

Production Patterns of Multinational Enterprises: The Knowledge-Capital Model Revisited

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Abstract

To prepare an answer to the question of how a developing country can attract FDI, this paper explored the factors and policies that may help bring FDI into a developing country by utilizing an extended version of the knowledge-capital model. With a special focus on the effects of FTA/EPA between a market country and a developing country, simulations with the model revealed the following: (1) although FTA/EPA generally tends to increase FDI to a developing country, the possibility to improve welfare through increased demand for skilled and unskilled labor becomes lower as the size of the country grows; (2) a developing country may suffer severe welfare losses through FTA/EPA if the availability of skilled labor is extremely limited; (3) because the additional implementation of cost-saving policies to reduce the firm-type/trade-link specific fixed cost tends to depreciate the price of skilled labor by saving its input, a developing country can enhance welfare gains from FTA, and it is even possible to recover the welfare effects from negative to positive, by making the arrangement to be EPA.

Keywords: foreign direct investment; multinational enterprise; export platform; complex integration; free trade agreement; economic partnership agreement

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1. Introduction

How can a developing country attract foreign direct investment (FDI)? This question has long been the subject of debate among policy-makers in developing economies who regard FDI as an important catalyst for economic growth. As the global economy has become increasingly interdependent, multinational enterprises (MNEs) form multilateral production networks, where production processes are subdivided into several stages and some developing countries have successfully participated in certain parts of these networks. The purpose of this paper is to explore the factors and policies that may help to bring FDI into a developing country.

While research on the activities of MNEs has been conducted widely since the late 1980s, a limited number of studies have comprehensively handled every operational pattern of MNEs in one model. Especially, the export-platform is not much discussed in the theoretical studies, even though its importance has been revealed by the empirical side. Because a low-cost developing country may play an important role as an export-platform, an analytical model for this study must include this type in addition to the typical horizontal- and vertical-type MNEs.

One of the most sophisticated studies that consider typical types of MNEs including export-platforms in the same analytical framework was presented by Ekholm, Forslid, and Markusen (2007). Using a numerical simulation model, in which two market countries and one exogenously given developing country are considered, they explored the conditions under four types of firm strategy while gradually changing two types of costs, one for trading components and the other for assembling components. However, their model has only one factor of production, and the non-market country is just assumed to set exogenous factor pricing in a partial equilibrium framework. Another work that nests every type of MNE in one model is presented by Ito (2013). Extending the two-region, four-country (two countries in each region) model developed by Navaretti and Venebles (2004) to include export-platform, he showed that a reduction in trade costs, either inter-regional or intra-regional, induces firms to choose export-platform rather than other types. To enable the theoretical model to yield testable hypotheses for empirical testing, he incorporated only trade costs abstracting production costs away.

A good candidate for the base of an analytical model that includes both trade and production costs in a general equilibrium setting is the knowledge-capital model developed by Markusen (1997) and further extended by Zhang and Markusen (1999). Although export-platform is not taken into account, the computational model is able to verify effects

of changes in firm-type on factor prices in the countries where the MNEs are active. As employment and labor wages in the host country are important factors MNEs use to decide on a production strategy, this feature based on the general equilibrium nature of the knowledge-capital model is essential for our study. Thus, we utilized an extended version of the model for this study.

The remainder of this paper is organized as follows. Section 2 illustrates the structure and main assumptions of the analytical model. Section 3 explains how the model is parameterized as a numerical model. In Section 4, we perform simulations and report on the results that reveal conditions for which each type of firms would be active in a given economic environment with a special focus on the effects of trade liberalization and optional cost-saving policies. Finally, Section 5 presents the conclusions of this paper.

2. The Extended Knowledge-Capital Model

The model used in this study is a simple extension of the knowledge-capital model that was used as the workhorse in Markusen (2002), including national enterprises (NEs), horizontal MNEs (HMNEs), vertical MNEs (VMNEs), horizontal export-platforms (HEPs), vertical export-platforms (VEPs), and complexly integrated MNEs (CMNEs). The complex integration strategy, which was introduced by Yeaple (2003) and studied by Grossman, Helpman, and Szeidl (2006), is a combination of the horizontal integration for a foreign market so as to reduce trade costs and the vertical export-platform for the home market to reduce production costs. The model is also extended to include two developing countries, in which the final assembly process of multinational production may take place while the finished products are not sold locally but exported, which is in addition to the original assumption of two developed countries in which MNEs are established and there are markets for the commodity produced by those MNEs.¹

An important point here is that we do not limit the volumes of those developing (non-market) countries, which always stay small in terms of factor endowments. Because the knowledge-capital model is a general equilibrium model, branching out and setting up subsidiaries by MNEs in a non-market country affects the local factor prices. If the host country is relatively small, factor prices appreciate more than they would in a relatively

¹ While we mainly regard developed and developing countries respectively correspond to market and non-market countries in this paper, we do not exclude the possibility that a developing country is considered as a market. For example, China could be considered as both final market and non-market production-platform depending on one's research interest.

large country. This may substantially frustrate the incentive of the MNE to stay in the country and trigger it to find another place where cheaper production factors are available.

With this model, we investigate which production pattern is adopted by firms established in two countries out of four to sell Product in both home and foreign (target) markets under certain economic circumstances.

2.1 Environment

There are four countries A , B , C , and D , indexed as r . A and B are assumed to be countries in which MNEs are established and there are markets for the commodity produced by those MNEs. We index these countries i or j as a subset of r . C and D are countries in which the final assembly process of multinational productions may take place while the finished products are not sold locally but exported. The index of these countries is w , another subset of r .

There are three types of goods, X , Y , and Z . The intermediate good (a component) X is used to produce the final product Y by the MNE. This sector exhibits increasing returns to scale (IRTS) so that the market is assumed to be imperfectly competitive. X is produced only in the home of the MNE, country i , and is sent to country r where the final assembly process takes place. The finished product Y is sold on the target market j . Note that all MNEs in each production type, national N , horizontal H , vertical V , horizontal export-platform EH , vertical export-platform EV , and complex integration CI , indexed as q , share identical technologies and productivities. On the other hand, Z is a regular product based on a constant-returns-to-scale (CRTS) technology so that the market is perfectly competitive. Z is produced in every country r , and is sold on the international market as a perfect substitute.

Production factors are of two types, K and L , which are immobile among national boundaries. Although we mainly regard K as skilled labor (human capital) in this study, it can be further extended to include the status of institutions (rules and regulations) and/or the business environment. L is unskilled labor. The national endowments of these factors are set exogenously in the model. In the experimental simulations, we change the relative factor endowments for either the market- or non-market-country groups given absolute levels of total endowments for the groups.

In the IRTS sector, two types of fixed cost, F and G , are required to start operating a firm. Whereas G , measured in units of unskilled labor L , is needed to set up an assembly plant in country r (country specific), F , measured in units of skilled labor K , is required

to establish a firm and its local subsidiary in a foreign country (firm-type/trade-link specific).

There are also trade costs for international transport of X and Y , which are specific to each trade link. We assume that unskilled labor L in the exporting country is used for this. On the other hand, it is assumed for simplicity that shipping Z does not generate any cost.

2.2 Type-Y Good Producer

There are two groups of firms producing Y , one is established and headquartered in country A and the other in B (country i). The markets for Y are limited to countries A and B (country j). Good Y is produced in two stages with IRTS technology by imperfectly competitive firms. In the first stage, each firm produces its components (intermediate good) X only in its home country using skilled labor K . In the second stage, a firm may send its components to a foreign subsidiary and finalize the production of Y there, assembling components X using locally hired unskilled labor L . This assembly process can take place in any country r . If the assembly is taking place in a non-market country w , all of the final products are exported to one or both of the market countries j . If it is performed in the home country i , the products are sold domestically or exported to a foreign market j . If it takes place in a foreign market country i , the products are sold locally or exported back to the home market j .

There are both firm-level and plant-level scale economies. By free entry and exit of firms in each operational pattern, a production regime, which refers to a combination of firm types in an equilibrium, is determined. Following Ekholm, Forslid, and Markusen (2007), regimes will be denoted by suffices with letters, the first letter referring to a firm's home country i , the second one referring to the destination market j , and the third one referring to the location of its assembly plant (i or w). When it is possible to omit some of those letters without creating any confusion, the length of the suffix becomes shorter. The regimes are categorized into six types, N , H , V , EH , EV , and CI , which express the production pattern of a firm. The six production types are defined as follows.

Type-N: NEs that maintain a single plant with headquarters in country i . This type of firms produces both components X and final products Y in country i . A fraction of the products Y may or may not be exported to country j .

Type-H: HMNEs that maintain plants in both market countries, with headquarters in country i . This type of firms produces components X in country i , some of which are shipped to an assembly plant in country j . The final products Y are produced in both market countries. No fraction of product Y may be exported.

Type-V: VMNEs that maintain a single plant in the foreign market country j , with headquarters in country i . This type of firm produces components X in country i , which are then shipped to the assembly plant in country j . A fraction of the products Y may or may not be exported back to the home market in country i .

Type-EH: HEPs that maintain a plant in one of the non-market countries w , in addition to a plant and headquarters in home country i . This type of firms produces components X in country i , some of which are shipped to an assembly plant in country w . All of the final products Y produced in country w are exported to the foreign market in country j , while the ones produced in the home country are sold domestically.

Type-EV: VEPs that maintain a single plant in one of the non-market countries w , with headquarters in country i . This type of firm produces components X in country i , which are then shipped to the assembly plant in country w . All of the final products Y are exported to both of the market countries j .

Type-CI: CMNEs that maintain plants both in one of the non-market countries w and in the foreign market country j , with headquarters in country i . This type of firm produces components X in country i , which are then shipped to the assembly plant in countries w and j . All of the final products Y produced in country w are exported back to the home market in country i , while the ones produced in the foreign market country are sold locally.

Figure 1 shows schematic images of these six types of production patterns. In each pattern, the headquarters of the firm is located in the country placed on the left-hand side of the image.

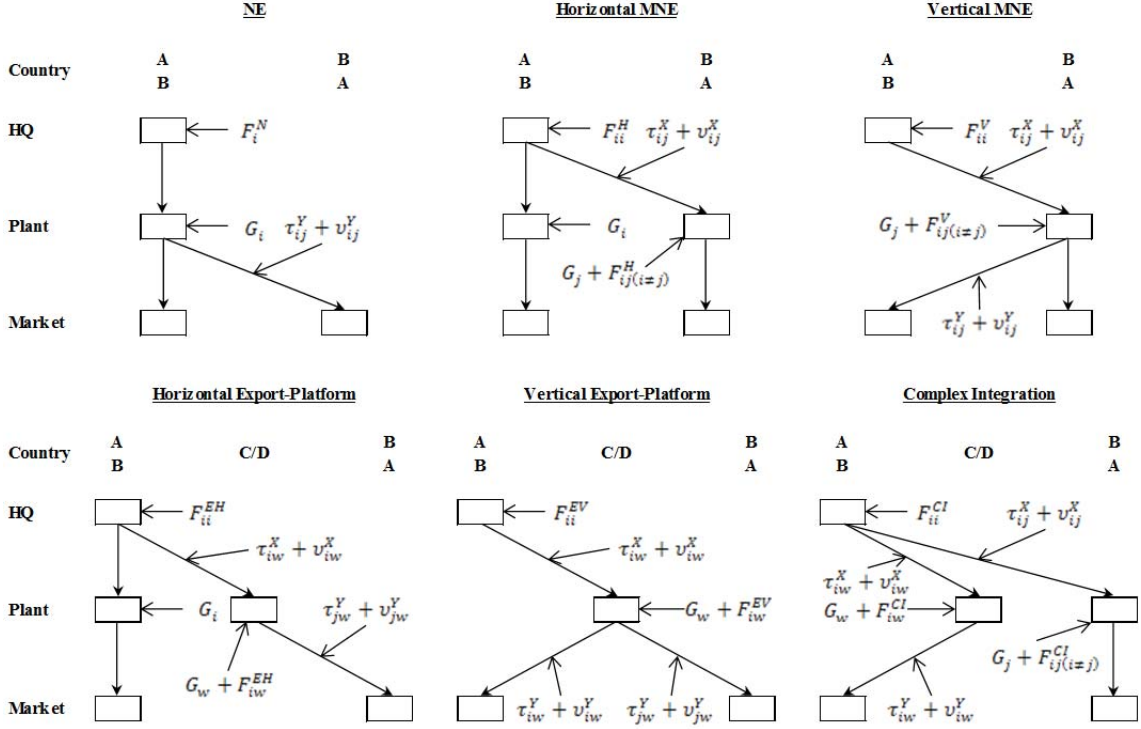


Figure 1: Six Types of Production Patterns

2.2.1 Type-N Firm Established in Country i

A type-N firm produces three types of products: components X_i^N ; final products for the domestic market $Y_{ij(i=j)}^N$; and final products for the foreign market $Y_{ij(i \neq j)}^N$. The skilled labor requirements to produce one unit of a component in home country i can be expressed as:

$$K_i^N = \theta^K X_i^N + F_i^N, \quad (1)$$

where

- K_i^N is the skilled labor input hired in country i ;
- X_i^N is the quantity of components produced;
- F_i^N is the fixed cost to establish a NE in country i ; and
- θ^K is the unit input requirement for skilled labor.

Similarly, the requirements for both unskilled labor and components to produce one unit of final product in home country i can be expressed as:

$$L_i^N = \theta^L \sum_j Y_{ij}^N + (\tau_{ij}^Y Y_{ij}^N)_{(i \neq j)} + G_i; \quad (2)$$

and

$$X_i^N = \theta^X \sum_j Y_{ij}^N, \quad (3)$$

where

L_i^N is the unskilled labor hired in country i ;
 Y_{ij}^N is the quantity of final products;
 G_i is the fixed cost to set up an assembly plant in country i ;
 θ^L is the unit input requirement for unskilled labor;
 θ^X is the unit input requirement for components; and
 $\tau_{ij(i \neq j)}^Y$ is the rate of transportation margin on final products.

Then, the cost function for a type-N firm is given by:

$$\begin{aligned} & p_i^K K_i^N + p_i^L L_i^N + \text{Tariff} \\ & = \{(p_i^K \theta^K \theta^X + p_i^L \theta^L) Y_{ij}^N\}_{(i=j)} \\ & \quad + [(1 + v_{ij}^Y) \{p_i^K \theta^K \theta^X + p_i^L (\theta^L + \tau_{ij}^Y) Y_{ij}^N\}]_{(i \neq j)} \\ & \quad + (p_i^K F_i^N + p_i^L G_i), \end{aligned} \quad (4)$$

where

p_i^K is the price of skilled labor;
 p_i^L is the price of unskilled labor; and
 $v_{ij(i \neq j)}^Y$ is the rate of import tariff on final products.

The first term on the right-hand side of Equation (4) corresponds to the variable cost with respect to $Y_{ij(i=j)}^N$. Similarly, the second term corresponds to the one with respect to $Y_{ij(i \neq j)}^N$. The last term corresponds to the total fixed cost.

2.2.2 Type-H Firm Established in Country i

A type-H firm produces four types of products: components $X_{ij(i=j)}^H$; components $X_{ij(i \neq j)}^H$; final products for the domestic market $Y_{ij(i=j)}^H$; and final products for the foreign market $Y_{ij(i \neq j)}^H$. The skilled labor requirements to produce one unit of components in the home country i can be expressed as:

$$K_{ii}^H = \theta^K \sum_j X_{ij}^H + F_{ii}^H, \quad (5)$$

where

K_{ii}^H is the skilled labor input hired in country i ;
 X_{ij}^H is the quantity of components produced; and
 F_{ii}^H is the fixed cost to establish a HMNE in country i .

To ship components $X_{ij(i \neq j)}^H$ from country i to destination j , the following amount of unskilled labor must be hired in country i :

$$L_{ii}^{HT} = (\tau_{ij}^X X_{ij}^H)_{(i \neq j)}, \quad (6)$$

where

L_{ii}^{HT} is the unskilled labor hired for international shipping; and
 $\tau_{ij(i \neq j)}^X$ is the rate of transportation margin on components.

Next, the requirements for both unskilled labor and components to produce one unit of final products in home country i can be expressed as:

$$L_{ii}^{HP} = \theta^L Y_{ii}^H + G_i; \quad (7)$$

and

$$X_{ii}^H = \theta^X Y_{ii}^H, \quad (8)$$

where

L_{ii}^{HP} is the unskilled labor input hired in country i ; and
 Y_{ii}^H is the quantity of final products assembled in country i .

Similarly, the requirements for both unskilled labor and components to produce one unit of final products in the foreign market country j are:

$$L_{ij(i \neq j)}^{HP} = \theta^L Y_{ij(i \neq j)}^H + G_j; \quad (9)$$

and

$$X_{ij(i \neq j)}^H = \theta^X Y_{ij(i \neq j)}^H, \quad (10)$$

where

L_{ij}^{HP} is the unskilled labor input hired in country j ;
 Y_{ij}^H is the quantity of final products assembled in country j ; and
 G_j is the fixed cost to set up an assembly plant in country j .

At the local subsidiary in the foreign market country j , skilled labor is needed to train unskilled labor how to handle the intermediate:

$$K_{ij(i \neq j)}^H = F_{ij(i \neq j)}^H, \quad (11)$$

where

$K_{ij(i \neq j)}^H$ is the skilled labor input hired in country j ; and
 $F_{ij(i \neq j)}^H$ is the fixed cost to set up an assembly plant in country i .

Then, the cost function for a type-H firm is given by:

$$\begin{aligned} & p_i^K K_{ii}^H + p_i^L (L_{ii}^{HP} + L_{ii}^{HT}) + (p_j^K K_{ij}^H)_{(i \neq j)} + (p_j^L L_{ij}^{HP})_{(i \neq j)} + \text{Tariff} \\ & = \{(p_i^K \theta^K \theta^X + p_i^L \theta^L) Y_{ij}^H\}_{(i=j)} \end{aligned}$$

$$\begin{aligned}
& + [\{ (1 + v_{ij}^X) (p_i^K \theta^K + p_i^L \tau_{ij}^X) \theta^X + p_j^L \theta^L \} Y_{ij(i \neq j)}^H] \\
& + \sum_j (p_j^K F_{ij}^H + p_j^L G_j), \tag{12}
\end{aligned}$$

where

$v_{ij(i \neq j)}^X$ is the rate of import tariff on components.

As in the case of the type-N firm, the first term on the right-hand side of Equation (12) corresponds to the variable cost with respect to $Y_{ij(i=j)}^H$. The second term corresponds to the one with respect to $Y_{ij(i \neq j)}^H$. The third term is the total fixed cost.

2.2.3 Type-V Firm Established in Country i

A type-V firm produces three types of products: components $X_{ij(i \neq j)}^V$; final products for the home market $Y_{ii(i \neq j)}^V$; and final products for the foreign market $Y_{jj(i \neq j)}^V$. The skilled labor requirements to produce one unit of components in the home country i can be expressed as:

$$K_{ii}^V = \theta^K X_{ij(i \neq j)}^V + F_{ii}^V, \tag{13}$$

where

K_{ii}^V is the skilled labor input hired in country i ;
 $X_{ij(i \neq j)}^V$ is the quantity of components produced; and
 F_{ii}^V is the fixed cost to establish a VMNE in country i .

To ship components $X_{ij(i \neq j)}^V$ from country i to destination j , the following amount of unskilled labor must be hired in country i :

$$L_{ii}^V = (\tau_{ij}^X X_{ij}^V)_{(i \neq j)}, \tag{14}$$

where

L_{ii}^V is the unskilled labor hired for international shipping.

Next, the requirements for both unskilled labor and components to produce one unit of final products in the foreign market country j can be expressed as:

$$L_{ij(i \neq j)}^V = \left(\theta^L \sum_i Y_{ii'j}^V + \tau_{ij}^Y Y_{ii'j}^V + G_j \right)_{(i \neq j)}; \tag{15}$$

and

$$X_{ij(i \neq j)}^V = \theta^X \sum_i Y_{ii'j(i \neq j)}^V, \tag{16}$$

where

$L_{ij(i \neq j)}^V$ is the unskilled labor input hired in country j ; and

$Y_{ii'(i \neq j)}^V$ is the quantity of final products assembled in country j .

Similarly to the case of the type-H firm, skilled labor is needed at the local subsidiary to train unskilled labor how to handle the intermediate:

$$K_{ij(i \neq j)}^V = F_{ij(i \neq j)}^V, \quad (17)$$

where

$K_{ij(i \neq j)}^V$ is the skilled labor input hired in country j ; and

$F_{ij(i \neq j)}^V$ is the fixed cost to set up an assembly plant in country i .

Then, the cost function for a type-V firm is given by:

$$\begin{aligned} & p_i^K K_{ii}^V + p_i^L L_{ii}^V + p_j^K K_{ij(i \neq j)}^V + p_j^L L_{ij(i \neq j)}^V + \text{Tariff} \\ &= [(1 + v_{ij}^Y) \{ (1 + v_{ij}^X) (p_i^K \theta^K + p_i^L \tau_{ij}^X) \theta^X + p_j^L (\theta^L + \tau_{ij}^Y) \} Y_{ii'(i \neq j)}^V] \\ & \quad + [\{ (1 + v_{ij}^X) (p_i^K \theta^K + p_i^L \tau_{ij}^X) \theta^X + p_j^L \theta^L \} Y_{ijj}^V]_{(i \neq j)} \\ & \quad + \sum_j p_j^K F_{ij}^V + \sum_j (p_j^L G_j)_{(i \neq j)}. \end{aligned} \quad (18)$$

Note that $Y_{ijj}^V(i=j) = 0$. The first term on the right-hand side of Equation (18) corresponds to the variable cost with respect to $Y_{ii'(i \neq j)}^V$. The second term corresponds to the one with respect to $Y_{ijj}^V(i \neq j)$. The third term is the total fixed cost.

2.2.4 Type-EH Firm Established in Country i

A type-EH firm produces four types of products: components $X_{ij(i=j)}^{EH}$; components X_{iw}^{EH} ; final products for the domestic market Y_i^{EHD} ; and final products for the foreign market $Y_{ijw(i \neq j)}^{EHF}$. The skilled labor requirements to produce one unit of a component in home country i can be expressed as:

$$K_{ii}^{EH} = \theta^K (X_{ii}^{EH} + X_{iw}^{EH}) + F_{ii}^{EH}, \quad (19)$$

where

K_{ii}^{EH} is the skilled labor input hired in country i ;

X_{ii}^{EH} is the quantity of components produced for the domestic plant;

X_{iw}^{EH} is the quantity of components produced for the plant in country w ; and

F_{ii}^{EH} is the fixed cost to establish a HEP in country i .

To ship components X_{iw}^{EH} from country i to a non-market country w , the following amount of unskilled labor must be hired in country i :

$$L_i^{EHT} = \tau_{iw}^X X_{iw}^{EH}, \quad (20)$$

where

L_i^{EHT} is the unskilled labor hired for international shipping; and
 τ_{iw}^X is the rate of transportation margin on components.

The requirements for both unskilled labor and components to produce one unit of final products in home country i can be expressed as:

$$L_{ii}^{EHP} = \theta^L Y_i^{EHD} + G_i; \quad (21)$$

and

$$X_{ii}^{EH} = \theta^X Y_i^{EHD}, \quad (22)$$

where

L_{ii}^{EHP} is the unskilled labor input hired in country i ; and
 Y_i^{EHD} is the quantity of final products assembled in country i .

Similarly, the requirements for both unskilled labor and components to produce one unit of final products in non-market country w are:

$$L_{iw}^{EHP} = \{(\theta^L + \tau_{jw}^Y) Y_{ijw}^{EHF}\}_{(i \neq j)} + G_w; \quad (23)$$

and

$$X_{iw}^{EH} = \theta^X Y_{ijw(i \neq j)}^{EHF}, \quad (24)$$

where

L_{iw}^{EHP} is the unskilled labor input hired in country w ;
 $Y_{ijw(i \neq j)}^{EHF}$ is the quantity of final products assembled in country w for country j ;
 G_w is the fixed cost to set up an assembly plant in country w ; and
 τ_{jw}^Y is the rate of transportation margin on final products.

At the local subsidiary in the foreign market country j , skilled labor is needed to train unskilled labor how to handle the intermediate:

$$K_{iw}^{EH} = F_{iw}^{EH}, \quad (25)$$

where

K_{iw}^{EH} is the skilled labor input hired in country w ; and
 F_{iw}^{EH} is the fixed cost to set up an assembly plant in country w .

Then, the cost function for a type-EH firm is given by:

$$\begin{aligned} & p_i^K K_{ii}^{EH} + p_i^L (L_{ii}^{EHP} + L_{ii}^{EHT}) + p_w^K K_{iw}^{EH} + p_w^L L_{iw}^{EHP} + \text{Tariff} \\ & = (p_i^K \theta^K \theta^X + p_i^L \theta^L) Y_i^{EHD} \\ & \quad + [(1 + v_{jw}^Y) \{ (1 + v_{iw}^X) (p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X + p_w^L (\theta^L + \tau_{jw}^Y) \} Y_{ijw}^{EHF}]_{(i \neq j)} \\ & \quad + (p_i^K F_{ii}^{EH} + p_i^L G_i + p_w^K F_{iw}^{EH} + p_w^L G_w), \end{aligned} \quad (26)$$

where

u_{jw}^Y is the rate of import tariff on final products; and

u_{iw}^X is the rate of import tariff on components.

Note that $Y_{ijw(i=j)}^{EF} = 0$ and $F_{ij(i \neq j)}^E = 0$. The correspondence between the expressions on the right-hand side of Equation (26) and the variable or fixed cost is the same as before.

2.2.5 Type-EV Firm Established in Country i

A type-EV firm produces two types of products: components X_{iw}^{EV} ; and final products for market countries Y_{ijw}^{EV} . The skilled labor requirements to produce one unit of a component in home country i can be expressed as:

$$K_{ii}^{EV} = \theta^K X_{iw}^{EV} + F_{ii}^V, \quad (27)$$

where

K_{ii}^{EV} is the skilled labor input hired in country i ;

X_{iw}^{EV} is the quantity of components produced for the plant in country w ; and

F_{ii}^V is the fixed cost to establish a VEP in country i .

To ship components X_{iw}^{EV} from country i to a non-market country w , the following amount of unskilled labor must be hired in country i :

$$L_{ii}^{EV} = \tau_{iw}^X X_{iw}^{EV}, \quad (28)$$

where

L_{ii}^{EV} is the unskilled labor hired for international shipping.

The requirements for both unskilled labor and components to produce one unit of final product in country w can be expressed as:

$$L_{iw}^{EV} = \theta^L \sum_j Y_{ijw}^{EV} + \sum_j \tau_{jw}^Y Y_{ijw}^{EV} + G_w; \quad (29)$$

and

$$X_{iw}^{EV} = \theta^X \sum_j Y_{ijw}^{EV}, \quad (30)$$

where

L_{iw}^{EV} is the unskilled labor input hired in country w ; and

Y_{ijw}^{EV} is the quantity of final products assembled in country w for country j .

As in the previous cases, skilled labor is needed at the local subsidiary to train unskilled labor how to handle the intermediate:

$$K_{iw}^{EV} = F_{iw}^{EV}, \quad (31)$$

where

K_{iw}^{EV} is the skilled labor input hired in country w ; and

F_{iw}^{EV} is the fixed cost to set up an assembly plant in country w .

Then, the cost function for a type-E firm is given by:

$$\begin{aligned}
& p_i^K K_{ii}^{EV} + p_i^L L_{ii}^{EV} + p_w^K K_{iw}^{EV} + p_w^L L_{iw}^{EV} + \text{Tariff} \\
& = (1 + v_{jw}^Y) \{ (1 + v_{iw}^X) (p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X + p_w^L (\theta^L + \tau_{jw}^Y) \} Y_{ijw}^{EV} \\
& \quad + (p_i^K F_{ii}^{EV} + p_w^K F_{iw}^{EV} + p_w^L G_w). \tag{32}
\end{aligned}$$

Note that $F_{ij(i \neq j)}^{EV} = 0$. The first term on the right-hand side of Equation (32) corresponds to the variable cost with respect to Y_{ijw}^{EV} , and the second term is the total fixed cost.

2.2.6 Type-CI Firm Established in Country i

A type-CI firm produces four types of products: components $X_{ij(i \neq j)}^{CI}$; components X_{iw}^{CI} ; final products for the domestic market Y_{iiw}^{CID} ; and final products for the foreign market $Y_{ij(i \neq j)}^{CIF}$. The skilled labor requirements to produce one unit of a component in home country i can be expressed as:

$$K_{ii}^{CI} = \theta^K (X_{ij(i \neq j)}^{CI} + X_{iw}^{CI}) + F_{ii}^{CI}, \tag{33}$$

where

- K_{ii}^{CI} is the skilled labor input hired in country i ;
- $X_{ij(i \neq j)}^{CI}$ is the quantity of components produced for the plant in country j ;
- X_{iw}^{CI} is the quantity of components produced for the plant in country w ; and
- F_{ii}^{CI} is the fixed cost to establish a CMNE in country i .

To ship components $X_{ij(i \neq j)}^{CI}$ and X_{iw}^{CI} from country i to countries j and w , the following amount of unskilled labor must be hired in country i :

$$L_{ii}^{CI} = (\tau_{ij}^X X_{ij}^{CI})_{(i \neq j)} + \tau_{iw}^X X_{iw}^{CI}, \tag{34}$$

where

L_{ii}^{CI} is the unskilled labor hired for international shipping.

The requirements for both unskilled labor and components to produce one unit of final products in the foreign market country j can be expressed as:

$$L_{ij(i \neq j)}^{CI} = \theta^L Y_{ij(i \neq j)}^{CIF} + G_j; \tag{35}$$

and

$$X_{ij(i \neq j)}^{CI} = \theta^X Y_{ij(i \neq j)}^{CIF}, \tag{36}$$

where

- $L_{ij(i \neq j)}^{CI}$ is the unskilled labor input hired in country i ; and
- $Y_{ij(i \neq j)}^{CIF}$ is the quantity of final products assembled in country j for local sales.

Similarly, the requirements for both unskilled labor and components to produce one unit of final products in non-market country w are:

$$L_{iw}^{CI} = (\theta^L + \tau_{iw}^Y)Y_{iw}^{CID} + G_w; \quad (37)$$

and

$$X_{iw}^{CI} = \theta^X Y_{iw}^{CID}, \quad (38)$$

where

L_{iw}^{CI} is the unskilled labor input hired in country w ; and

Y_{iw}^{CID} is the quantity of final products assembled in country w for country i .

At the local subsidiaries in countries j and w , skilled labor is needed to train unskilled labor how to handle the intermediate, respectively:

$$K_{ij(i \neq j)}^{CI} = F_{ij(i \neq j)}^{CI}; \quad (39)$$

and

$$K_{iw}^{CI} = F_{iw}^{CI}, \quad (40)$$

where

$K_{ij(i \neq j)}^{CI}$ is the skilled labor input hired in country j ;

$F_{ij(i \neq j)}^{CI}$ is the fixed cost to set up an assembly plant in country j .

K_{iw}^{CI} is the skilled labor input hired in country w ; and

F_{iw}^{CI} is the fixed cost to set up an assembly plant in country w .

Then, the cost function for a type-CI firm is given by:

$$\begin{aligned} & p_i^K K_{ii}^{CI} + p_i^L L_{ii}^{CI} + p_j^K K_{ij(i \neq j)}^{CI} + p_j^L L_{ij(i \neq j)}^{CI} + p_w^K K_{iw}^{CI} + p_w^L L_{iw}^{CI} + \text{Tariff} \\ & = (1 + v_{iw}^Y) \{ (1 + v_{iw}^X) (p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X + p_w^L (\theta^L + \tau_{iw}^Y) \} Y_{iw}^{CID} \\ & \quad + [\{ (1 + v_{ij}^X) (p_i^K \theta^K + p_i^L \tau_{ij}^X) \theta^X + p_j^L \theta^L \} Y_{ij}^{CIF}]_{(i \neq j)} \\ & \quad + \sum_r p_r^K F_{ir}^V + (p_j^L G_j)_{(i \neq j)} + p_w^L G_w. \end{aligned} \quad (41)$$

Note that $Y_{ij(i=j)}^{CIF} = 0$. The first term on the right-hand side of Equation (41) corresponds to the variable cost with respect to Y_{iw}^{CID} . The second term corresponds to the one with respect to $Y_{ij(i \neq j)}^{CIF}$. The rest is the total fixed cost.

2.2.7 Production Volume of a Firm

In an equilibrium, the production volume of a firm in its respective type of production pattern is determined by a pricing relation that assures marginal revenue does not exceed marginal cost. The pricing relations for every type of production pattern can be expressed as:

$$p_j^Y (1 - \sigma_{ij}^N) \leq (1 + v_{ij(i \neq j)}^Y) \left\{ \begin{array}{l} p_i^K \theta^K \theta^X \\ + p_i^L (\theta^L + \tau_{ij(i \neq j)}^Y) \end{array} \right\} \perp Y_{ij}^N; \quad (42)$$

$$p_j^Y (1 - \sigma_{ij}^H) \leq (1 + v_{ij(i \neq j)}^X) \left(\frac{p_i^K \theta^K}{+p_i^L \tau_{ij(i \neq j)}^X} \right) \theta^X + p_j^L \theta^L \quad \perp Y_{ij}^H; \quad (43)$$

$$p_j^Y (1 - \sigma_{ij'}^V) \leq (1 + v_{ji'(j \neq i')}^Y) \left\{ \begin{array}{l} (1 + v_{ii'}^X) \left(\frac{p_i^K \theta^K}{+p_i^L \tau_{ii'}^X} \right) \theta^X \\ + p_i^L (\theta^L + \tau_{ji'(j \neq i')}^Y) \end{array} \right\} \quad \perp Y_{ij'}^V; \quad (44)$$

$$p_j^Y (1 - \sigma_i^{EHD}) \leq p_i^K \theta^K \theta^X + p_i^L \theta^L \quad \perp Y_i^{EHD}; \quad (45)$$

$$p_j^Y (1 - \sigma_{ijw}^{EHF}) \leq (1 + v_{jw}^Y) \left\{ \begin{array}{l} (1 + v_{iw}^X) \left(\frac{p_i^K \theta^K}{+p_i^L \tau_{iw}^X} \right) \theta^X \\ + p_w^L (\theta^L + \tau_{jw}^Y) \end{array} \right\} \quad \perp Y_{ijw}^{EHF}; \quad (46)$$

$$p_j^Y (1 - \sigma_{ijw}^{EV}) \leq (1 + v_{jw}^Y) \left\{ \begin{array}{l} (1 + v_{iw}^X) \left(\frac{p_i^K \theta^K}{+p_i^L \tau_{iw}^X} \right) \theta^X \\ + p_w^L (\theta^L + \tau_{jw}^Y) \end{array} \right\} \quad \perp Y_{ijw}^{EV}; \quad (47)$$

$$p_j^Y (1 - \sigma_{iw}^{CID}) \leq (1 + v_{iw}^Y) \left\{ \begin{array}{l} (1 + v_{iw}^X) \left(\frac{p_i^K \theta^K}{+p_i^L \tau_{iw}^X} \right) \theta^X \\ + p_w^L (\theta^L + \tau_{iw}^Y) \end{array} \right\} \quad \perp Y_{iw}^{CID}; \quad (48)$$

and

$$p_j^Y (1 - \sigma_{ij}^{CIF}) \leq (1 + v_{ij}^X) (p_i^K \theta^K + p_i^L \tau_{ij}^X) \theta^X + p_j^L \theta^L \quad \perp Y_{ij}^{CIF}, \quad (49)$$

where

p_j^Y is the price of good Y ; and

σ_{ijw}^q is the markup of price over marginal cost ($q = N, H, V, EH, EV, CI$).

The perpendicular symbol “ \perp ” shows the complementary slackness relationships between inequalities and endogenous variables. When a relation holds with equality, the corresponding variable takes a positive value.

The optimal markup in a Cournot model with homogeneous products is defined by the firm’s share divided by the Marshallian price elasticity of demand in the market. Because the Marshallian elasticity of demand is -1 in the present model with Cobb-Douglas demand, a firm’s markup σ_{ijw}^q can be defined as:

$$\sigma_{ijw}^q \equiv \frac{p_j^Y Y_{ijw}^q}{\beta_j (p_j^K \bar{K}_j + p_j^L \bar{L}_j + T_j)}, \quad (50)$$

where

β_j is the share of type- Y goods in the representative consumer’s utility function;

\bar{K}_j is an exogenously given level of skilled labor endowment for country j ;

\bar{L}_j is an exogenously given level of unskilled labor endowment for country j ; and

T_j is tariff revenue in country j .

Applying (50) to Relations (42) through (49) gives the following:

$$Y_{ij}^N \geq \beta_j \left(\frac{p_j^K \bar{K}_j}{+p_j^L \bar{L}_j} \right) \left[\frac{p_j^Y - (1+v_{ij(i \neq j)}^Y) \{ p_i^K \theta^K \theta^X + p_i^L (\theta^L + \tau_{ij(i \neq j)}^Y) \}}{(p_j^Y)^2} \right] \perp Y_{ij}^N; \quad (51)$$

$$Y_{ij}^H \geq \beta_j \left(\frac{p_j^K \bar{K}_j}{+p_j^L \bar{L}_j} \right) \left\{ \frac{p_j^Y - (1+v_{ij(i \neq j)}^X) (p_i^K \theta^K + p_i^L \tau_{ij(i \neq j)}^X) \theta^X - p_j^L \theta^L}{(p_j^Y)^2} \right\} \perp Y_{ij}^H; \quad (52)$$

$$Y_{iji}^V \geq \beta_j \left(\frac{p_j^K \bar{K}_j}{+p_j^L \bar{L}_j} \right) \left[\frac{p_j^Y - (1+v_{ji(j \neq i)}^Y) \left\{ \frac{(1+v_{ii}^X) (p_i^K \theta^K + p_i^L \tau_{ii}^X) \theta^X}{+p_i^L (\theta^L + \tau_{ji(j \neq i)}^Y)} \right\}}{(p_j^Y)^2} \right] \perp Y_{iji}^V; \quad (53)$$

$$Y_i^{EHD} \geq \beta_i \left(\frac{p_j^K \bar{K}_j}{+p_j^L \bar{L}_j} \right) \left\{ \frac{p_i^Y - p_i^K \theta^K \theta^X - p_i^L \theta^L}{(p_i^Y)^2} \right\} \perp Y_i^{EHD}; \quad (54)$$

$$Y_{ijw}^{EHF} \geq \beta_j \left(\frac{p_j^K \bar{K}_j}{+p_j^L \bar{L}_j} \right) \left[\frac{p_j^Y - (1+v_{jw}^Y) \left\{ \frac{(1+v_{iw}^X) (p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X}{+p_w^L (\theta^L + \tau_{jw}^Y)} \right\}}{(p_j^Y)^2} \right] \perp Y_{ijw}^{EHF}; \quad (55)$$

$$Y_{ijw}^{EV} \geq \beta_j \left(\frac{p_j^K \bar{K}_j}{+p_j^L \bar{L}_j} \right) \left[\frac{p_j^Y - (1+v_{jw}^Y) \left\{ \frac{(1+v_{iw}^X) (p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X}{+p_w^L (\theta^L + \tau_{jw}^Y)} \right\}}{(p_j^Y)^2} \right] \perp Y_{ijw}^{EV}; \quad (56)$$

$$Y_{iw}^{CID} \geq \beta_i \left(\frac{p_j^K \bar{K}_j}{+p_j^L \bar{L}_j} \right) \left[\frac{p_i^Y - (1+v_{iw}^Y) \left\{ \frac{(1+v_{iw}^X) (p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X}{+p_w^L (\theta^L + \tau_{iw}^Y)} \right\}}{(p_i^Y)^2} \right] \perp Y_i^{CID}; \quad (57)$$

and

$$Y_{ij}^{CIF} \geq \beta_j \left(\frac{p_j^K \bar{K}_j}{+p_j^L \bar{L}_j} \right) \left\{ \frac{p_j^Y - (1+v_{ij}^X) (p_i^K \theta^K + p_i^L \tau_{ij}^X) \theta^X - p_j^L \theta^L}{(p_j^Y)^2} \right\} \perp Y_{ij}^{CIF}. \quad (58)$$

2.2.8 Number of Firms

Similarly to the production volume of a firm, number of firms in each type of production pattern is determined by a zero profit condition that assures markup revenue does not

exceed fixed cost payment. The zero profit conditions for every type of production pattern can be expressed as:

$$\sum_j \sigma_{ij}^N p_j^Y Y_{ij}^N \leq p_i^K F_i^N + p_i^L G_i \quad \perp M_i^N; \quad (59)$$

$$\sum_j \sigma_{ij}^H p_j^Y Y_{ij}^H \leq \sum_j (p_j^K F_{ij}^H + p_j^L G_j) \quad \perp M_i^H; \quad (60)$$

$$\sum_j \sum_{i'} \left(\sigma_{ij i'}^V p_j^Y Y_{ij i'}^V \right)_{(i \neq i')} \leq \sum_{i'} \left\{ p_{i'}^K F_{i i'}^V + (p_{i'}^L G_{i'})_{(i \neq i')} \right\} \quad \perp M_i^V; \quad (61)$$

$$\sigma_i^{EHD} p_i^Y Y_i^{EHD} + \sum_j (\sigma_{ijw}^{EHF} p_j^Y Y_{ijw}^{EHF})_{(i \neq j)} \leq p_i^K F_{ii}^{EH} + p_i^L G_i + p_w^K F_{iw}^{EH} + p_w^L G_w \quad \perp M_{iw}^{EH}; \quad (62)$$

$$\sum_j \sigma_{ijw}^{EV} p_j^Y Y_{ijw}^{EV} \leq p_i^K F_{ii}^{EV} + p_w^K F_{iw}^{EV} + p_w^L G_w \quad \perp M_{iw}^{EV}; \quad (63)$$

and

$$\sigma_{iw}^{CID} p_i^Y Y_{iw}^{CID} + \sum_j (\sigma_{ij}^{CIF} p_j^Y Y_{ij}^{CIF})_{(i \neq j)} \leq \sum_r p_r^K F_{ir}^{CI} + \sum_j (p_j^L G_j)_{(i \neq j)} + p_w^L G_w \quad \perp M_{iw}^{CI}, \quad (64)$$

where

M_i^N is the number of type-N firms established in country i ;

M_i^H is the number of type-H firms established in country i ;

M_i^V is the number of type-V firms established in country i ;

M_{iw}^{EH} is the number of type-EH firms established in country i ;

M_{iw}^{EV} is the number of type-EV firms established in country i ;

M_{iw}^{CI} is the number of type-CI firms established in country i ;

$$Y_{ij i'}^V (i=i) = 0;$$

$$Y_{ijw}^{EHF} (i=j) = 0;$$

$$Y_{ij}^{CIF} (i=j) = 0;$$

$$F_{ij}^{EH} (i \neq j) = 0; \text{ and}$$

$$F_{ij}^{EV} (i \neq j) = 0.$$

Using Relations (42) through (49), and (59) through (64) can be rewritten to:

$$\sum_j \left(\left[p_j^Y - (1 + v_{ij(i \neq j)}^Y) \left\{ \frac{p_i^K \theta^K \theta^X}{+ p_i^L (\theta^L + \tau_{ij(i \neq j)}^Y)} \right\} \right] Y_{ij}^N \right) \leq p_i^K F_i^N + p_i^L G_i \quad \perp M_i^N; \quad (65)$$

$$\sum_j \left[\left\{ p_j^Y - (1 + v_{ij(i \neq j)}^X) \left(\frac{p_i^K \theta^K}{+ p_i^L \tau_{ij(i \neq j)}^X} \right) \theta^X - p_j^L \theta^L \right\} Y_{ij}^H \right] \leq \sum_j (p_j^K F_{ij}^H + p_j^L G_j) \quad \perp M_i^H; \quad (66)$$

$$\begin{aligned} & \sum_j \sum_{i'} \left(\left[p_j^Y - (1 + v_{ji'}^Y) \left\{ \begin{array}{l} (1 + v_{ii'}^X)(p_i^K \theta^K + p_i^L \tau_{ii'}^X) \theta^X \\ + p_i^L (\theta^L + \tau_{ji'}^Y) \end{array} \right\} \right] Y_{ij'i}^V \right)_{(i \neq i')} \\ & \leq \sum_{i'} \left\{ p_i^K F_{ii'}^V + (p_i^L G_{i'})_{(i \neq i')} \right\} \quad \perp M_{i'}^V; \quad (67) \end{aligned}$$

$$\begin{aligned} & (p_j^Y - p_i^K \theta^K \theta^X - p_i^L \theta^L) Y_i^{EHD} \\ & + \sum_j \left(\left[p_j^Y - (1 + v_{jw}^Y) \left\{ \begin{array}{l} (1 + v_{iw}^X)(p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X \\ + p_w^L (\theta^L + \tau_{jw}^Y) \end{array} \right\} \right] Y_{ijw}^{EHF} \right)_{(i \neq j)} \\ & \leq p_i^K F_{ii}^{EH} + p_i^L G_i + p_w^K F_{iw}^{EH} + p_w^L G_w \quad \perp M_{iw}^{EH}; \quad (68) \end{aligned}$$

$$\begin{aligned} & \sum_j \left(\left[p_j^Y - (1 + v_{jw}^Y) \left\{ \begin{array}{l} (1 + v_{iw}^X)(p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X \\ + p_w^L (\theta^L + \tau_{jw}^Y) \end{array} \right\} \right] Y_{ijw}^{EV} \right) \\ & \leq p_i^K F_{ii}^{EV} + p_w^K F_{iw}^{EV} + p_w^L G_w \quad \perp M_{iw}^{EV}; \quad (69) \end{aligned}$$

and

$$\begin{aligned} & \left[p_i^Y - (1 + v_{iw}^Y) \left\{ \begin{array}{l} (1 + v_{iw}^X)(p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X \\ + p_w^L (\theta^L + \tau_{iw}^Y) \end{array} \right\} \right] Y_{iw}^{CID} \\ & + \sum_j \left[\{ p_j^Y - (1 + v_{ij}^X)(p_i^K \theta^K + p_i^L \tau_{ij}^X) \theta^X - p_j^L \theta^L \} Y_{ij}^{CIF} \right]_{(i \neq j)} \\ & \leq \sum_r p_r^K F_{ir}^{CI} + \sum_j (p_j^L G_j)_{(i \neq j)} + p_w^L G_w \quad \perp M_{iw}^{CI}. \quad (70) \end{aligned}$$

To summarize the type-Y good sector in the model, the output levels and number of firms categorized in the six types of production patterns are respectively determined by Inequalities (51) through (58) and (65) through (70), given the factor and commodity prices determined by the market-clearing conditions we will see later.

2.3 Type-Z Good Producer

A Type-Z good is produced in every country r with skilled and unskilled labor using a Cobb-Douglas CRTS technology under perfect competition. The production function is:

$$Z_r = \gamma_r (K_r^Z)^{\alpha_r} (L_r^Z)^{1-\alpha_r}, \quad (71)$$

where

Z_r is the output volume of type-Z good in country r ;

K_r^Z is the skilled labor input;

L_r^Z is the unskilled labor input;

α_r is the share of skilled labor; and

γ_r is a scaling factor of measuring units.

The producer in every country r chooses the levels of Z_r , K_r^Z , and L_r^Z , to maximize profit subject to (71) given the prices of skilled and unskilled labor, p_r^K and p_r^L , and the output p^Z . The first order conditions (FOCs) for the optimum are given by:

$$p_r^K = \alpha_r p^Z \left(\frac{Z_r}{K_r^Z} \right); \quad (72)$$

and

$$p_r^L = (1 - \alpha_r) p^Z \left(\frac{Z_r}{L_r^Z} \right). \quad (73)$$

By Equations (71) through (73), the levels of Z_r , K_r^Z , and L_r^Z are determined.

2.4 Consumer

The representative consumer in every country r maximizes her/his utility subject to their budget constraints given the price of commodities.

2.4.1 Consumer in Country i

The welfare level of a representative consumer in a market country i is assumed to be given by the following Cobb-Douglas utility function:

$$U_i = \delta_i (Y_i^U)^{\beta_i} (Z_i^U)^{1-\beta_i}, \quad (74)$$

where

- U_i is the welfare level of the representative consumer in country i ;
- Y_i^U is the consumption level of type-Y goods produced in the IRTS sector;
- Z_i^U is the consumption level of type-Z goods produced in the CRTS sector;
- β_i is the share of type-Y goods (mentioned in Subsection 2.2.7); and
- δ_i is a scaling factor.

The budget constraint for the consumer is expressed as:

$$p_i^Y Y_i^U + p^Z Z_i^U = p_i^K \bar{K}_i + p_i^L \bar{L}_i + T_i, \quad (75)$$

where the expenditure enters the left-hand side, while the budget is sourced by factor income and tariff revenue appearing in the right-hand side of Equation (75). Note that we implicitly assume balanced trade so that there are no foreign savings.

The representative consumer in country i chooses the consumption levels of Y_i^U and Z_i^U to maximize her/his utility defined by Equation (74) subject to (75). The FOCs for the optimum are:

$$\lambda_i p_i^Y = \beta_i \delta_i \left(\frac{Y_i^U}{Z_i^U} \right)^{\beta_i - 1}, \quad (76)$$

and

$$\lambda_i p_i^Z = (1 - \beta_i) \delta_i \left(\frac{Y_i^U}{Z_i^U} \right)^{\beta_i}, \quad (77)$$

where λ_i is the Lagrange multiplier with respect to budget constraint (75). By Equations (76) and (77), the levels of Y_i^U and Z_i^U are determined.

2.4.2 Consumer in Country w

The welfare level of the representative consumer in non-market country w is measured solely by the consumption level of the type-Z good because the type-Y good is sold only in the market countries:

$$U_w = Z_w^U, \quad (78)$$

where

U_w is the welfare level of the representative consumer in country w ; and

Z_w^U is the consumption level of the type-Z good produced in the CRTS sector.

Similarly to the previous case, the budget constraint equates expenditure with factor income and tariff revenue as follows:

$$p^Z Z_w^U = p_w^K \bar{K}_w + p_w^L \bar{L}_w + T_w. \quad (79)$$

Again, balanced trade is assumed.

The representative consumer in country w chooses the consumption level of Z_w^U to maximize her/his utility as defined by Equation (78) subject to (79). The FOC for the optimum is:

$$\lambda_w p^Z = 1, \quad (80)$$

where λ_w is the Lagrange multiplier with respect to budget constraint (79). By Equation (80), the level of Z_w^U is determined.

2.4.3 Tariff Revenue

The tariff revenues in countries i and w are respectively defined as follows:

$$\begin{aligned} T_i \equiv & \sum_j [M_j^N v_{ji}^Y \{p_j^K \theta^K \theta^X + p_j^L (\theta^L + \tau_{ji}^Y)\} Y_{ji}^N]_{(i \neq j)} \\ & + \sum_j \{M_j^H v_{ji}^X (p_j^K \theta^K + p_{ij}^L \tau_{ji}^X) \theta^X Y_{ji}^H\}_{(i \neq j)} \end{aligned}$$

$$\begin{aligned}
& + \sum_j \left[M_i^V v_{ij}^Y \left\{ \frac{(1 + v_{ij}^X)(p_i^K \theta^K + p_i^L \tau_{ij}^X) \theta^X}{+ p_j^L (\theta^L + \tau_{ij}^Y)} \right\} Y_{ij}^V \right]_{(i \neq j)} \\
& + \sum_j \sum_i \left\{ M_j^Y v_{ji}^X (p_j^K \theta^K + p_j^L \tau_{ji}^X) \theta^X Y_{ji}^V \right\}_{(i \neq j)} \\
& + \sum_j \sum_w \left[M_{jw}^{EH} v_{iw}^Y \left\{ \frac{(1 + v_{jw}^X)(p_j^K \theta^K + p_j^L \tau_{jw}^X) \theta^X}{+ p_w^L (\theta^L + \tau_{iw}^Y)} \right\} Y_{jw}^{EHF} \right]_{(i \neq j)} \\
& + \sum_j \sum_w \left[M_{jw}^{EV} v_{iw}^Y \left\{ \frac{(1 + v_{jw}^X)(p_j^K \theta^K + p_j^L \tau_{jw}^X) \theta^X}{+ p_w^L (\theta^L + \tau_{iw}^Y)} \right\} Y_{jw}^{EV} \right] \\
& + \sum_w \left[M_{iw}^{CI} v_{iw}^Y \left\{ \frac{(1 + v_{iw}^X)(p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X}{+ p_w^L (\theta^L + \tau_{iw}^Y)} \right\} Y_{iw}^{CID} \right] \\
& + \sum_j \sum_w \left\{ M_{jw}^{CI} v_{ji}^X (p_i^K \theta^K + p_i^L \tau_{ji}^X) \theta^X Y_{ji}^{CIF} \right\}_{(i \neq j)};
\end{aligned}$$

and

$$\begin{aligned}
T_w & \equiv \sum_i \sum_j \left\{ M_{iw}^{EH} v_{iw}^X (p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X Y_{ijw}^{EHF} \right\}_{(i \neq j)} \\
& + \sum_i \sum_j \left\{ M_{iw}^{EV} v_{iw}^X (p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X Y_{ijw}^{EV} \right\} \\
& + \sum_j \left\{ M_{iw}^{CI} v_{iw}^X (p_i^K \theta^K + p_i^L \tau_{iw}^X) \theta^X Y_{iw}^{CID} \right\}.
\end{aligned}$$

We presume that the tariff revenue in each country just is transferred to the representative consumer.

2.5 Market Equilibrium

The market-clearing conditions determine the price levels of the corresponding production factors and commodities in an equilibrium.

2.5.1 Factor Market Clearing

In each market country i , the following two labor market-clearing conditions hold in an equilibrium:

$$\begin{aligned}
\bar{K}_i & = K_i^Z + M_i^N K_i^N + M_i^H K_{ii}^H + \sum_j (M_j^H K_{ji}^H)_{(i \neq j)} \\
& + M_i^V K_{ii}^V + \sum_j (M_j^V K_{ji}^V)_{(i \neq j)} + \sum_w M_{iw}^{EH} K_{ii}^{EH} + \sum_w M_{iw}^{EV} K_{ii}^{EV}
\end{aligned}$$

$$+ \sum_w \left\{ M_{iw}^{CI} K_{ii}^{CI} + \sum_j (M_{jw}^{CI} K_{ji}^{CI})_{(i \neq j)} \right\}; \quad (81)$$

and

$$\begin{aligned} \bar{L}_i = & L_i^Z + M_i^N L_i^N + M_i^H (L_i^{HT} + L_{ii}^{HP}) + \sum_j (M_j^H L_{ji}^{HP})_{(i \neq j)} \\ & + M_i^V L_{ii}^V + \sum_j (M_j^V L_{ji}^V)_{(i \neq j)} + \sum_w M_{iw}^{EH} (L_i^{EHT} + L_{ii}^{EHP}) + \sum_w M_{iw}^{EV} L_{ii}^{EV} \\ & + \sum_w \left\{ M_{iw}^{CI} L_{ii}^{CI} + \sum_j (M_{jw}^{CI} L_{ji}^{CI})_{(i \neq j)} \right\}. \end{aligned} \quad (82)$$

Equations (81) and (82), respectively, determine the levels of factor prices p_i^K and p_i^L .

In each non-market country w , the following two market-clearing conditions hold in an equilibrium:

$$\bar{K}_w = K_w^Z + \sum_w M_{iw}^{EH} K_{iw}^{EH} + \sum_w M_{iw}^{EV} K_{iw}^{EV} + \sum_w M_{iw}^{CI} K_{iw}^{CI}; \quad (83)$$

and

$$\bar{L}_w = L_w^Z + \sum_w M_{iw}^{EH} L_{iw}^{EHP} + \sum_w M_{iw}^{EV} L_{iw}^{EV} + \sum_w M_{iw}^{CI} L_{iw}^{CI}. \quad (84)$$

The price levels of skilled and unskilled labor in country w , p_w^K and p_w^L , are determined by Equations (83) and (84).

2.5.2 Commodity Market Clearing

The demand and supply of the two types of commodity for final consumption are equated to determine their price levels as follows:

$$\begin{aligned} Y_i^U = & \sum_j \left(M_j^N Y_{ji}^N + M_j^H Y_{ji}^H + M_j^V \sum_{i'} Y_{jii'}^{EV} \right)_{(j \neq i)} + \sum_w M_{jw}^{EV} Y_{jiw}^{EV} \\ & + \sum_j \left\{ M_{iw}^{EH} Y_i^{EHD} + \sum_j (M_{jw}^{EH} Y_{jiw}^{EHF})_{(i \neq j)} \right\} \\ & + \sum_j \left\{ M_{iw}^{CI} Y_{iw}^{CID} + \sum_j (M_{jw}^{CI} Y_{ji}^{CIF})_{(i \neq j)} \right\}; \end{aligned} \quad (85)$$

and

$$\sum_r Z_r^U = \sum_r Z_r. \quad (86)$$

By Equations (85) and (86), the price levels of both type-Y and type-Z goods, p_i^Y and p_i^Z , are determined.

Then, notice that one of the market-clearing conditions (81) through (86) automatically holds because of *Walras' Law*. Therefore, we drop Equation (86) from the system, treating the type-Z good as the numéraire. In consequence, p^Z is set to unity given

exogenously.

2.6 System Equations/Inequalities

In the model, the output volumes of the type-Y good in each of the six types of production pattern (Y_{ij}^N , Y_{ij}^H , $Y_{ij'}^V$, Y_i^{EHD} , Y_{ijw}^{EHF} , Y_{ijw}^{EV} , Y_{iw}^{CID} , and Y_{ij}^{CIF}), number of firms in the six types of production pattern (M_i^N , M_i^H , M_i^V , M_{iw}^{EH} , M_{iw}^{EV} , and M_{iw}^{CI}), the output volume of the type-Z good (Z_r), the input volume of skilled and unskilled labor in the production of the type-Z good (K_r^Z and L_r^Z), the Lagrange multiplier with respect to the representative consumer's budget constraint in country i (λ_i), the consumption levels of the two types of commodity by the representative consumer in country i (Y_i^U and Z_i^U), the Lagrange multiplier with respect to the representative consumer's budget constraint in country w (λ_w), the consumption/welfare level of the type-Z good by the representative consumer in country w (Z_w^U), the price levels of skilled and unskilled labor in country i (p_i^K and p_i^L), the price levels of the two types of labor in country w (p_w^K and p_w^L), and the price level of the type-Y good (p_i^Y) are determined by Inequalities (51) through (58) and (65) through (70), and Equations (71) through (73), (75) through (77), (79), (80), (81) through (84), and (85), respectively.

3. Numerical Implementation of the Model

Markusen (2002) noted that one may face two types of computational difficulty in the numerical application of an analytical model such as the one we introduced in the previous section. One is due to the high-dimensionality of the model, and the other is brought by the handling of inequalities. Versions of the knowledge-capital model, an objective of which is to analyze emerging patterns of independent firm-types under different economic conditions, require us to appropriately manage corner-solutions based on the Karush-Kuhn-Tucker conditions. For this reason, the model used in this study was coded in the General Algebraic Modeling System (GAMS) and solved by its PATH solver, which enables us to easily handle complementary slackness.²

In experimental simulations, we change the relative factor endowments for either the

² Brook, Kendrick, and Meeraus (1992) and Ferris and Munson (1998).

market- or non-market-country groups, given absolute levels of total endowments for the group. The factor endowments for the group not being focused on are kept identical for the two countries in the group. Then, a box diagram à la *Edgeworth box* is drawn placing the total skilled labor endowment for the focused group on the vertical axis and the total unskilled labor endowment on the horizontal axis to capture the regime, welfare level, factor prices, and so on in each cell corresponding to the relative factor endowments of the two countries.

The model is calibrated to the center of the box diagram, where the two countries in each group are totally identical. At this point, it is assumed that only HMNEs are active due to the existence of high trade cost between the two market countries in the base case. Then, there are no local subsidiaries and plants in the non-market countries, and no trade with respect to the type-Z good takes place. Calibration of the model requires a set of information that includes a social accounting matrix (SAM), which corresponds to the center of the box diagram, levels of fixed and trade costs (transportation cost and import tariff), and input coefficients. Especially, careful setting of the firm-type/trade-link specific fixed cost F is required because simulation results tend to be sensitive to this setting, in addition to the fact that the firm types other than type-H do not enter the given SAM.

3.1 Setting of the Firm-Type/Trade-Link Specific Fixed Cost F

Let us recall the three important assumptions for the knowledge-capital model defined by Markusen (2002:129):

***Fragmentation:** the location of knowledge based assets may be fragmented from production. Any incremental cost of supplying services of the asset to a single foreign plant versus the cost to a single domestic plant is small.*

***Skilled-labor Intensity:** knowledge-based assets are skilled labor intensive relative to final production.*

***Jointness:** the services of knowledge based assets are (at least partially) joint (“public”) inputs into multiple production facilities. The added cost of a second plant is small compared to the cost of establishing a firm with local plant.*

The values of parameters such as fixed and trade costs should be set in line with these three

properties, because a firm's decisions to choose which operational type under a certain economic condition are crucially motivated by these properties.

Based on the three properties, we make the following four assumptions on the firm-type/trade-link specific fixed cost F for a firm established in country A :

$$2F_A^N > F_{AA}^H + F_{AB}^H > F_A^N; \quad (87)$$

$$F_{AA}^{CI} \geq F_{AA}^{EH} \geq F_{AA}^H > F_A^N > F_{AA}^{EV} \geq F_{AA}^V; \quad (88)$$

$$F_{AB}^H = F_{AB}^V = F_{AB}^{CI} > F_{AC}^{EH} = F_{AD}^{EH} = F_{AC}^{EV} = F_{AD}^{EV} = F_{AC}^{CI} = F_{AD}^{CI}; \quad (89)$$

and

$$\begin{aligned} F_{AA}^{CI} + F_{AB}^{CI} + F_{AC}^{CI} &= F_{AA}^{CI} + F_{AB}^{CI} + F_{AD}^{CI} > F_{AA}^H + F_{AB}^H \\ &> F_{AA}^{EH} + F_{AC}^{EH} = F_{AA}^{EH} + F_{AD}^{EH} \geq F_{AA}^V + F_{AB}^V \\ &> F_{AA}^{EV} + F_{AC}^{EV} = F_{AA}^{EV} + F_{AD}^{EV} > F_A^N. \end{aligned} \quad (90)$$

The case for a firm established in country B is the same. Relation (87) is based on the jointness assumption shown above.

Relation (88) is related to the headquarter cost. First, a type-H firm is costly compared to a type-N firm because additional skilled labor is required in the headquarters for managerial and coordination activities. Second, the additional cost of managerial and coordination activities for the operation of a local subsidiary might be higher in a non-market country (type-EH and type-CI) than in a market country (type-H). Similar relation applies to type-V and type-EV firms. Third, a type-N firm is costly compared to a type-V or type-EV firm because the latter may hire local skilled labor to train unskilled labor at a cheaper price in the host country.

Relation (89) is related to the local affiliate cost. In non-market countries, cheaper skilled labor is available.

Relation (90) is related to the total cost. Type-V and type-EV firms are less costly compared to the cases of type-H and type-EH because the former has only one assembly plant in a non-market country so that the additional payment for managerial coordination activities is not required. Among the type-H and type-EH firms, we assume that operating an assembly plant is more costly in a market country than in a non-market country. The most costly firm is Type-CI because this type operates its headquarters and two assembly plants in three different countries. Relation (90) also implies that technology transfer incurs some amount of cost so that fragmentation is not perfect.

Finally, the parameter values for the firm-type/trade-link specific fixed cost F are set as follows:

$$\begin{aligned} F_i^N &= 4.0; \\ F_{ij}^H &= 4.2 \ (i = j), 1.4 \ (i \neq j); \end{aligned}$$

$$\begin{aligned}
F_{ij}^V &= 3.4 \ (i = j), 1.4 \ (i \neq j); \\
F_{ir}^{EH} &= 4.2 \ (r = i), 0 \ (r \neq i), 1.3 \ (r = w); \\
F_{ir}^{EV} &= 3.4 \ (r = i), 0 \ (r \neq i), 1.3 \ (r = w); \text{ and} \\
F_{ir}^{CI} &= 4.2 \ (r = i), 1.4 \ (r \neq i), 1.3 \ (r = w).
\end{aligned}$$

These values tend to be set high to perform comparative statics between the base case and a counterfactual equilibrium where some of the values are set substantially lower.

3.2 Calibration Based on a Social Accounting Matrix

Along with the firm-type/trade-link specific fixed cost, transportation cost and import tariff related to the two types of commodity, intermediate and final goods and input coefficients are assumed as follows:

$$\begin{aligned}
\tau_{ir}^X &= \tau_{jr}^Y = 0.1; \\
v_{ir}^X &= v_{jr}^Y = 0.2; \\
\theta^K &= 1; \\
\theta^L &= 0.875; \text{ and} \\
\theta^X &= 0.125.
\end{aligned}$$

In addition, initial levels of prices are given as a usual cliché in the parameterization process of a general equilibrium model, in which not absolute but only relative levels of prices matter:

$$\begin{aligned}
p_w^K &= p_w^L = p^Z = 1; \text{ and} \\
p_i^Y &= 1.25.
\end{aligned}$$

Then, the initial values of some endogenous variables and a part of the country specific setup cost G are calibrated from a SAM. In this study, we assume the following value is obtained from a SAM.

$$\beta_j(p_j^K \bar{K}_j + p_j^L \bar{L}_j) = 101.0145373.$$

In the second step, the initial values of Y_{ij}^H is calculated using Equation (52):

$$Y_{ij}^H = 16.1623 \ (i = j), 13.5764 \ (i \neq j).$$

Third, M_i^H is derived using the following relation:

$$M_i^H = \frac{\beta_i(p_i^K \bar{K}_i + p_i^L \bar{L}_i)}{\sum_j p_i^Y Y_{ji}^H} = \frac{101.0145373}{1.25 \times (16.1623 + 13.5764)} = 2.71738945 \dots$$

σ_{ij}^H is also obtained by Equation (50):

$$\sigma_{ij}^H = 0.2 \ (i = j), 0.168 \ (i \neq j).$$

Finally, G_j is calibrated using Equation (66) because the two market countries are identical:

$$G_j = 0.6458.$$

Based on this calibrated value, G_w is also set to 0.6458 in the base case.

The whole picture of the SAM assumed in this study is shown in Table 1, where TC_i^H , U_r , MR_{ij}^H , FC_i^H , I_r , and E_i denote total cost, consumption, markup revenue, fixed cost, income of a representative consumer, and income of the type-H firms owner, respectively.

	Z_A	Z_B	Z_C	Z_D	$M_A^H Y_{AA}^H$	$M_A^H Y_{AB}^H$	$M_B^H Y_{BA}^H$	$M_B^H Y_{BB}^H$	FC_A^H	FC_B^H	U_A	U_B	U_C	U_D	I_A	I_B	I_C	I_D	E_A	E_B	Total	
Z_A^U	100.00										-100.00										0	
Z_B^U		100.00										-100.00										0
Z_C^U			200.00										-200.00									0
Z_D^U				200.00										-200.00								0
Y_A^U					54.90		46.12				-101.01											0
Y_B^U						46.12		54.90				-101.01										0
TC_A^H									18.73											-18.73		0
TC_B^H										18.73											-18.73	0
L_A	-80.00				-38.43		-32.74		-1.75	-1.75					154.68							0
L_B		-80.00				-32.74		-38.43	-1.75	-1.75						154.68						0
L_C			-154.68														154.68					0
L_D				-154.68														154.68				0
K_A	-20.00				-5.49	-4.61			-11.41	-3.80					45.32							0
K_B		-20.00					-4.61	-5.49	-3.80	-11.41						45.32						0
K_C			-45.32														45.32					0
K_D				-45.32														45.32				0
T_A							-1.01								1.01							0
T_B						-1.01										1.01						0
T_C																						0
T_D																						0
U_A											201.01				-201.01							0
U_B												201.01				-201.01						0
U_C													200.00				-200.00					0
U_D														200.00				-200.00				0
MR_{AA}^H					-10.98														10.98			0
MR_{AB}^H						-7.75													7.75			0
MR_{BA}^H							-7.75													7.75		0
MR_{BB}^H								-10.98													10.98	0
Total	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 1: Social Accounting Matrix for the Center of the Box Diagram

In this case, we presume that all of the four countries have the same amount of factor endowments. In the later simulation experiments, we will consider different country sizes for the non-market group.

Using this SAM, the parameters in the two Cobb-Douglas aggregator functions (71) and (74), α_r , β_i , γ_r , and δ_i , are calibrated.

4. Simulations

We now report on the results of simulations performed with the extended

knowledge-capital model introduced previously. The simulations are categorized into two groups. The first one is to reveal some of the behavioral characteristics of the model, and the second is to examine whether a free trade agreement (FTA) or an economic partnership agreement (EPA) would be effective for a developing (non-market) country to stimulate incoming FDI, in a situation where the country is left behind another developing rival in forming a free trade area with one of the market countries. In the simulations, we change the relative factor endowments for either the market- or non-market-country groups given absolute levels of total endowments for the group, and we calculate every equilibrium of the economy under the selected sets of national endowments. The factor endowments for the group not under focus are kept identical to two the members in the group. Then, trade and fixed costs are respectively reduced from their initial values set in the base case to see how the pattern of regimes changes.

4.1 Basic Characteristics of the Model

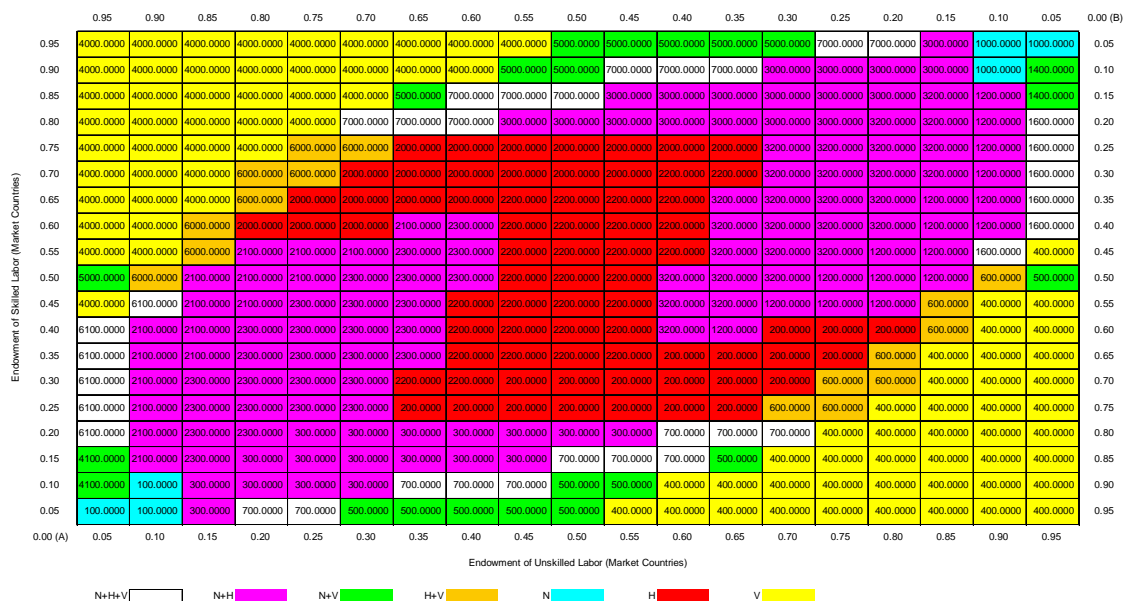


Figure 2: Equilibrium Regime in the Base Case (Market Countries)

Figure 2 is a box diagram for the case when relative factor endowments for the market countries are changed given the absolute levels of total endowments shown in the benchmark SAM (Table 1). This will be the base case for comparison with the results

obtained when a set of parameters or exogenous variables are changed. The initial levels of trade and fixed costs assumed in the base case are:

$$\begin{aligned}
\tau_{ir}^X &= \tau_{jr}^Y = 0.1; \\
v_{ir}^X &= v_{jr}^Y = 0.2; \\
F_i^N &= 4.0; \\
F_{ij}^H &= 4.2 \ (i = j), 1.4 \ (i \neq j); \\
F_{ij}^V &= 3.4 \ (i = j), 1.4 \ (i \neq j); \\
F_{ir}^{EH} &= 4.2 \ (r = i), 0 \ (r \neq i), 1.3 \ (r = w); \\
F_{ir}^{EV} &= 3.4 \ (r = i), 0 \ (r \neq i), 1.3 \ (r = w); \\
F_{ir}^{CI} &= 4.2 \ (r = i), 1.4 \ (r \neq i), 1.3 \ (r = w); \text{ and} \\
G_j &= 0.6458.
\end{aligned}$$

In the box, the vertical axis corresponds to the total endowment of skilled labor for the two market countries, and the horizontal axis to that of unskilled labor. The division of the factor endowments between the two countries is shown with country *A* measured from the southwest (SW) corner and country *B* measured from the northeast (NE) corner. The model is repeatedly solved for each cell 361 (19×19) times, altering the distribution of factor endowments. Each cell represents an equilibrium regime and the number inside shows which type of firm is active in the regime. The regime number is defined as:

$$\begin{aligned}
\Omega &= \omega_A^N + \omega_B^N + \omega_A^H + \omega_B^H + \omega_A^V + \omega_B^V + \omega_{AC}^{EH} + \omega_{AD}^{EH} + \omega_{BC}^{EH} + \omega_{BD}^{EH} \\
&\quad + \omega_{AC}^{EV} + \omega_{AD}^{EV} + \omega_{BC}^{EV} + \omega_{BD}^{EV} + \omega_{AC}^{CI} + \omega_{AD}^{CI} + \omega_{BC}^{CI} + \omega_{BD}^{CI},
\end{aligned}$$

where

$$\begin{aligned}
\omega_A^N &= 1000 \ \text{if Type-N firms established in country } A \ \text{are active, otherwise } 0; \\
\omega_B^N &= 100 \ \text{if Type-N firms established in country } B \ \text{are active, otherwise } 0; \\
\omega_A^H &= 2000 \ \text{if Type-H firms established in country } A \ \text{are active, otherwise } 0; \\
\omega_B^H &= 200 \ \text{if Type-H firms established in country } B \ \text{are active, otherwise } 0; \\
\omega_A^V &= 4000 \ \text{if Type-V firms established in country } A \ \text{are active, otherwise } 0; \\
\omega_B^V &= 400 \ \text{if Type-V firms established in country } B \ \text{are active, otherwise } 0; \\
\omega_{AC}^{EH} &= 10 \ \text{if Type-EH firms established in country } A \ \text{operating in country } C \\
&\quad \text{are active, otherwise } 0; \\
\omega_{AD}^{EH} &= 20 \ \text{if Type-EH firms established in country } A \ \text{operating in country } D \\
&\quad \text{are active, otherwise } 0; \\
\omega_{BC}^{EH} &= 1 \ \text{if Type-EH firms established in country } B \ \text{operating in country } C \\
&\quad \text{are active, otherwise } 0; \\
\omega_{BD}^{EH} &= 2 \ \text{if Type-EH firms established in country } B \ \text{operating in country } D \\
&\quad \text{are active, otherwise } 0;
\end{aligned}$$

$\omega_{AC}^{EV} = 0.1$ if Type-EV firms established in country A operating in country C are active, otherwise 0;
 $\omega_{AD}^{EV} = 0.2$ if Type-EV firms established in country A operating in country D are active, otherwise 0;
 $\omega_{BC}^{EV} = 0.01$ if Type-EV firms established in country B operating in country C are active, otherwise 0;
 $\omega_{BD}^{EV} = 0.02$ if Type-EV firms established in country B operating in country D are active, otherwise 0;
 $\omega_{AC}^{CI} = 0.001$ if Type-CI firms established in country A operating in country C are active, otherwise 0;
 $\omega_{AD}^{CI} = 0.002$ if Type-CI firms established in country A operating in country D are active, otherwise 0;
 $\omega_{BC}^{CI} = 0.0001$ if Type-CI firms established in country B operating in country C are active, otherwise 0; and
 $\omega_{BD}^{CI} = 0.0002$ if Type-CI firms established in country B operating in country D are active, otherwise 0.

Figure 2 shows that only type-H firms are active around the center of the box diagram, where two market countries are similar in both size and relative endowment. If the countries are different in size while being similar in relative endowment, type-N firms established in the country with abundant factors dominate the production and occupy both markets, as confirmed around the SW and NE corners. When the price of unskilled labor in a market country becomes cheaper, foreign type-H firms become active in the country, as confirmed in the northwest (NW) and southeast (SE) neighborhoods surrounding the central area. Toward the NW corner from the center, the price of skilled/unskilled labor in country A becomes lower/higher while that in country B goes opposite. Toward the SE corner, it reverses. Thus, firms in a market country where the price of unskilled labor becomes extremely high, go out to the other market country as type-V firms, as confirmed around the NW and SE corners.

Figure 3 is a box diagram for the case when relative factor endowments for the non-market countries are changed and the absolute levels of total endowments for the group are given. This is also the base case. Figure 3 shows that along the diagonal between the SW and NE corners, where non-market countries are similar in relative endowment, MNEs never setup plants in non-market countries but go straight to the market countries as type-H firms. This occurs because there is no substantial difference between relative factor prices among the countries. On the other hand, around the NW and SE corners where cheaper

skilled labor is available in either of the non-market countries, type-EV firms become active. For instance, around the SE corner, skilled labor is relatively abundant in country C so that type-EV firms from both countries A and B operate in C . Around the NW corner, firms operating in country D dominate. Note that, in this base case captured by Figures 2 and 3, type-EH and type-CI firms never show up.

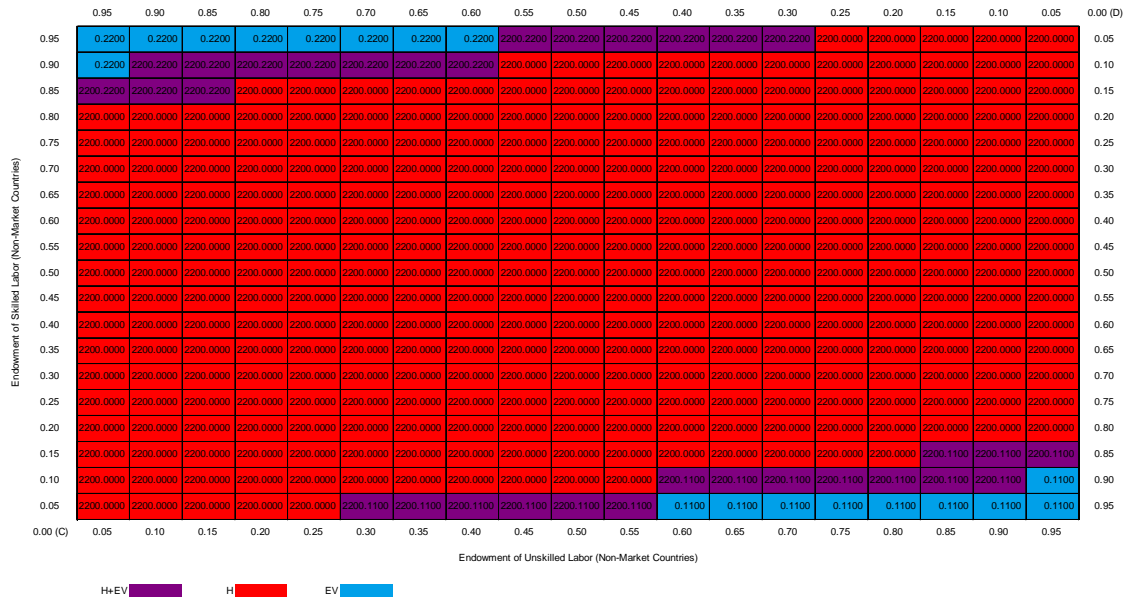


Figure 3: Equilibrium Regime in the Base Case (Non-Market Countries)

Next, let us see what happens when selected values of trade and fixed costs change. If the transportation cost of components concerning the trade-link between the market countries is lowered, type-H firms extend their influence (Figure 4). It is quite natural that sending components to the foreign market country becomes cheaper in this case. As the type-H firms increase, the incentive to operate in non-market countries as a type-EV firm becomes weak.

When the transportation cost of finished products concerning the trade-link between the market countries is lowered, type-N firms increase (Figure 5). This is also natural because exporting finished products to the foreign market country becomes cheaper in this case. Type-N firms extend their influence along the SW-NE diagonals where the relative endowment of countries and factor prices tend to be similar. On the other hand, if there is a difference in factor availability even to a slight extent, the firms established in the larger

country dominate the production and occupy both markets, as in the previous case. The incentive to operate in non-market countries is still weak as in the case of the trade cost of components.

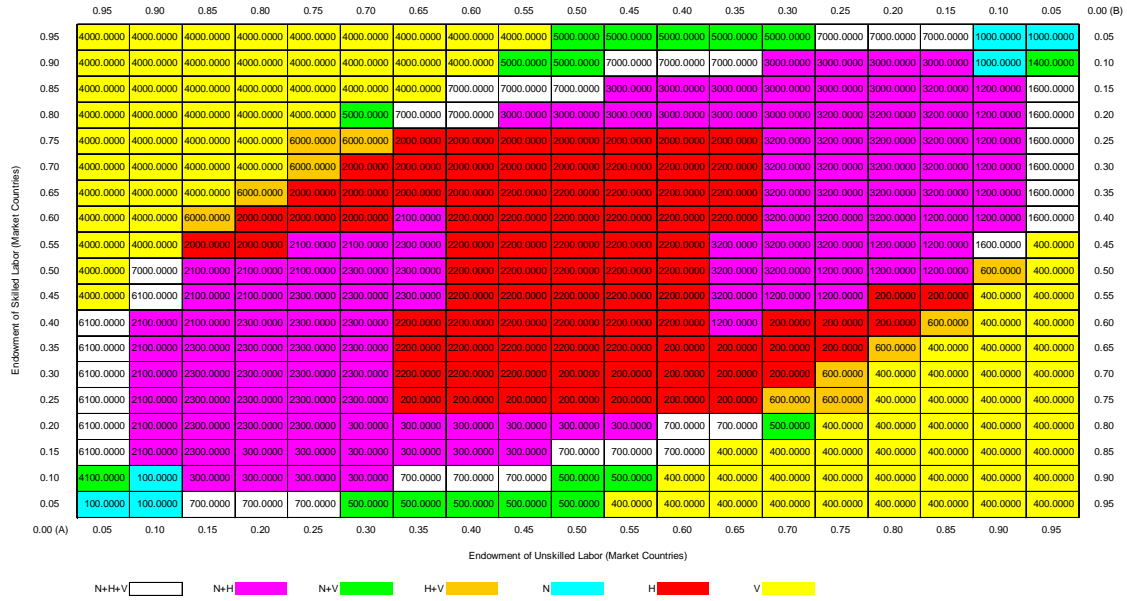


Figure 4: Lower Transportation Cost of Components ($\tau_{ij}^X = 0$, Market Countries)

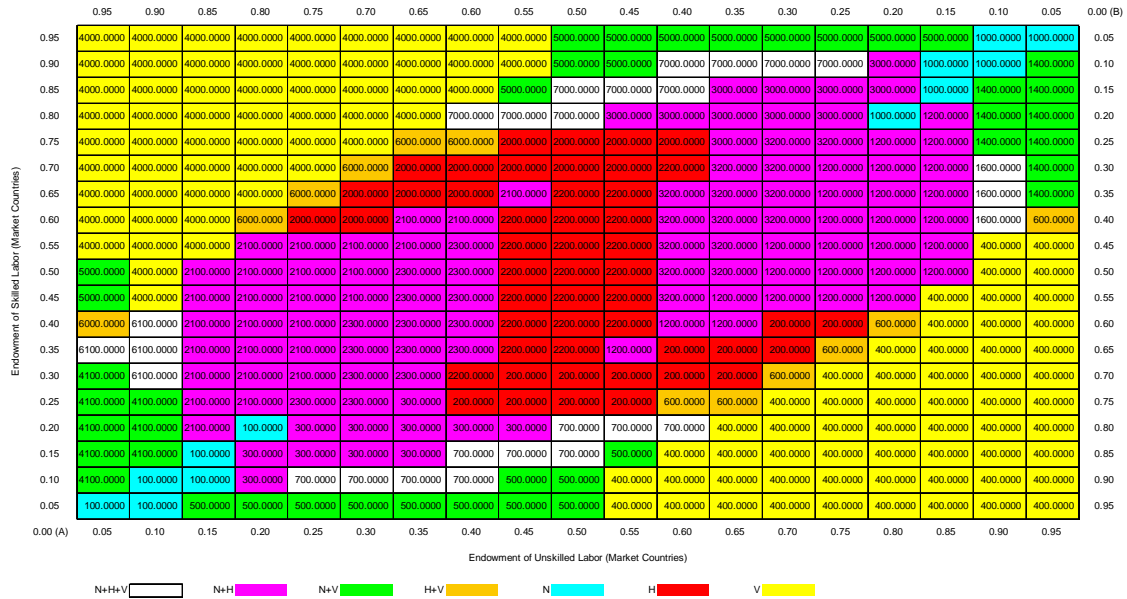


Figure 5: Lower Transportation Cost of Finished Products ($\tau_{ij}^Y = 0$, Market Countries)

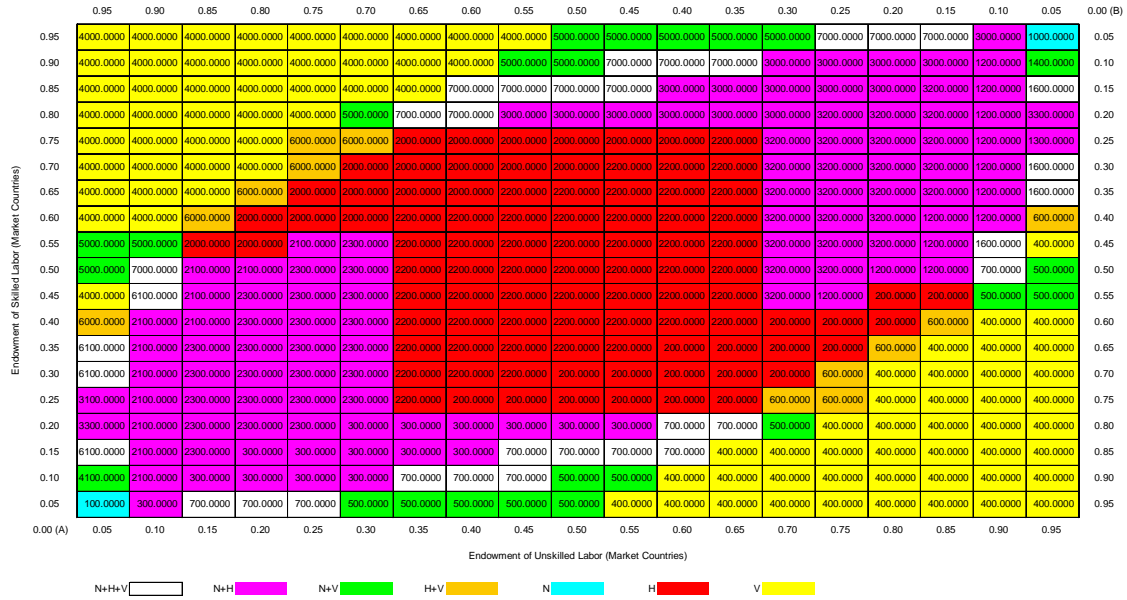


Figure 6: Lower Import Tariff on Components ($v_{ij}^X = 0$, Market Countries)

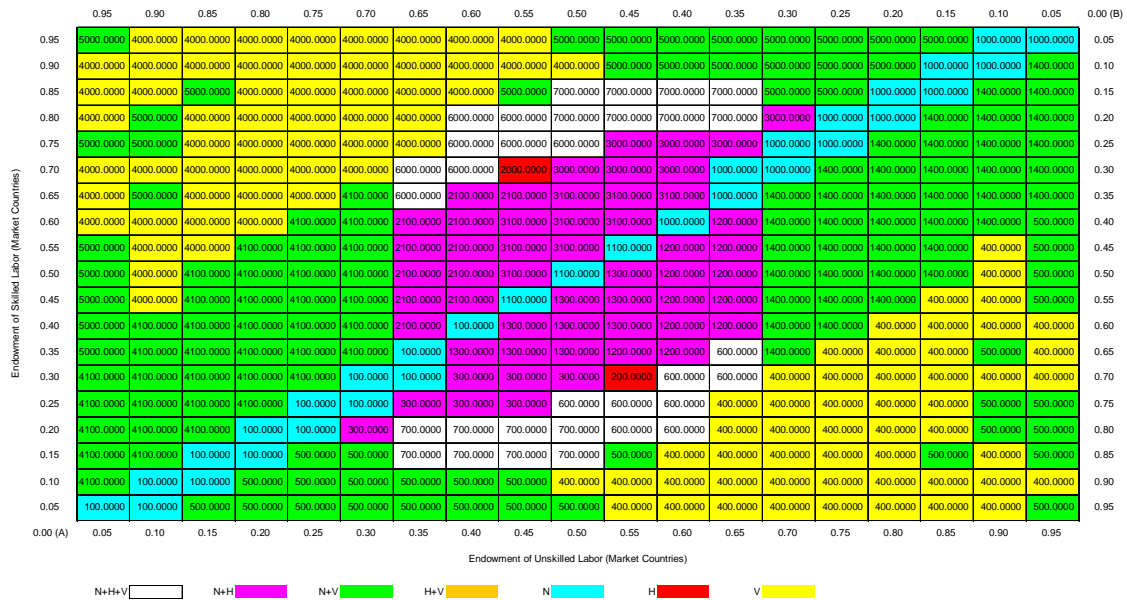


Figure 7: Lower Import Tariff on Finished Products ($v_{ij}^Y = 0$, Market Countries)

Let us move to the case of import tariff. The main difference between transportation

cost and import tariff is that a decrease in the former tends to reduce demand for the unskilled labor in the exporting country so that the relative wage of the factor depreciates, while a decrease in the latter just reduces income in the importing country. If the import tariff on components concerning the trade-link between two market countries is lowered, type-H firms extend their influence as in the case of transportation cost (Figure 6). In the present setting, the difference between transportation cost and import tariff noted above does not crucially affect the simulation results so that directions of the effects of lowering two items are identical. On the other hand, the volume of the effects is larger in this case of import tariff because the initial rate is much higher (0.2) than the one of transportation cost (0.1). This tendency is quite obvious if we see the case when the import tariff on finished products concerning the trade-link between the market countries is lowered. Figure 7 shows that type-H firms are replaced by type-N and type-V especially around the four corners.

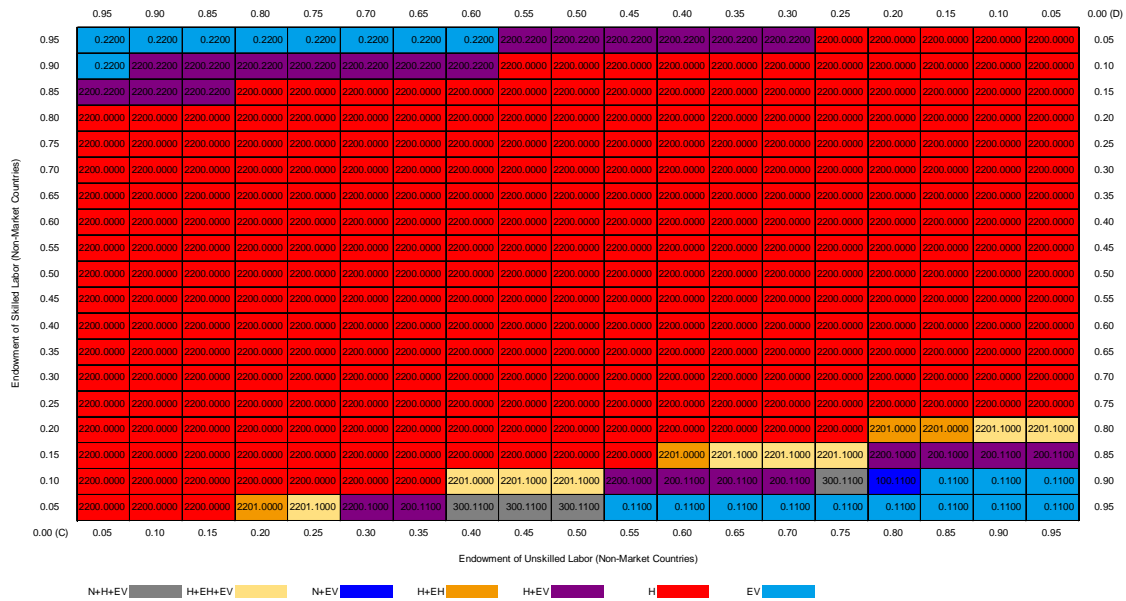


Figure 8: Lower Transportation Cost of Finished Products
 $(\tau_{AC}^Y = 0, \text{Non-Market Countries})$

When two non-market countries differ in size and relative factor endowment, lowering the transportation cost of finished products concerning the trade-link just between countries A and C motivates firms in country B to be type-EH and operate in country C . This phenomenon is obvious around the SE part in Figure 8, where the price of unskilled

labor in country C is relatively cheap. This result is consistent with the one obtained by Ekholm, Forslid, and Markusen (2007). Thus, type-EH firms tend to arise in the low-cost countries adjacent to a final market. In addition, the changing strategy by firms in country B to be type-EH, which may reduce cost burden, makes more efficient resource allocation possible. In consequence, type-N firms also increases in country B .

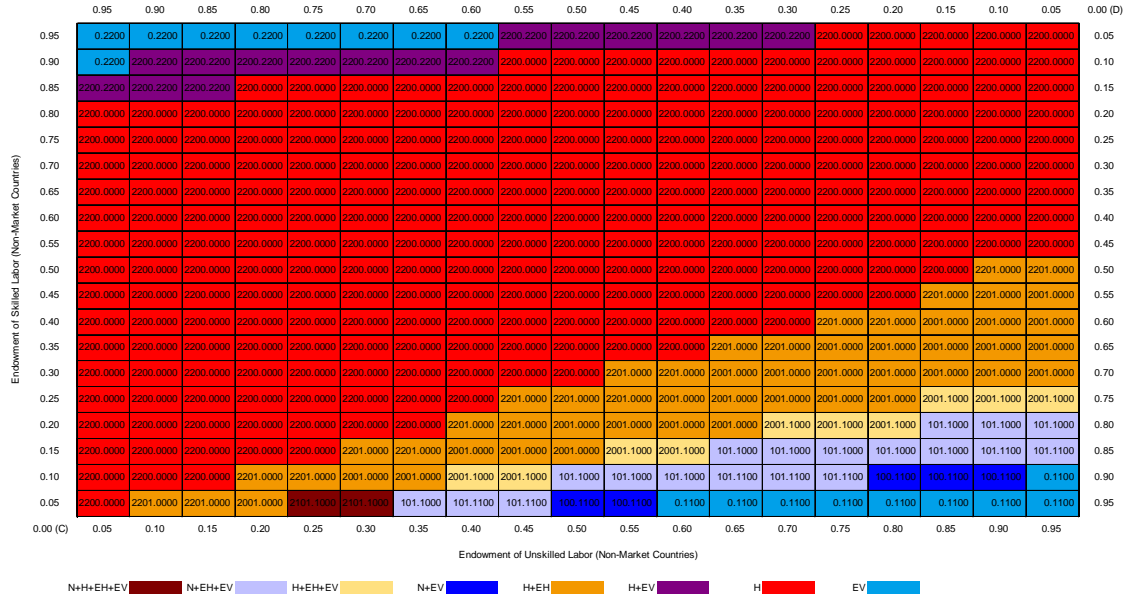


Figure 9: Lower Import Tariff on Finished Products
 $(v_{AC}^Y = 0, \text{Non-Market Countries})$

In the case of import tariff, much larger number of type-H firms in country B , which are serving for the market in country A , change their strategy to be type-EH operating in country C , for the same reason related to the initial rates of transportation cost and import tariff. Figure 9 shows the effects when the import tariff on finished products concerning the trade-link just between countries A and C is totally removed. In this case, it can be interpreted that type-EH firms arise in the low-cost countries in a free-trade area to serve the market in a FTA member.

Type-N firms also increases in country B as in the previous case. Since the impact is much larger than before, type-H firms in country A are superseded by type-N firms in country B beside the SE corner.

Then, one may notice that type-CI firms have never shown up so far. In which

circumstances do CMNEs emerge? The case when type-CI firms enter around the NW and SE corners, where cheaper skilled labor is available in either of the non-market countries, is captured by Figure 10. This picture is obtained with an extremely special setting, in which $\tau_{fr}^X = 0$, $\tau_{ij}^Y = \tau_{AD}^Y = \tau_{BC}^Y = 0.1 \times 10$, and $v_{AC}^Y = v_{BD}^Y = 0$. The setting implies that type-CI firms emerge in a case when a market country and a non-market country liberalize trade in the environment where transportation cost of components is low while the cost of finished products concerning the trade-link between market countries are high. An example of low transportation cost of components is the use of internet to send blue prints from headquarters to a local affiliate.

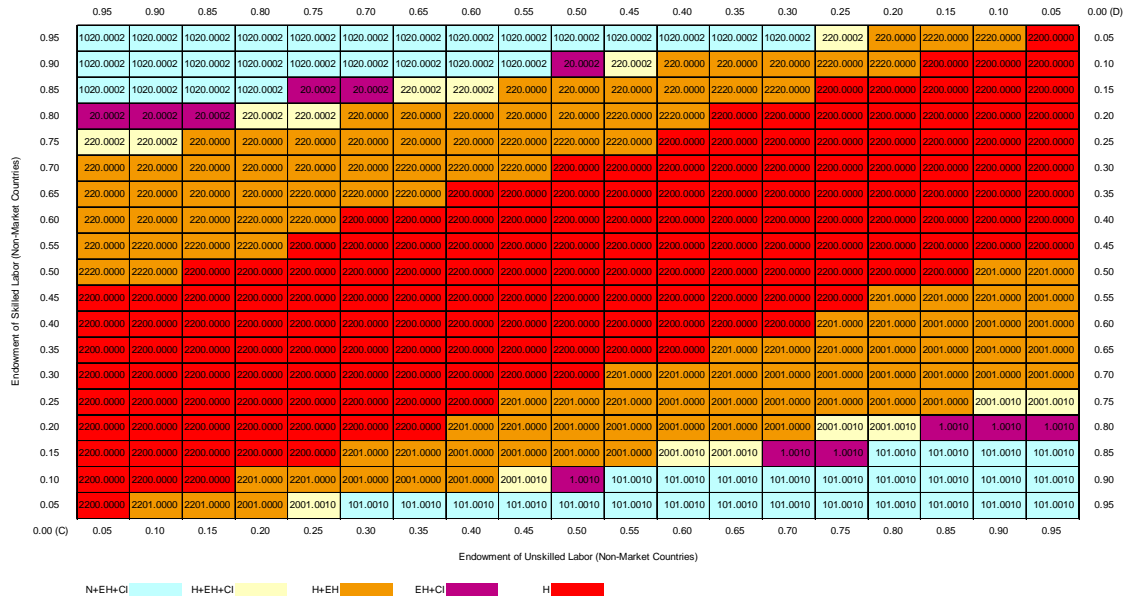


Figure 10: Complexly Integrated MNEs

Finally, no substantial difference can be observed with respect to other items, such as the country specific fixed cost G or the firm-type/trade-link specific cost F , from the base case patterns in either case when relative factor endowments for the market and non-market countries respectively are changed. The effects of independently controlling fixed cost on the type of active firms seem not to be large compared to those of trade costs in the present setting.

4.2 Experiments: Is FTA/EPA Effective for a Developing Country to Attract FDI?

Let us proceed to more scenario-oriented simulations. With these experiments, we examine the effects of liberalizing trade between a pair of market and developing (non-market) countries and of implementing cost-saving policies, such as standardizing rules or simplifying procedures related to opening business in the member countries, assuming the situation that the developing country in question is left behind of another rival in settling an economic partnership.³ Suppose that the country is in need of FDI to accelerate economic growth to catch up with rival countries.

To simulate trade liberalization between a pair of market and developing countries, both v_{iw}^X and v_{jw}^Y are set to zero (permanent removal). Let us call this case “FTA”. The additional cost-saving policy is expressed by lowering F_{iw}^{EH} , F_{iw}^{EV} , and F_{iw}^{CI} by almost half (0.7). We call the set of FTA plus this additional policy “EPA”. An example of the cost-saving policies is construction of special economic zones and industrial parks where kinds of preferential treatment in trade-related procedures are available.

4.2.1 Basic Environment

Onto the setting we observed previously, we introduce the situation that FTA between countries A and C has already been implemented. This is expressed by setting $\tau_{AC}^X = \tau_{AC}^Y = 0$. Figure 11 is a box diagram for the economic environment before country D concludes FTA with any market country. The regime pattern closely resembles the one captured in Figure 9 ($\tau_{AC}^Y = 0$). In the SE area, where the price of unskilled labor is relatively low, type-EV firms from both market countries A and B , and type-EH firms from country B operates in country C . As the central part of the box is approached, it implies that the relative price of skilled to unskilled labor falls, and firms established in country B change their form from type-EV to type-EH.

Note that the size of the area at the SE corner, where only type-EV firms are active, shrinks as the absolute level of total endowments for the developing countries become smaller. As we test different sizes of developing countries from double to half the size of the market countries, the impact on factor prices of one unit of foreign firm entrance becomes large for a small-sized country.

³ In this section, we suppose the non-market countries as developing ones.

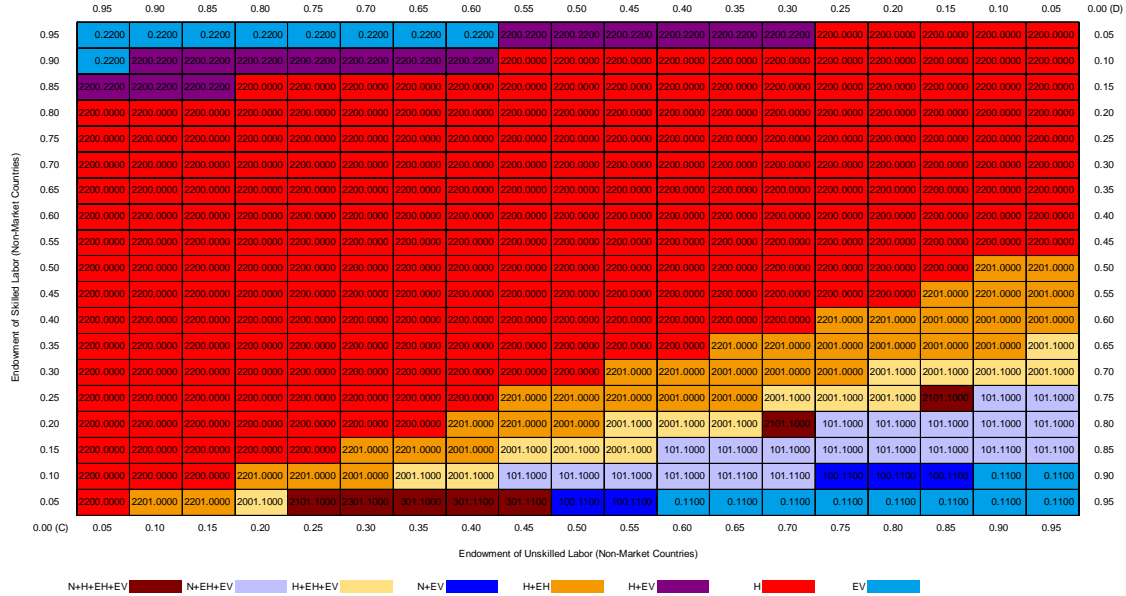


Figure 11: Lower Import Tariff on Components and Finished Products

$$(v_{AC}^X = v_{AC}^Y = 0, \text{ Non-Market Countries})$$

4.2.2 Effects of FTA/EPA with Country D on Firm Type

Suppose country D liberalizes trade with one of the market countries. When country A is selected, it is expressed by setting $\tau_{AD}^X = \tau_{AD}^Y = 0$. Figure 12 shows the regime pattern when both non-market countries C and D have liberalized trade with country A . It is clear that the perfectly identical pattern appears in the opposite corner leaving the pattern around the SE corner completely unaffected. In this case, a group of type-H firms established in country B turn into type-EH firms and start operating in country D to serve the market in country A . The participation of country D in the partnership with country A will not affect the welfare level or factor prices in country C . Furthermore, country D 's choice of FTA partner will not affect the regime pattern, as well as welfare levels and factor prices in both developing countries C and D , in the present setting wherein the two market countries are perfectly symmetric. The difference can be found in the nationality of the firms operating in country D , and in welfare levels in the market countries. If country D 's FTA partner is changed to country B , type-EH firms from country B are replaced by those from country A . In consequence, type-EH firms from country A and type-EV firms

from country B start operating in country D . The welfare level in the country that settles FTA with country D improves, while the country that has not been chosen as the FTA partner is worse off.

Another important point is that MNEs will not operate in non-market countries even though FTAs take place if their relative factor endowments are similar. To attract inward FDI, a developing country must have substantially cheap unskilled labor based on the rich relative endowment of the factor.

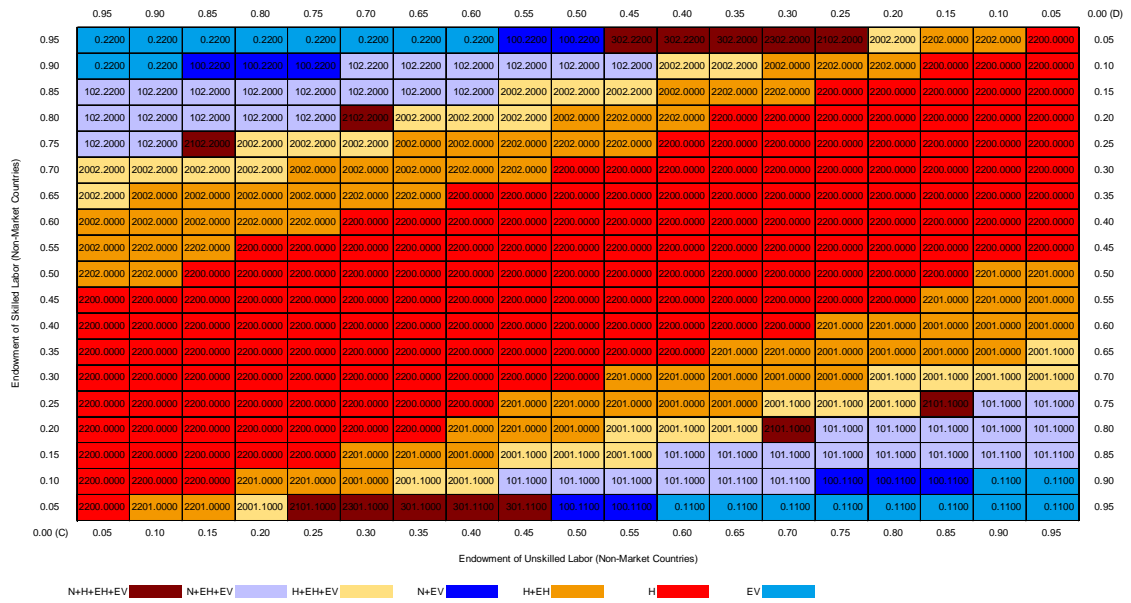


Figure 12: FTA with Countries D ($v_{AD}^X = v_{AD}^Y = 0$, Non-Market Countries)

Next, let us consider the case that country D settles an economic partnership program in which a cost-saving policy related to the firm-type/trade-link specific fixed cost is added to a regular FTA with one of the market countries. It is expressed by setting $F_{iD}^{EH} = F_{iD}^{EV} = F_{iD}^{CI} = 0.7$. Again, country D 's choice of FTA partner does not matter apart from the welfare levels of the market countries. Hence, either country A or B , whichever is selected as the FTA partner, is applied to the suffix i in F_{iD}^{EH} , F_{iD}^{EV} , and F_{iD}^{CI} . Note that the FTA between countries A and C does not include this additional option. The purpose is to see whether the subsequent starter, country D , can go further beyond the forerunner, country C .

Figure 13 shows the regime pattern when country A simultaneously establishes FTA

with country C and EPA with country D . In this case, type-EV firms extend their sphere of influence in the NW area. It is because lowering the firm-type/trade-link specific fixed cost saves skilled labor input, so that it becomes easier to integrate assembly plant in country D closing the plant in the home country. On the other hand, the border between the pure horizontal area and the area in which type-H and type-EH firms coexist does not move from the previous case. The requirement given a substantial difference in relative factor endowments to have assembly plants in a non-market country seems to be strong.

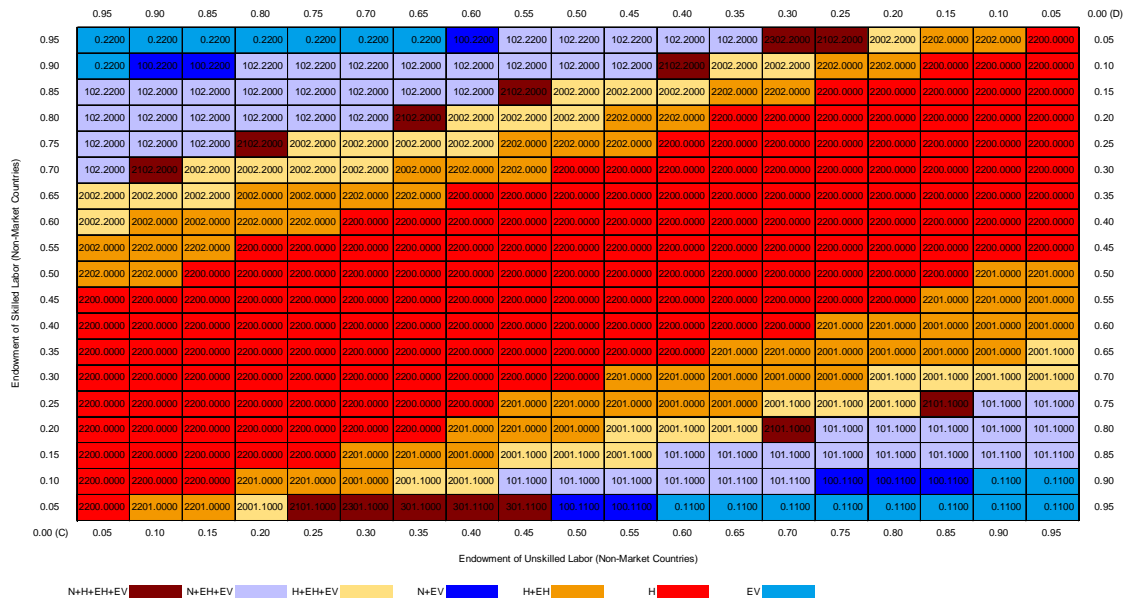


Figure 13: EPA with Country D

$$(F_{AD}^{EH} = F_{AD}^{EV} = F_{AD}^{CI} = 0.7 \text{ with FTA, Non-Market Countries})$$

4.2.2 Welfare Effects of FTA/EPA with Country D

Let us turn to verifying whether FTA/EPA brings benefits to country D . For this task, we examine welfare levels as well as factor prices as the source of income. In the present model, which does not consider any spillover effects from inward FDI that may help to enhance long-run growth rates, the advantage of having an assembly plant is just in the fact that it may increase income through affecting factor prices by extra demand for skilled and unskilled labor. Therefore, factor prices play an important role as the source of welfare gains. In the meantime, the implementation of FTA by country D never affects the welfare

level or factor prices in country C , as mentioned before.

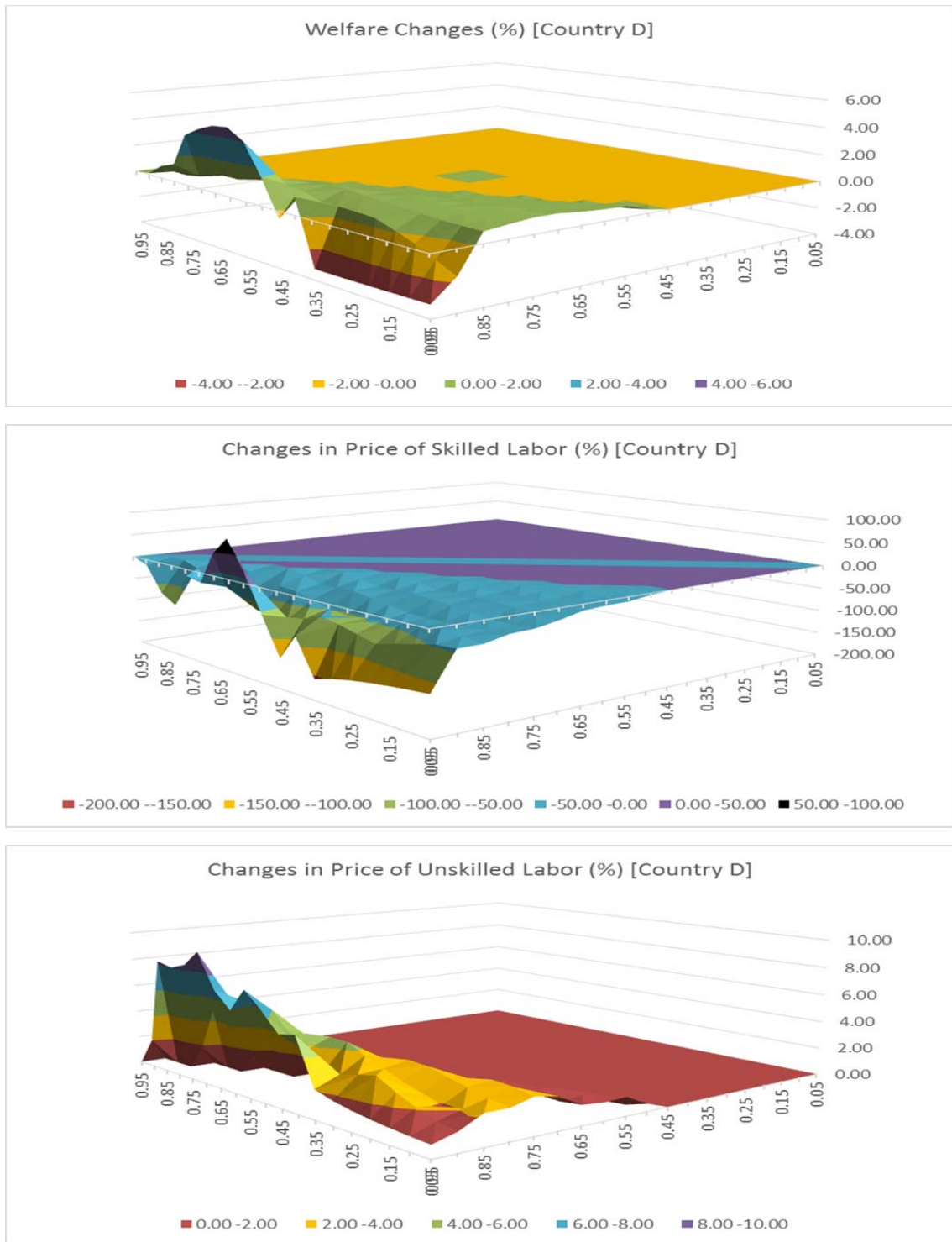


Figure 14: Effects of Implementing FTA with Country D

Figure 14 shows the effects of implementing FTA between country D and one of the market countries on welfare and factor prices. All values are in terms of percentage change with respect to the level of the corresponding item at the base case, which is captured by the benchmark SAM (Table 1). Hence, every value at the center of the box diagram becomes zero because we calibrated the model at the center of the diagram.

Notice that the FTA brings negative effects on welfare around the NW corner (front-most part in the pictures) where the price of unskilled labor is relatively low. This is the result of changes in the prices of two factors. As the picture in the middle shows, the effects on the price of skilled labor approaches from negative to zero if we trace the values from the NW corner to the center. In contrast, the effect on the price of unskilled labor changes from positive to zero (picture at the bottom). As we saw previously, the number of type-EH and type-EV firms established in country B/A and operating in country D expands by the FTA between countries A/B and D . This trend increases demand for unskilled labor in country D . As a result, relative wages of skilled/unskilled labor depreciates/appreciates.

The area that shows negative welfare impact corresponds to the points where the total income from both skilled and unskilled labor is lower than the base case. When the total endowments for the developing countries are smaller, the possibility of facing welfare losses is lower. On the other hand, the possibility grows as the total endowments become larger. This is because the rate of change of factor prices per unit increase of assembly plant becomes large in a small-sized country. A way to avoid welfare losses is to increase the availability of skilled labor in the country. Investing to educate nations and other efforts to accumulate human capital may help.

In the area around the NE corner (left-hand side in the pictures) where unskilled labor is relatively scarce and valuable, welfare levels much improve. In this area, the price of unskilled labor is relatively sensitive to a unit increase of assembly plant. Therefore, the increase of type-EH firms raises the price of unskilled labor to a large extent around the NE corner. This trend brings welfare gains to country D by the FTA.

Next, Figure 15 shows the effects of implementing the cost-saving policies in addition to the FTA between country D and one of the market countries. The supplementary option may enhance welfare gains from the FTA, and there is a possibility to recover the welfare effects from negative to positive around the neighborhoods surrounding the NW corner where type-EV firms may extend their influence. This tendency becomes strong when the total endowments for the developing countries are large.

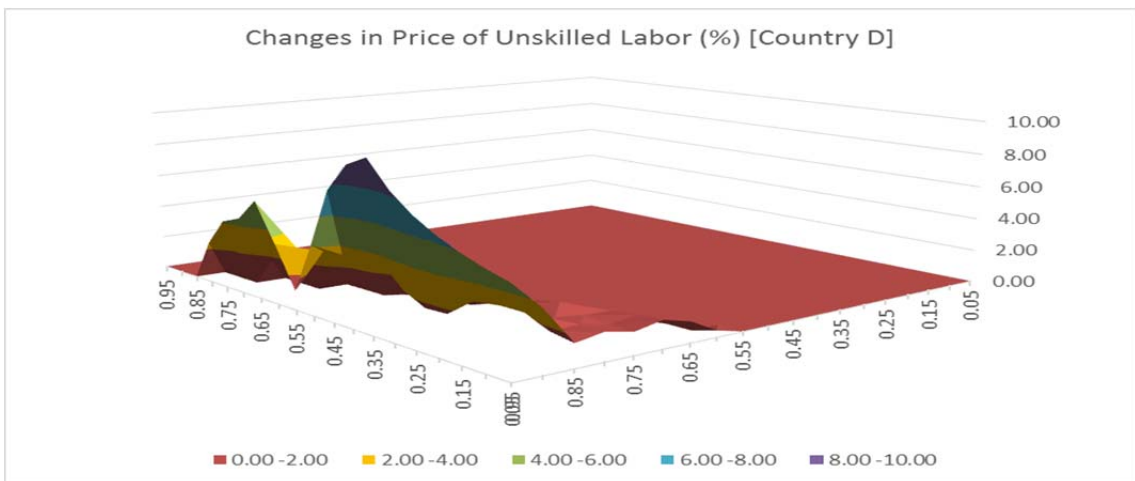
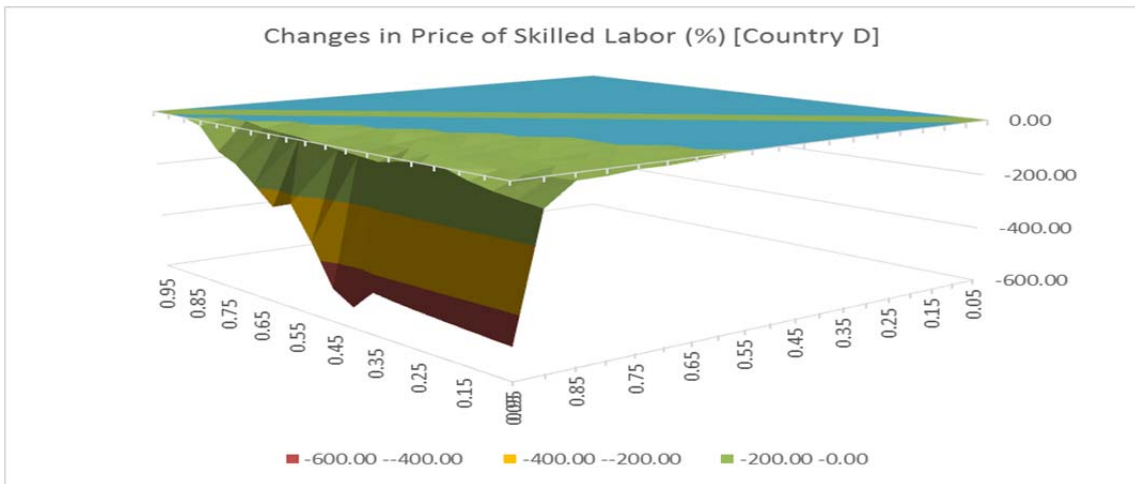
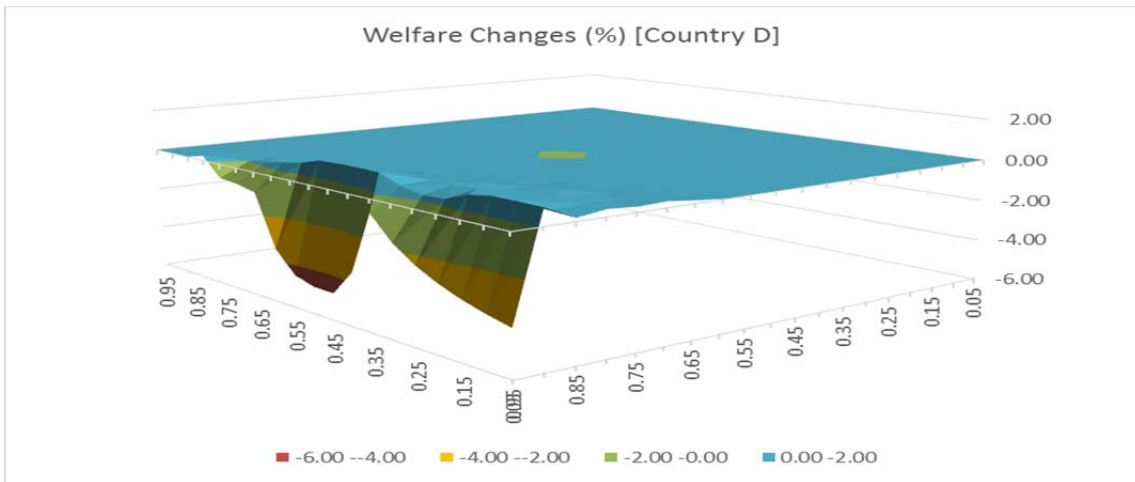


Figure 15: Effects of Additional Implementation of Cost-Saving Policies

5. Concluding Remarks

To prepare an answer to the question of how a developing country can attract FDI, this paper explored the factors and policies that may help bring FDI into a developing country, utilizing an extended version of the knowledge-capital model that includes six types of firms and four countries grouped into developed (market) and developing (non-market) ones in a general equilibrium framework. Simulations with the model revealed conditions for which each type of firm would be active in a given economic environment. With a special focus on the effects of FTA/EPA between a market country and a developing country, the key findings can be summarized as follows.

1. When two developing countries differ in size and relative factor endowment, lowering the trade cost (transportation cost or import tariff) of finished products concerning a trade-link between a market country and a developing country motivates firms in a country “not” on the link to be an export-platform MNE operating in the developing country on the link.
2. Complexly integrated MNEs emerge in a case when a market country and a developing country liberalize trade in the environment where transportation cost of components is low while the cost of finished products concerning the trade-link between market countries are high.
3. MNEs will not setup plants in developing countries if their relative factor endowments are similar even when FTA takes place between some of those countries and a country where there is a market for the commodity produced by the MNE. To attract inward FDI, a developing country must have substantially cheap unskilled labor based on a rich relative endowment of the factor.
4. In the present setting wherein two market countries are perfectly symmetric, a developing country’s choice of FTA partner from among the market countries will not affect the production pattern of firms, welfare levels, or factor prices in the developing countries. On the other hand, the welfare level in the market country that settles the FTA with a developing country improves, while the market country that has not been chosen as the FTA partner is worse off.

5. Although FTA/EPA generally tends to increase FDI to a developing country, the possibility to improve welfare through increased demand for skilled and unskilled labor becomes lower as the size of the country grows. This is because the rate of change of factor prices per unit assembly plant increase becomes small in a large-sized country.
6. A developing country may suffer severe welfare losses through FTA/EPA if the availability of skilled labor is extremely limited. To avoid this problem, policies to increase the availability of skilled labor in the country, such as investing in education, may help.
7. Because the additional implementation of cost-saving policies to reduce the firm-type/trade-link specific fixed cost tends to depreciate the price of skilled labor by saving its input, a developing country, in which skilled labor is relatively scarce but not extremely scarce, can enhance welfare gains from FTA, and it is even possible to recover the welfare effects from negative to positive, by making the arrangement to be EPA. This tendency becomes strong when the total endowments for the developing countries are large.

There are several potentially important issues that we have not yet taken into account in our analytical framework. First, the present model does not consider any spillover effects from inward FDI that may contribute to enhance long-run growth rates. Inclusion of such positive effects possibly brought by FDI will change some of the results listed above (#5 and #6). Second, the production of components in foreign market countries and in developing countries is obvious in the real economy. Although such a model must be highly complicated, it is worth challenging.

References

- Brooke, A., D. Kendrick, and A. Meeraus (1992), *GAMS: A User's Guide. Release 2.25.*, Scientific Press: San Francisco.
- Ekholm, K., R. Forslid, and J. R. Markusen (2007), "Export-Platform Foreign Direct Investment," *Journal of the European Economic Association*, 5(4), pp. 776-795.
- Ferris, M. C., and T. S. Munson (1998), "Complementarity Problems in GAMS and the

- PATH Solver,” *Journal of Economic Dynamics and Control*, 24, pp. 165-188.
- Grossman, G. M., E. Helpman, and A. Szeidl (2006), “Optimal Integration Strategies for the Multinational Firm,” *Journal of International Economics*, 70, pp. 216-238.
- Ito, T. (2013), “Export Platform Foreign Direct Investment: Theory and Evidence,” *The World Economy*, 36(5), pp. 563-581.
- Markusen, J. R. (1997), “Trade versus Investment Liberalization,” NBER Working Papers, 6231, National Bureau of Economic Research.
- Markusen, J. R. (2002), *Multinational Firms and the Theory of International Trade*, MIT Press: Cambridge.
- Navaretti, G. B., and A. Venables (2004), *Multinational Firms in the World Economy*, Princeton University Press: New Jersey.
- Yeaple, S. R. (2003), “The Complex Integration Strategies of Multinationals and Cross Country Dependencies in the Structure of Foreign Direct Investment,” *Journal of International Economics*, 60(2), pp. 293-314.
- Zhang, K. H., and J. R. Markusen (1999), “Vertical Multinationals and Host-Country Characteristics,” *Journal of Development Economics*, 59(2), pp. 233-252.