel of citrus fruit or melons.	-0.00053383 (0.0005434)	0.0060516** (0.0023706)	1287	0.773	-0.007	-2.597	(32)Tanning/dyeing extract; tannins & derivs; pigm etc	-0.00026513 (0.00025872)	0.0042531*** (0.0011238)	1368	0.875	-0.005	-3.715
(9)Coffee, tea, mat * and spices.	-0.00010012 (0.00050532)	-0.0080848*** (0.0021951)	1368	0.688	0.008	3.361	(33)Essential oils & resinoids; perf, cosmetic/toilet prep	-0.00067084*** (0.00022733)	-0.0078226*** (0.00098751)	1368	0.923	0.007	6.692
(10)Cereals.	-0.0013942* (0.00081063)	-0.018151** (0.008237)	765	0.572	0.017	1.984	(34)Soap, organic surface-active agents, washing prep, etc	-0.00074552*** (0.0002625)	0.0031151*** (0.0011403)	1368	0.866	-0.004	-3.128
(11)Prod mill indust; malt; starches; inulin; wheat gluten	-0.00011925 (0.00047037)	0.00006821 (0.0020432)	1368	0.655	0.000	-0.085	(35)Albuminoid sub; modified starches; glues;	-0.00079492*** (0.00025788)	0.0037694*** (0.0011202)	1368	0.880	-0.005	-3.765
(12)oil seed, oleagi fruits; miscell grain, seed, fruit etc	-0.0007083** (0.00027468)	-0.0012806 (0.0011932)	1368	0.889	0.001	0.443	(36)Explosives; pyrotechnic prod; matches; pyrop alloy; etc	-0.00088861 (0.00072097)	-0.0091914*** (0.0031619)	1278	0.568	0.008	2.429
(13)Lac; gums, resins & other vegetable saps & extracts.	-0.0014011*** (0.00050343)	0.01265*** (0.0021868)	1368	0.656	-0.014	-5.937	(37)Photographic or cinematographic goods.	-0.0013179*** (0.00025332)	-0.014696*** (0.0011004)	1368	0.943	0.013	11.233
(14)Vegetable plaiting materials; vegetable products nes	-0.0013363* (0.00077672)	-0.011408*** (0.0036596)	1233	0.407	0.010	2.560	(38)Miscellaneous chemical products.	-0.000087163 (0.00027844)	0.0011588 (0.0012095)	1368	0.838	-0.001	-0.952
(15)Animal/veg fats & oils & their cleavage products; etc	-0.00053211 (0.00033233)	0.0028804** (0.0014436)	1368	0.835	-0.003	-2.184	(39)Plastics and articles thereof.	-0.00080439*** (0.0001808)	-0.0012949* (0.00078537)	1368	0.923	0.000	0.577
(16)Prep of meat, fish or crustaceans, molluscs etc	-0.003093*** (0.00044758)	0.0060216*** (0.0019442)	1368	0.725	-0.009	-4.332	(40)Rubber and articles thereof.	-0.00029957 (0.00018553)	-0.0026755*** (0.00080593)	1368	0.893	0.002	2.724
(17)Sugars and sugar confectionery.	-0.0018921*** (0.00047373)	0.0029071 (0.0020578)	1368	0.612	-0.005	-2.155	(41)Raw hides and skins (other than furskins) and leather.	-0.00033848 (0.00043146)	0.0085659*** (0.0019265)	1359	0.730	-0.009	-4.283
(18)Cocoa and cocoa preparations.	-0.00049693 (0.0006839)	0.0029127 (0.0030008)	1332	0.571	-0.003	-1.054	(42)Articles of leather; saddlery/harness; travel goods	-0.0013463*** (0.00043815)	-0.0045725** (0.0019033)	1368	0.747	0.003	1.566
(19)Prep of cereal, flour, starch/milk; pastrycooks' prod	-0.0016192*** (0.00036352)	-0.0087262*** (0.0015791)	1368	0.807	0.007	4.158	(43)Furskins and artificial fur; manufactures thereof.	-0.0011524* (0.00062235)	-0.0010322 (0.0031226)	1143	0.639	0.000	-0.036
(20)Prep of vegetable, fruit, nuts or other parts of plants	-0.0018144*** (0.00052533)	0.0068742*** (0.002282)	1368	0.617	-0.009	-3.518	(44)Wood and articles of wood; wood charcoal.	-0.00059708 (0.00039753)	-0.0058316*** (0.0017269)	1368	0.684	0.005	2.801
(21)Miscellaneous edible preparations.	-0.0001129*** (0.00025668)	-0.0070829*** (0.0011155)	1368	0.884	0.006	4.947	(45)Cork and articles of cork.	-0.0010233 (0.00069235)	0.0057157* (0.0030206)	1314	0.546	-0.007	-2.067
(22)Beverages, spirits and vinegar.	-0.00073988** (0.00035363)	-0.0018544 (0.0015361)	1368	0.829	0.001	0.670	(46)Manufactures of straw, esparto/other plaiting mat; etc	-0.0002369 (0.00070705)	-0.0042934 (0.0034159)	1242	0.479	0.004	1.104
(23)Residues & waste from the food indust; prep ani fodder	-0.00086675** (0.00039011)	-0.0069112*** (0.0016946)	1368	0.678	0.006	3.296	(47)Pulp of wood/of other fibrous cellulosic mat; waste etc	0.00087714 (0.00068381)	0.0063894** (0.0029886)	1332	0.447	-0.006	-1.706
(24)Tobacco and manufactured tobacco substitutes.	0.0022015*** (0.00082926)	-0.029514*** (0.0033604)	1152	0.581	0.032	8.631	(48)Paper & paperboard; art of paper pulp, paper/paperboard	-0.00072355*** (0.00019193)	-0.0037712*** (0.00083371)	1368	0.869	0.003	3.378

Note: For expository purpose, coefficients for f(dist)\*L\_im and ER statistics are presented after original estimated coefficients are multiplied by 1,000,000,000,000,000. Figures in parenthesis are heteroskedastic consistent standard errors. \*, \*\*, \*\*\* denote statistical significance at ten, five, and one percent level, respectively. ER stat is the difference between two coefficients and ER test represents statistics given in equation (35) where critical value for ten percent significance level is 1.282.

**Table 4 (continued). Export Ratio Regression**

Industry	f(dist)*L_im	f(dist)*L_reg	NOB	Adj. R <sup>2</sup>	ER Stat	ER test	Industry	f(dist)*L_im	f(dist)*L_reg	NOB	Adj. R <sup>2</sup>	ER Stat	ER test
(49)Printed books, newspapers, pictures & other product etc	-0.0017477***	-0.01226***	1368	0.845	0.011	7.073	(73)Articles of iron or steel.	0.000091482	-0.00073713	1368	0.881	0.001	0.881
(50)Silk.	(0.00031614)	(0.0013733)					(74)Copper and articles thereof.	(0.00020005)	(0.00086898)				
(51)Wool, fine/coarse animal hair, horsehair yarn & fabric	-0.00057918	-0.0051926**	1332	0.716	0.005	1.851	(75)Nickel and articles thereof.	-0.00098693***	-0.00026648	1368	0.832	-0.001	-0.602
(52)Cotton.	(0.00052805)	(0.0023039)					(76)Aluminium and articles thereof.	(0.00025441)	(0.0011051)				
(53)other vegetable textile fibres; paper yarn & woven fab	-0.00042499	0.0052675***	1359	0.861	-0.006	-3.149	(77)Lead and articles thereof.	-0.0012352***	-0.0019334	1368	0.686	0.001	0.320
(54)Man-made filaments.	(0.00037522)	(0.0016754)					(78)Zinc and articles thereof.	(0.0004642)	(0.0020164)				
(55)Man-made staple fibres.	-0.00037479	0.0019147	1368	0.940	-0.002	-1.807	(79)Tin and articles thereof.	-0.00079563***	0.00057075	1368	0.849	-0.001	-1.076
(56)Wadding, felt & nonwoven; yarns; twine, cordage, etc	(0.00026953)	(0.0011708)					(80)other base metals; cermet; articles thereof.	(0.00027021)	(0.0011738)				
(57)Carpets and other textile floor coverings.	-0.00018732	0.0047946***	1368	0.869	-0.005	-2.758	(81)Tool, implement, cutlery, spoon & fork, of base met etc	-0.0012947***	0.000066174	1368	0.652	-0.001	-0.587
(58)Special woven fab; tufted tex fab; lace; tapestries etc	(0.0003842)	(0.0016689)					(82)Miscellaneous articles of base metal.	(0.00049353)	(0.0021438)				
(59)Impregnated, coated, cover/laminated textile fabric etc	-0.00021328	0.0032002**	1368	0.909	-0.003	-2.515	(83)Nuclear reactors, boilers, mchy & mech appliance; parts	-0.00042379	-0.010244***	1368	0.557	0.010	3.905
(60)Knitted or crocheted fabrics.	(0.00028868)	(0.001254)					(84)Electrical mchy equip parts thereof; sound recorder etc	(0.00053494)	(0.0023237)				
(61)Art of apparel & clothing access, knitted or crocheted.	-0.00044069	0.00153	1368	0.896	-0.002	-1.386	(85)Railw/tramw locom, rolling-stock & parts thereof; etc	0.00045949	0.0014089	1359	0.719	-0.001	-0.400
(62)Art of apparel & clothing access, not knitted/crocheted	(0.00030237)	(0.0013135)					(86)Vehicles o/t railw/tramw roll-stock, pts & accessories	(0.00049672)	(0.0021947)				
(63)other made up textile articles; sets; worn clothing etc	-0.00016805	0.0012314	1368	0.892	-0.001	-1.138	(87)Aircraft, spacecraft, and parts thereof.	-0.00049633	-0.0061917***	1368	0.750	0.006	2.869
(64)Footwear, gaiters and the like; parts of such articles.	(0.00026148)	(0.0011358)					(88)Ships, boats and floating structures.	(0.0004222)	(0.001834)				
(65)Headgear and parts thereof.	-0.00049194	-0.0028792	1368	0.651	0.002	0.931	(89)optical, photo, cine, meas, checking, precision, etc	-0.0006445***	-0.0032904***	1368	0.894	0.003	2.617
(66)Umbrellas, walking-sticks, seat-sticks, whips, etc	(0.0005452)	(0.0023683)					(90)Musical instruments; parts and access of such articles	(0.00021506)	(0.00093418)				
(67)Prepr feathers & down; arti flower; articles human hair	-0.00037258	0.00086551	1368	0.872	-0.001	-0.837	(91)Arms and ammunition; parts and accessories thereof.	-0.00040017	0.0035644***	1368	0.858	-0.004	-3.129
(68)Art of stone, plaster, cement, asbestos, mica/sim mat	(0.00031474)	(0.0013672)					(92)Furniture; bedding, mattress, matt support, cushion	(0.00026952)	(0.0011708)				
(69)Ceramic products.	-0.0004284	0.0055781***	1368	0.896	-0.006	-4.823	(93)Toys, games & sports requisites; parts & access	-0.00034104**	-0.0043***	1368	0.929	0.004	5.242
(70)Glass and glassware.	(0.00026491)	(0.0011507)					(94)Miscellaneous manufactured articles.	(0.00016064)	(0.00069781)				
(71)Natural/cultured pearls, prec stones & metals, coin etc	0.000019281	-0.0004235	1368	0.925	0.000	0.334	(95)Works of art, collectors' pieces and antiques.	-0.00070894***	-0.010308***	1368	0.931	0.010	11.289
(72)Iron and steel.	(0.00028192)	(0.0012246)						(0.00018086)	(0.00078565)				

Note: For expository purpose, coefficients for f(dist)\*L\_im and ER statistics are presented after original estimated coefficients are multiplied by 1,000,000,000,000. Figures in parenthesis are heteroskedastic consistent standard errors. \*, \*\*, \*\*\* denote statistical significance at ten, five, and one percent level, respectively. ER stat is the difference between two coefficients and ER test represents statistics given in equation (35) where critical value for ten percent significance level is 1.282.