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Kazuhiko OYAMADA

July 2017

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To prepare an answer to the question of how a developing country can attract foreign direct investment (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 a free trade agreement (FTA) or an economic partnership agreement (EPA) between a pair of market and non-market countries, simulations with the model revealed the following: (1) although FTA/EPA generally tends to increase FDI to a developing country, the possibility of improving welfare through increased demand for skilled and unskilled labor decreases 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; and (3) a developing country can enhance welfare gains from a FTA, and it is even possible to recover the welfare effects from negative to positive, by making the arrangement an EPA.

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

JEL classification: F11; F12; F15; F23

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INSTITUTE OF DEVELOPING ECONOMIES (IDE), JETRO
3-2-2, WAKABA, MIHAMA-KU, CHIBA-SHI
CHIBA 261-8545, JAPAN

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

Kazuhiko OYAMADA[†]

July 15, 2017

Abstract

To prepare an answer to the question of how a developing country can attract foreign direct investment (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 a free trade agreement (FTA) or an economic partnership agreement (EPA) between a pair of market and non-market countries, simulations with the model revealed the following: (1) although FTA/EPA generally tends to increase FDI to a developing country, the possibility of improving welfare through increased demand for skilled and unskilled labor decreases 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; and (3) a developing country can enhance welfare gains from a FTA, and it is even possible to recover the welfare effects from negative to positive, by making the arrangement an EPA.

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[†] Institute of Developing Economies, Japan External Trade Organization (IDE-JETRO), 3-2-2 Wakaba, Mihama-Ku, Chiba-Shi, Chiba 261-8545, Japan (kazuhiko_oyamada@ide.go.jp).

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 widely been conducted since the late 1980s, few studies have comprehensively handled every operational pattern of MNEs in one model. In particular, the export-platform is not much discussed in the theoretical studies, even though its importance has been revealed by empirical research. As a low-cost developing country may play a significant 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 and includes export-platforms in one consistent 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 were 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 had only one factor of production, and the non-market country was just assumed to set exogenous factor pricing in a partial equilibrium framework. Another work that nests every type of MNE in one model was presented by Ito (2013). Extending the two-region, four-country (two countries in each region) model developed by Navaretti and Venables (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 can 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 that 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 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): we include 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, 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 non-market countries, in which the final assembly process of multinational production may take place, while the finished products are not sold locally but exported, in addition to the two market countries assumed in the original model, in which MNEs are established and there are final markets for the commodity produced by those MNEs.¹

An important point here is that we do not limit the volumes of those non-market countries, which always stay small in terms of factor endowments. As 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 the market and non-market countries in this paper as corresponding to developed and developing countries, respectively, 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 significantly 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 good, 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 the regular good produced by the non-MNE with a constant-returns-to-scale (CRTS) technology so that the market is perfectly competitive. Z is produced in every country r , and 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 group, given absolute levels of total endowments for the groups.

In the IRTS sector, two types of fixed costs, 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 to operate on a trade-link between the home and a foreign country (firm-type/trade-link specific).

There are trade costs (transportation cost and import tariff) 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 the transportation. 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 is established and headquartered in country 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 domestic and/or foreign subsidiary(ies) 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 takes 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 and/or exported to a foreign market j . If it takes place in a foreign market country i , the products are sold locally and/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 letter referring to the destination market j , and the third letter referring to the location of its assembly plant (i or w). When some of those letters can be omitted 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 firm 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 firm produces components X in country i , some of which are shipped to an assembly plant in country w . All the final products Y produced in country w are exported to the foreign market in country j , while those 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 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 the final products Y produced in country w are exported back to the home market in country i , while those 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 are located in the country placed on the left-hand side of the image.

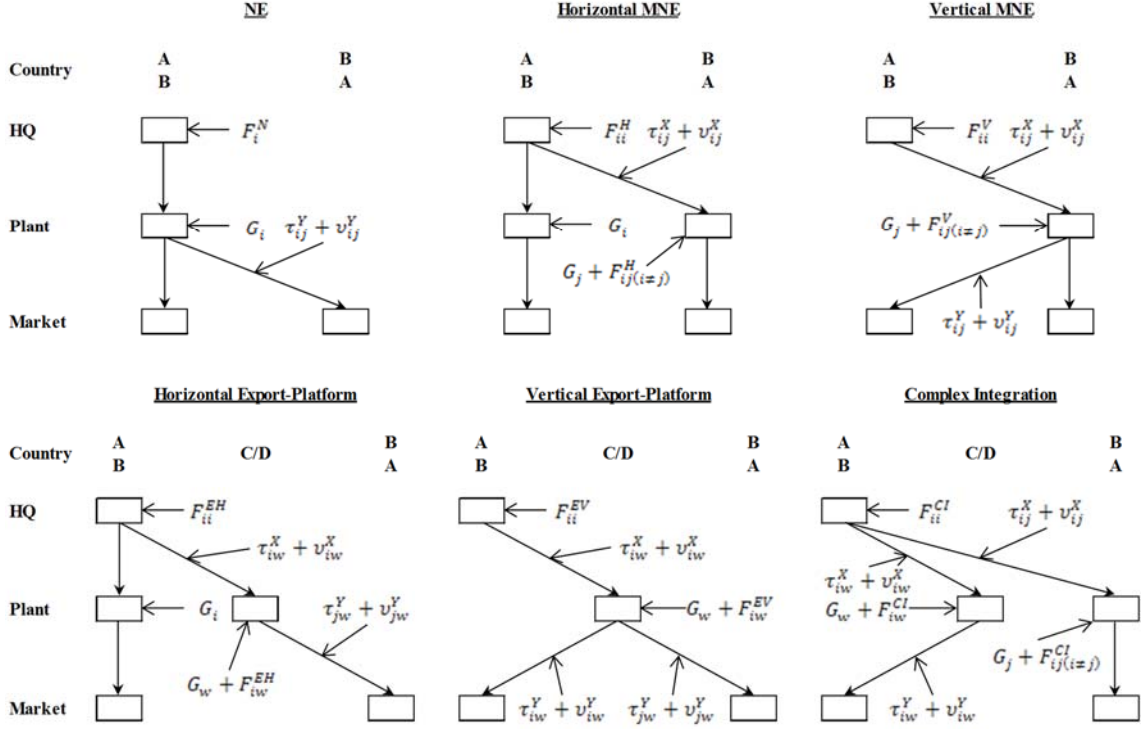


Figure 1: Six Types of Production Patterns

2.2.1 Type-N Firm Established in Country i

The type-N firms produce three kinds 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 the 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 costs with respect to $Y_{ij(i=j)}^N$. Similarly, the second term corresponds to the variable costs 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

The type-H firms produce four kinds 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 subsidiary in the foreign market country j , skilled labor is needed for local administration and management:

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

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 operate an assembly plant in country j .

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

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

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

where

v_{ij}^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}^H . The second term corresponds to those with respect to Y_{ij}^H . The third term is the total fixed cost.

2.2.3 Type-V Firm Established in Country i

The type-V firms produce three kinds of products: components X_{ij}^V , final products for the home market Y_{ii}^V , and final products for the foreign market Y_{jj}^V . The skilled labor requirements to produce one unit of components in the home country i can be expressed as:

$$K_{ii}^V = \theta^K X_{ij}^V + F_{ii}^V, \tag{13}$$

where

K_{ii}^V is the skilled labor input hired in country i ,
 X_{ij}^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}^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:

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

and

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

where

L_{ij}^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 .

Similar to the case of the type-H firm, skilled labor is needed at the subsidiary for local administration and management:

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

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 operate an assembly plant in country j .

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

2.2.4 Type-EH Firm Established in Country i

The type-EH firms produce four kinds 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 subsidiary in a non-market country w , skilled labor is needed for local administration and management:

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

where

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

Then, the cost function for the 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

The type-EV firms produce two kinds 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 subsidiary for local administration and management:

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

where

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

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

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

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

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

The type-CI firms produce four kinds of products: components $X_{ij(i \neq j)}^{CI}$, components X_{iw}^{CI} , final products for the domestic market Y_{iww}^{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 j 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 subsidiaries in countries j and w , skilled labor is needed for local administration and management, 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 operate 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 operate an assembly plant in country w .

Then, the cost function for the 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 type-Y good 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. As 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 good 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

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

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

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

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

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

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

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

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 as:

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

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

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

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

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

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 determined by Inequalities (51) through (58) and (65) through (70), respectively, given the factor and commodity prices determined by the market-clearing conditions that will be seen later.

2.3 Type-Z Good Producer

The 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

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

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

2.4 Consumer

The representative consumer in every country r maximizes her/his utility subject to the budget constraint, 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 good produced in the IRTS sector,
- Z_i^U is the consumption level of type-Z good produced in the CRTS sector,
- β_i is the share of type-Y good (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 appears in the right-hand side of Equation (75). Note that we implicitly assume balanced trade, so 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), which shows the marginal utility of income. Equations (76) and (77) determine the levels of Y_i^U and Z_i^U .

2.4.2 Consumer in Country w

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

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

where

U_w is the welfare level of the representative consumer in country w and Z_w^U is the consumption level of type-Z good produced in the CRTS sector.

Similar 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). Equation (80) determines the level of Z_w^U .

2.4.3 Tariff Revenue

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

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

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

and

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

We presume that the tariff revenue in each country 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:

$$\bar{K}_i = K_i^Z + M_i^N K_i^N + M_i^H K_{ii}^H + \sum_j (M_j^H K_{ji}^H)_{(i \neq j)}$$

$$\begin{aligned}
& + M_i^V K_{ii}^V + \sum_j (M_j^V K_{ji}^V)_{(i \neq j)} + \sum_w M_{iw}^{EH} K_{ii}^{EH} + \sum_w M_{iw}^{EV} K_{ii}^{EV} \\
& + \sum_w \left\{ M_{iw}^{CI} K_{ii}^{CI} + \sum_j (M_{jw}^{CI} K_{ji}^{CI})_{(i \neq j)} \right\}
\end{aligned} \tag{81}$$

and

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

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:

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

and

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

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 kinds of commodity for final consumption are equated to determine their price levels, as follows:

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

and

$$\sum_r Z_r^U = \sum_r Z_r. \tag{86}$$

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

As one of the market-clearing conditions (81) through (86) automatically holds,

because of *Walras' Law*, we drop Equation (86) from the system, treating the type-Z good as the numéraire. Consequently, 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 marginal utility of income for the representative consumer in country i (λ_i), the consumption levels of the two kinds of commodity by the representative consumer in country i (Y_i^U and Z_i^U), the marginal utility of income for the representative consumer 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 kinds 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 by 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 kinds of computational difficulty in the numerical application of an analytical model such as the one we introduced in the previous section. One difficulty 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 that is not being focused on are kept identical for the two countries in the group to avoid complexities in interpreting the results. Then, a box diagram à la *Edgeworth box* is drawn, placing the total skilled labor endowment for the focused group on one axis and the total unskilled labor endowment on another axis to capture the regime, welfare level, factor prices, etc., 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 identical. At this point, it is assumed that only HMNEs are active, due to the existence of high trade costs between the two market countries in the base case. Then, there are no local subsidiaries and plants in the non-market countries, and there is no trade with respect to the type-Z good. 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. In particular, 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 the 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 between operational types 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 similar. Relation (87) is based on the jointness assumption shown above.

Relation (88) is related to the headquarter cost. First, the type-H firm is more costly than the 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). A similar relation applies to the type-V and type-EV firms. Third, the type-N firm is costlier than either the type-V or type-EV firms, because the latter may hire local skilled labor to train unskilled labor in the host country.

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

Relation (90) is related to the total cost. The type-V and type-EV firms are less costly than the type-H and type-EH firms, because the former has only one assembly plant in a non-market country and, thus, additional payment for managerial and coordination activities is not required. Among the type-H and type-EH firms, we assume that operating an assembly plant is costlier in a market country than in a non-market country. A similar relation applies to the type-V and type-EV firms. The costliest firm is the 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 fragmentation is not perfect.

One point to note is that we presume the plant-level production of the type-Y good is less skilled-labor intensive than is that of the type-Z, which represents the composite of all kinds of other commodities, unlike the original theory (Carr, Markusen, and Maskus

2001:694; Markusen 2002:133). Based on the Global Trade Analysis Project (GTAP) 9A Data Base for 2011 (Hertel 1997), shares of skilled-labor in the total labor inputs with respect to the manufacturing sector and the sector that includes both primary industries and services in the 24 countries, in which the world's top 100 non-financial MNEs for 2015 (UNCTAD 2016) are established, are 37.837% and 56.795%, respectively, whereas the share with respect to the overall production in the rest of the world is 48.707%.³ The countries with the top 100 investors can be regarded as the market countries in this study, while the countries without are the non-market countries. Thus, assuming that MNEs mainly reside in the manufacturing sector, we stipulate the skilled-labor intensity of activities as

$$\begin{aligned}
& X_i \text{ (Headquarters Only)} \\
& > X_i + Y_r \text{ (Integrated Production of Type-Y)} \\
& > Z_r \text{ (Production of Type-Z)} \\
& > Y_r \text{ (Plant Only)}.
\end{aligned}$$

This assumption of factor-intensity significantly affects the simulation results, as will be seen later. While MNEs are often considered as being more skilled-labor intensive than are local firms in developing countries, we suspect that the hypothesis holds only for industries classified within the same category. In addition, there has long been debate over whether FDI may substantially increase the wage skill premium. As yet, there is no clear answer to this question (Verhoogen 2008; Amiti and Cameron 2012). Thus, we just set an assumption based on available data and perform simulation experiments.

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

$$\begin{aligned}
F_i^N &= 4.0, \\
F_{ij}^H &= 4.2 \text{ (} i = j \text{)}, 1.4 \text{ (} i \neq j \text{)}, \\
F_{ij}^V &= 3.4 \text{ (} i = j \text{)}, 1.4 \text{ (} i \neq j \text{)}, \\
F_{ir}^{EH} &= 4.2 \text{ (} r = i \text{)}, 0 \text{ (} r \neq i \text{)}, 1.3 \text{ (} r = w \text{)}, \\
F_{ir}^{EV} &= 3.4 \text{ (} r = i \text{)}, 0 \text{ (} r \neq i \text{)}, 1.3 \text{ (} r = w \text{)}, \text{ and}
\end{aligned}$$

³ The 24 countries are: Australia, China, Hong Kong, Japan, Korea, Taiwan, Malaysia, United States, Mexico, Brazil, Belgium, Denmark, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Spain, Sweden, United Kingdom, Switzerland, Norway, and Israel. If we also include the top 100 investors from developing and transition economies, 12 countries are added to the previous 24. Those are the Philippines, Singapore, Thailand, India, Argentina, Venezuela, Russian Federation, Kuwait, Qatar, Saudi Arabia, United Arab Emirates, and South Africa. While Algeria should also be included, it is not separately available in the GTAP 9A Data Base. In the latter case, shares of skilled-labor with respect to the three sectors become 37.316%, 56.385%, and 48.616%, respectively. Hence, the ranking of skilled-labor intensity of activities does not change.

$$F_{ir}^{CI} = 4.2 \quad (r = i), 1.4 \quad (r \neq i), 1.3 \quad (r = w).$$

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:

$$\tau_{ir}^X = \tau_{jr}^Y = 0.1,$$

$$v_{ir}^X = v_{jr}^Y = 0.2,$$

$$\theta^K = 1,$$

$$\theta^L = 0.875, \text{ and}$$

$$\theta^X = 0.125.$$

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

$$p_w^K = p_w^L = p^Z = 1 \text{ and}$$

$$p_i^Y = 1.25.$$

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):

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

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):

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

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 firm's owner, respectively. In this case, we presume that all 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.

	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

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 grouping is done to reveal some of the behavioral characteristics of the model. The second is done to examine whether a free trade agreement (FTA) or an economic partnership agreement (EPA) would be effective for a non-market (developing) country to stimulate incoming FDI, in a situation where the country is left behind another non-market (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 group, 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, respectively, are 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

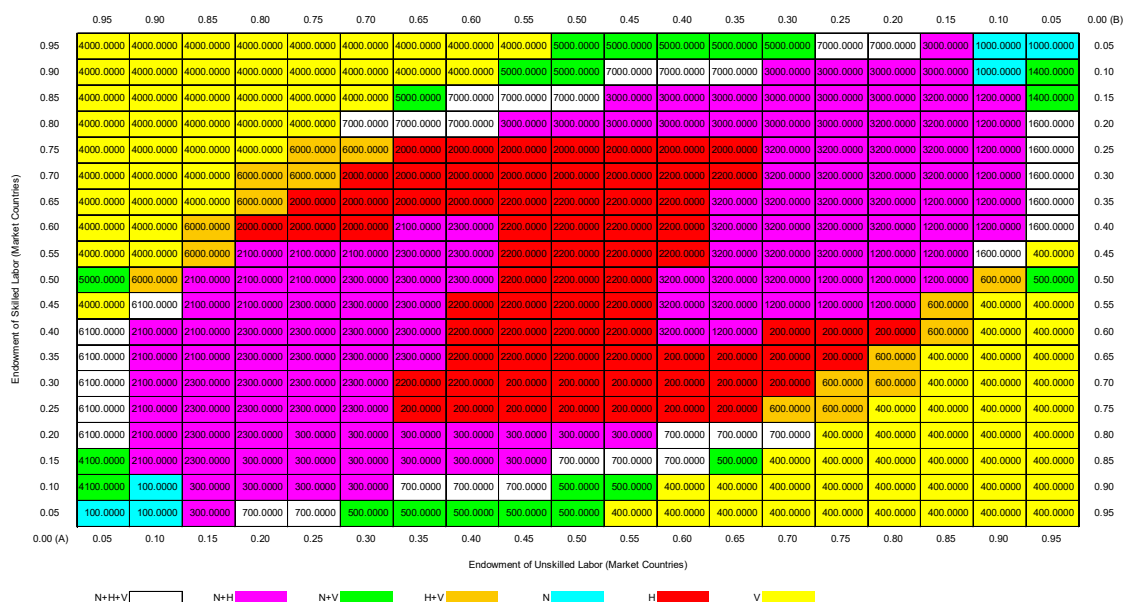


Figure 2: Equilibrium Regime in the Base Case (Market Countries)

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:

$$\begin{aligned} \tau_{ir}^X &= \tau_{jr}^Y = 0.1, \\ u_{ir}^X &= u_{jr}^Y = 0.2, \\ F_i^N &= 4.0, \\ F_{ij}^H &= 4.2 \quad (i = j), 1.4 \quad (i \neq j), \end{aligned}$$

$$\begin{aligned}
F_{ij}^V &= 3.4 \quad (i = j), 1.4 \quad (i \neq j), \\
F_{ir}^{EH} &= 4.2 \quad (r = i), 0 \quad (r \neq i), 1.3 \quad (r = w), \\
F_{ir}^{EV} &= 3.4 \quad (r = i), 0 \quad (r \neq i), 1.3 \quad (r = w), \\
F_{ir}^{CI} &= 4.2 \quad (r = i), 1.4 \quad (r \neq i), 1.3 \quad (r = w), \text{ and} \\
G_j &= 0.6458.
\end{aligned}$$

In the box, the vertical axis corresponds to the total endowment of skilled labor for the two market countries, and the horizontal axis corresponds 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

$$\begin{aligned}
\omega_A^N &= 1000 \text{ if type-N firms established in country } A \text{ are active, otherwise } 0, \\
\omega_B^N &= 100 \text{ if type-N firms established in country } B \text{ are active, otherwise } 0, \\
\omega_A^H &= 2000 \text{ if type-H firms established in country } A \text{ are active, otherwise } 0, \\
\omega_B^H &= 200 \text{ if type-H firms established in country } B \text{ are active, otherwise } 0, \\
\omega_A^V &= 4000 \text{ if type-V firms established in country } A \text{ are active, otherwise } 0, \\
\omega_B^V &= 400 \text{ if type-V firms established in country } B \text{ are active, otherwise } 0, \\
\omega_{AC}^{EH} &= 10 \text{ if type-EH firms established in country } A \text{ operating in country } C \\
&\quad \text{are active, otherwise } 0, \\
\omega_{AD}^{EH} &= 20 \text{ if type-EH firms established in country } A \text{ operating in country } D \\
&\quad \text{are active, otherwise } 0, \\
\omega_{BC}^{EH} &= 1 \text{ if type-EH firms established in country } B \text{ operating in country } C \\
&\quad \text{are active, otherwise } 0, \\
\omega_{BD}^{EH} &= 2 \text{ if type-EH firms established in country } B \text{ operating in country } D \\
&\quad \text{are active, otherwise } 0, \\
\omega_{AC}^{EV} &= 0.1 \text{ if type-EV firms established in country } A \text{ operating in country } C \\
&\quad \text{are active, otherwise } 0, \\
\omega_{AD}^{EV} &= 0.2 \text{ if type-EV firms established in country } A \text{ operating in country } D \\
&\quad \text{are active, otherwise } 0, \\
\omega_{BC}^{EV} &= 0.01 \text{ if type-EV firms established in country } B \text{ operating in country } C
\end{aligned}$$

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 the type-H firms prevail 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, the 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, the 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 follows the opposite pattern. These relationships reverse toward the SE corner. 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 set up plants in non-market countries but go straight to the market countries as type-H firms. This occurs because there is no significant difference between relative factor prices among the countries. On the other hand, around the NW and SE corners, where cheaper unskilled labor is available in either of the non-market countries, the type-EV firms become active. For instance, around the SE corner, unskilled labor is relatively abundant in country C , so the type-EV firms from both countries A and B operate in C . Around the NW corner, firms operating in country D will be dominant. Note that, in this base case captured by Figures 2 and 3, the type-EH and type-CI firms never show up.

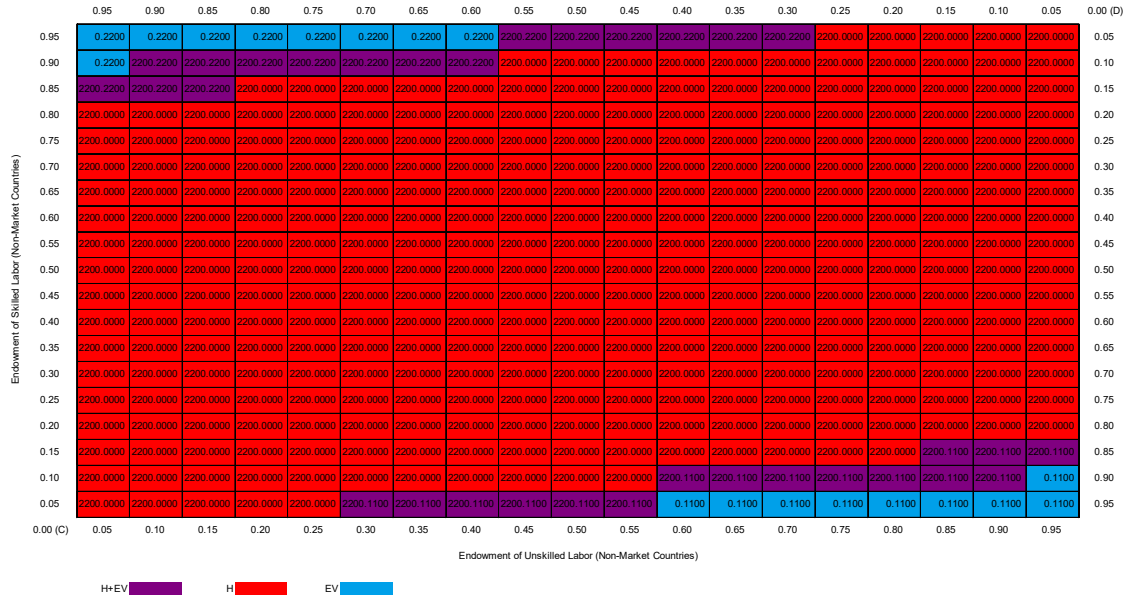


Figure 3: Equilibrium Regime in the Base Case (Non-Market Countries)

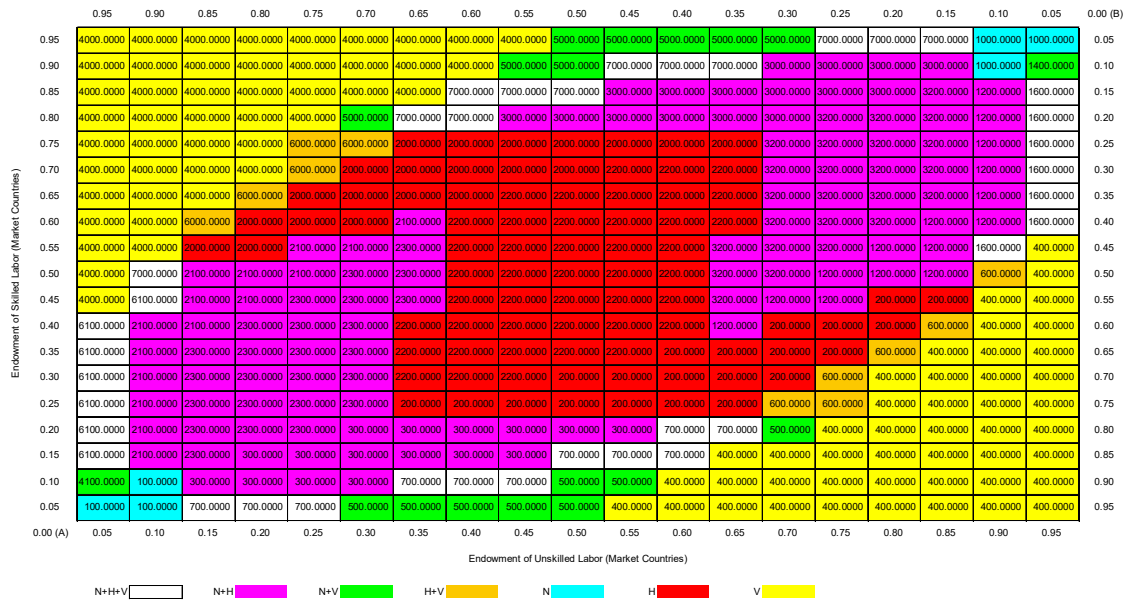


Figure 4: Lower Transportation Cost of Components ($\tau_{ij}^X = 0$, Market Countries)

Next, let us see what happens when selected values of trade and fixed costs change.

If the transportation cost of components sold on the trade-link between the market countries is lowered, the type-H firms extend their influence (Figure 4). In this case, it is quite natural that sending components to the foreign market country for local production becomes cheaper than does exporting finished products. As the type-H firms increase, the incentive to operate in non-market countries as the type-EV becomes weak.

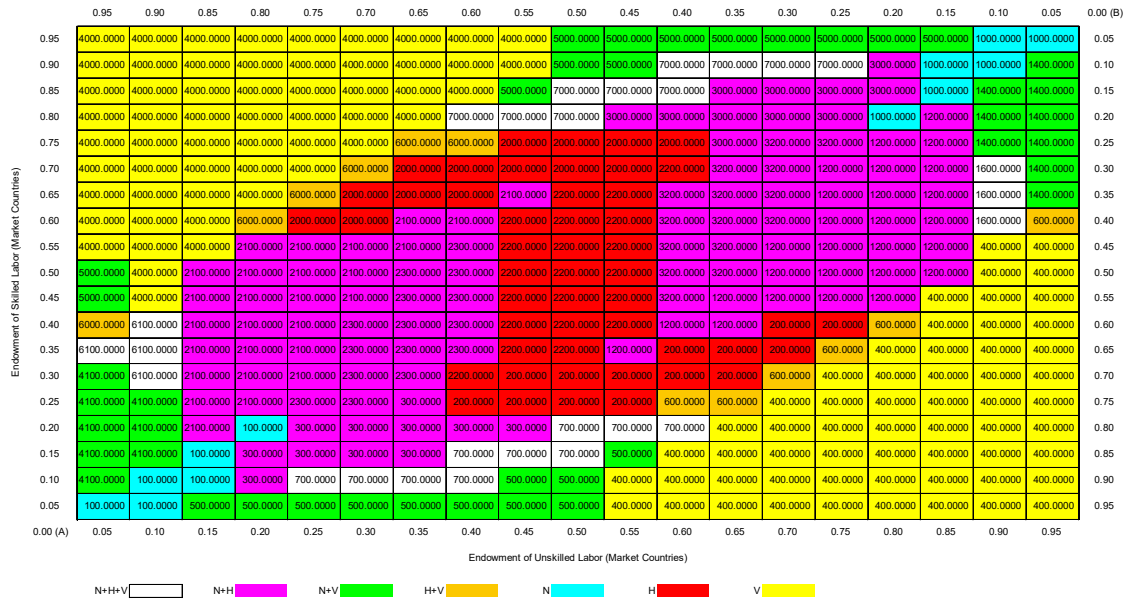


Figure 5: Lower Transportation Cost of Finished Products ($\tau_{ij}^Y = 0$, Market Countries)

When the transportation cost of finished products sold on the trade-link between the market countries is lowered, the type-N firms increase (Figure 5). In this case, contrary to the previous case, exporting finished products to the foreign market country becomes cheaper than is sending components for local production. The type-N firms extend their influence along the SW-NE diagonals where the relative factor endowment and factor prices tend to be similar in the two market countries. 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 costs of components.

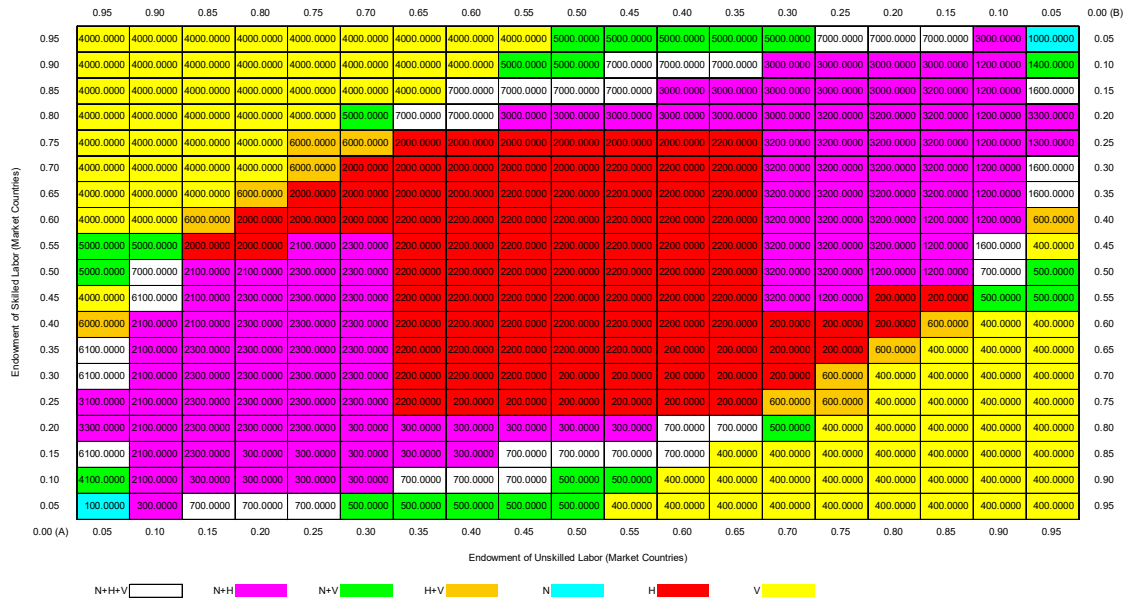


Figure 6: Lower Import Tariff on Components ($v_{ij}^X = 0$, Market Countries)

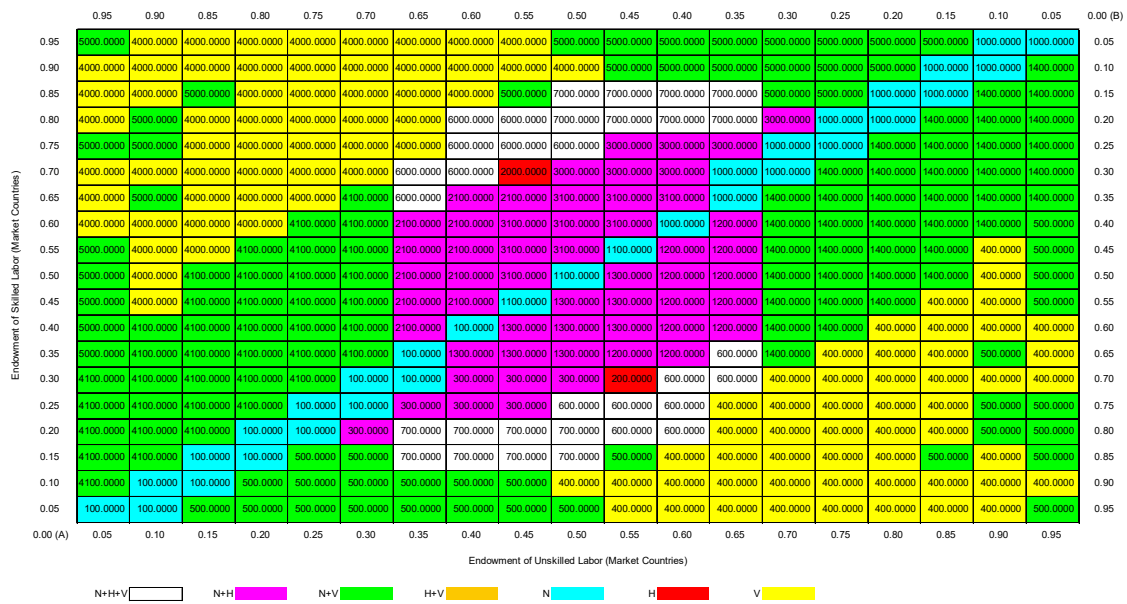


Figure 7: Lower Import Tariff on Finished Products ($v_{ij}^Y = 0$, Market Countries)

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 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 sold on the trade-link between two market countries is lowered, the 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, as noted above, does not crucially affect the simulation results, so working 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 is that of transportation cost (0.1). This tendency is quite obvious in view of the case when the import tariff on finished products sold on the trade-link between the market countries is lowered. Figure 7 shows that the type-H firms are replaced by the type-N and type-V firms, especially around the four corners.

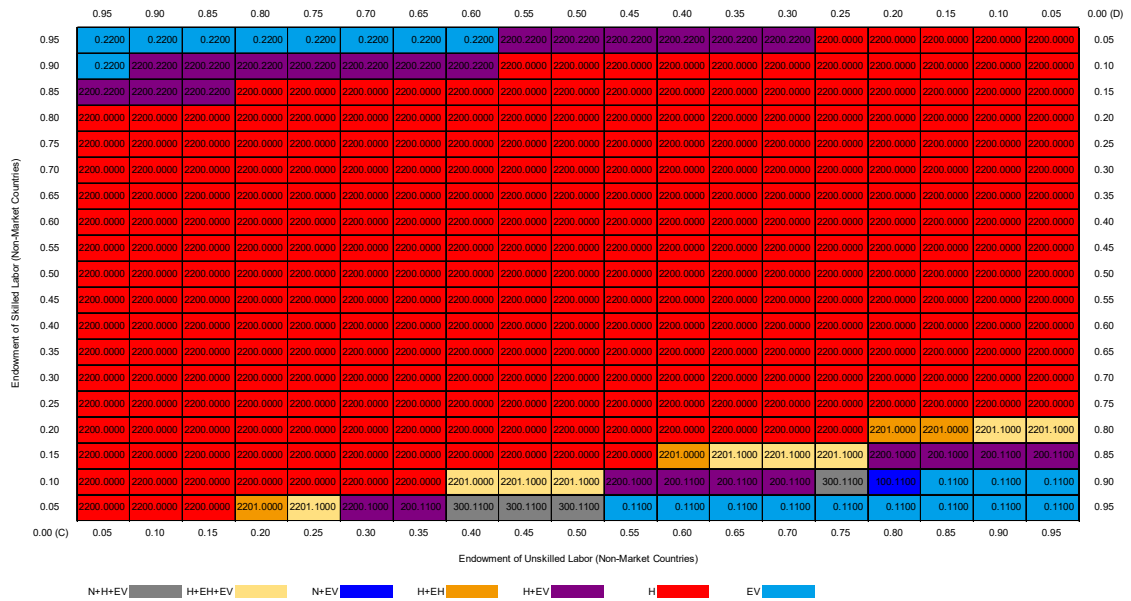


Figure 8: Lower Transportation Cost of Finished Products
 $(\tau_{AC}^Y = 0, \text{ Non-Market Countries})$

When two non-market countries differ in size and relative factor endowment, lowering the transportation cost of finished products sold on the trade-link between countries A and C motivates firms established in country B to be type-EH and to 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

that obtained by Ekholm, Forslid, and Markusen (2007). Thus, the type-EH firms tend to arise in the low-cost countries adjacent to a final market. In addition, the changing strategy of firms established in country B to be type-EH, which may reduce the cost burden, makes more efficient resource allocation possible. In consequence, the number of the type-N firms also increases in country B .

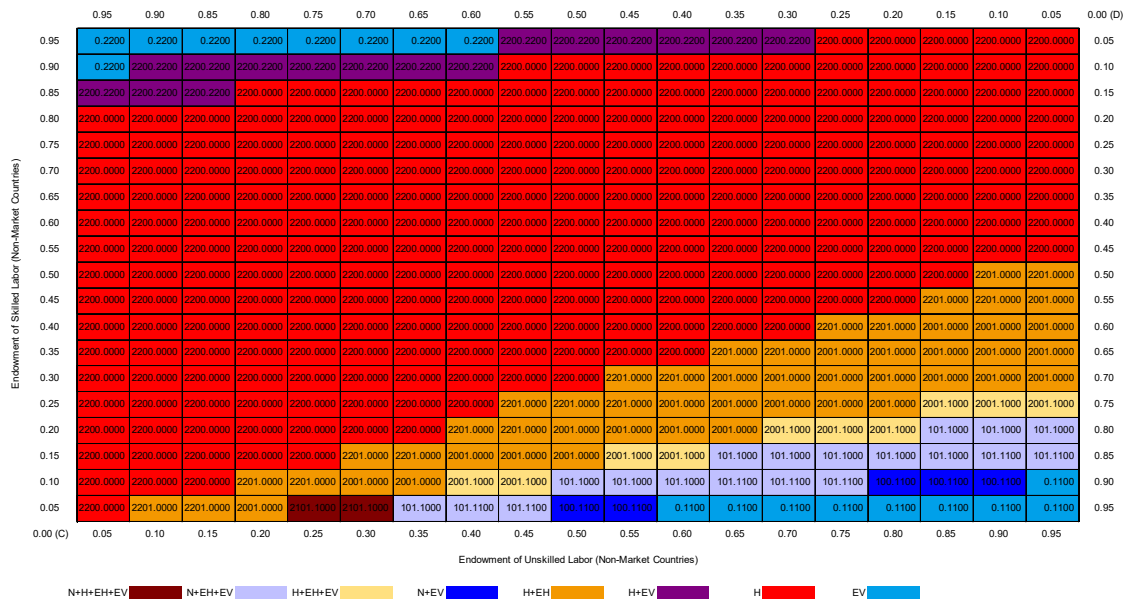


Figure 9: Lower Import Tariff on Finished Products
 $(v_{AC}^Y = 0, \text{Non-Market Countries})$

In the case of import tariff, many more of the type-H firms established in country B that are serving 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 sold on the trade-link between countries A and C is totally removed. In this case, the interpretation can be drawn that the type-EH firms arise in the low-cost countries in a free-trade area to serve the market in a FTA member.

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

It is apparent that the type-CI firms have not shown up so far. This begs the question,

"In which circumstances do CMNEs emerge"? The case in which the type-CI firms enter around the NW and SE corners, where cheaper unskilled 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 $\tau_{jr}^X = 0$, $\tau_{ij}^Y = \tau_{AD}^Y = \tau_{BC}^Y = 0.1 \times 10$, and $v_{AC}^Y = v_{BD}^Y = 0$. The setting implies that the type-CI firms emerge in a special case when a pair of market and non-market countries liberalize trade in the environment in which the transportation cost of components is low, while the cost of finished products sold on the trade-link between market countries is substantially high. An example of low transportation cost of components is the use of the internet to send blue prints from headquarters to a local affiliate.

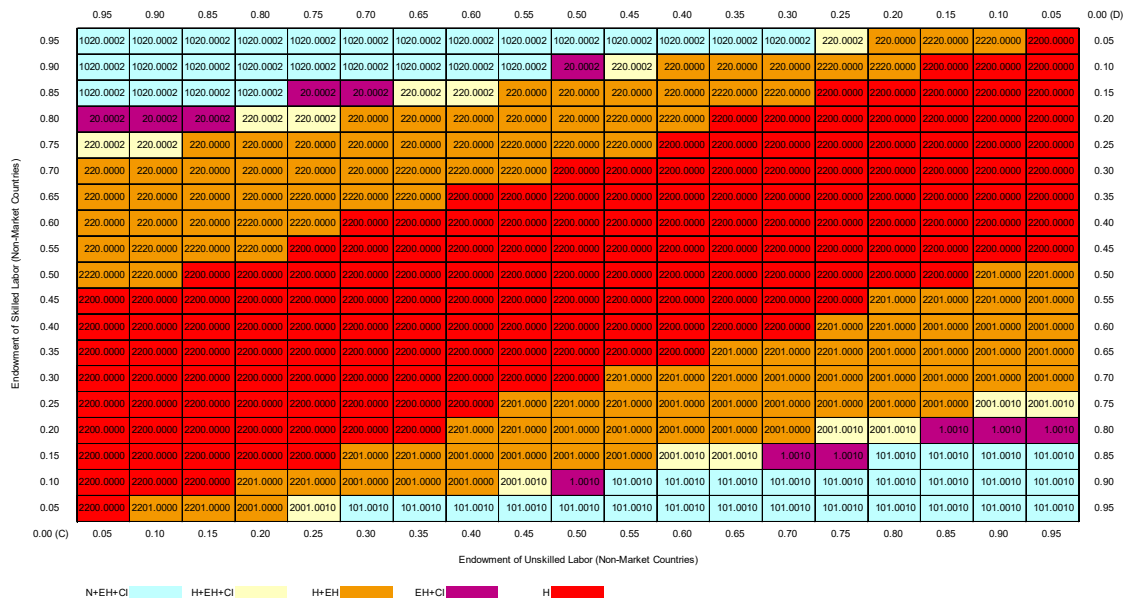


Figure 10: Complexly Integrated MNEs

Finally, no significant 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 are changed, respectively. The effects of independently controlling fixed costs on the type of 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 both liberalizing trade between a pair of market and non-market countries and implementing cost-saving policies, such as standardizing rules or simplifying procedures related to opening business in the member countries, assuming that the non-market country in question is left behind another rival in settling an economic partnership.⁴ 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 non-market 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 policies are 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 and, thus, some of the affiliate cost of local administration and management can be reduced.

4.2.1 Basic Environment

Into the setting observed previously, we introduce the situation that a 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 a FTA with any market country. The regime pattern closely resembles that captured in Figure 9 ($\tau_{AC}^Y = 0$). In the SE area, where the price of unskilled labor is relatively low, the type-EV firms from both market countries A and B , in addition to the type-EH firms from country B , operate in country C . As the central part of the box is approached, 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 the type-EV firms are active, shrinks as the absolute level of total endowments for the non-market countries becomes smaller. As we test different sizes of non-market countries, from double to half the size of the market countries, the impact on factor prices of one unit of foreign firm entrance

⁴ In this section, we suppose the non-market countries to be developing countries.

becomes large for a small-sized country.

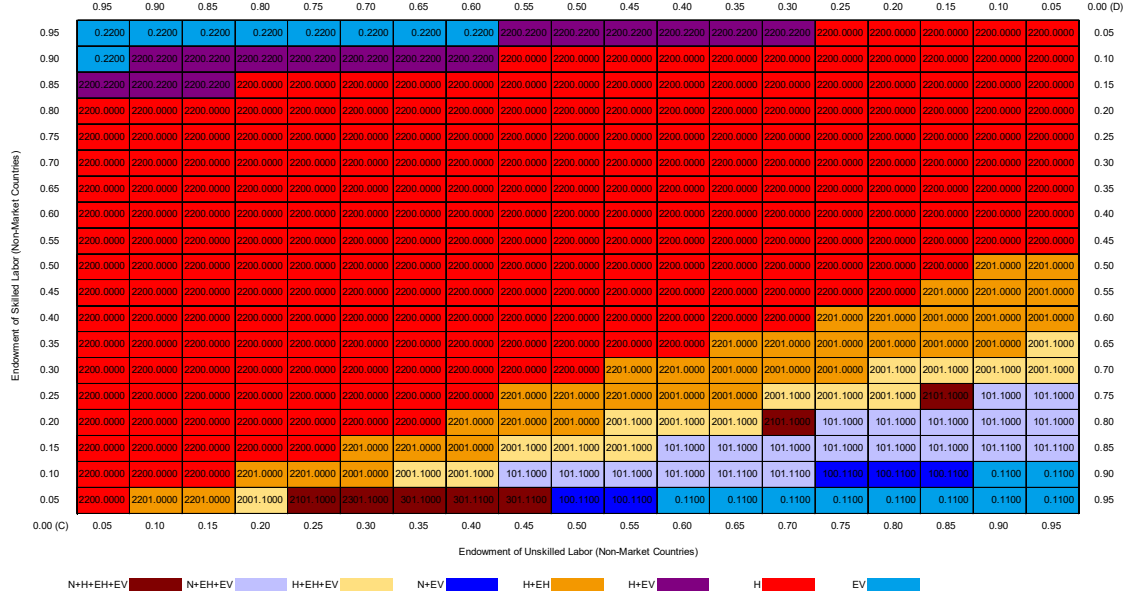


Figure 11: Lower Import Tariff on Components and Finished Products
 $(v_{AC}^X = v_{AC}^Y = 0, \text{ Non-Market Countries})$

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

Suppose that country D liberalizes trade with one of the market countries. When country A is selected, this can be 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 a perfectly identical pattern appears in the opposite corner leaving the pattern around the SE corner completely unaffected. In this case, a group of the type-H firms established in country B turn into type-EH 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 a FTA partner will not affect either the regime pattern, welfare levels, or factor prices in both non-market countries C and D in the present setting wherein the two market countries are perfectly symmetric. The difference can be found both 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 , the type-EH firms from

country B are replaced by those from country A . Consequently, the type-EH firms from country A and the type-EV firms from country B start operating in country D . The welfare level in the country that settles a FTA with country D improves, while another market country that has not been chosen as the FTA partner is worse off. Considering the present unrealistic assumption of perfectly symmetric market countries, this result can be regarded as supporting the empirical results of Baltagi, Egger, and Pfaffermayr (2008), which has shown that the indirect negative effects on a non-market country excluded from a FTA tend to be small when compared to the direct positive effects on the non-market country, whereby trade with a market country is liberalized.

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 non-market country must have a substantial amount of cheap unskilled labor based on the rich relative endowment of the factor.

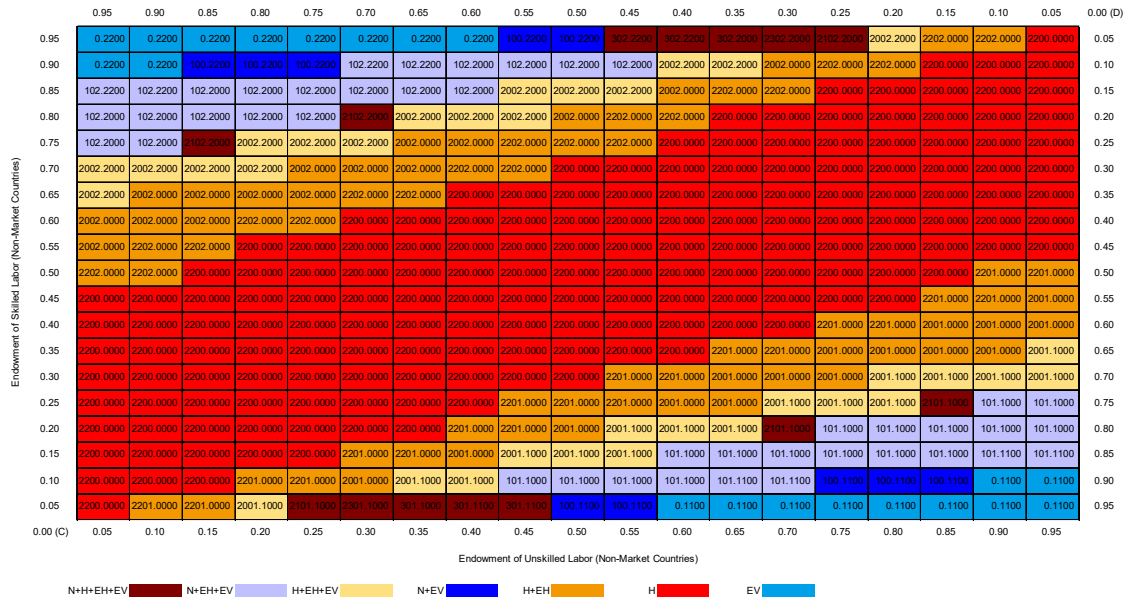


Figure 12: FTA with Countries D ($u_{AD}^X = v_{AD}^Y = 0$, Non-Market Countries)

Next, let us consider the case that country D settles an economic partnership program in which cost-saving policies related to the firm-type/trade-link specific fixed cost are added to a regular FTA with one of the market countries. This can be 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 effects on the welfare levels of the two 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 a FTA with country C and an EPA with country D . In this case, the type-EV firms extend their sphere of influence in the NW area. This is because lowering the firm-type/trade-link specific fixed cost saves skilled labor input, so that it becomes easier to integrate an 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 the type-H and type-EH firms coexist does not move from its position in the previous case. Given a substantial difference in relative factor endowments, the requirement to have assembly plants in a non-market country seems to be strong.

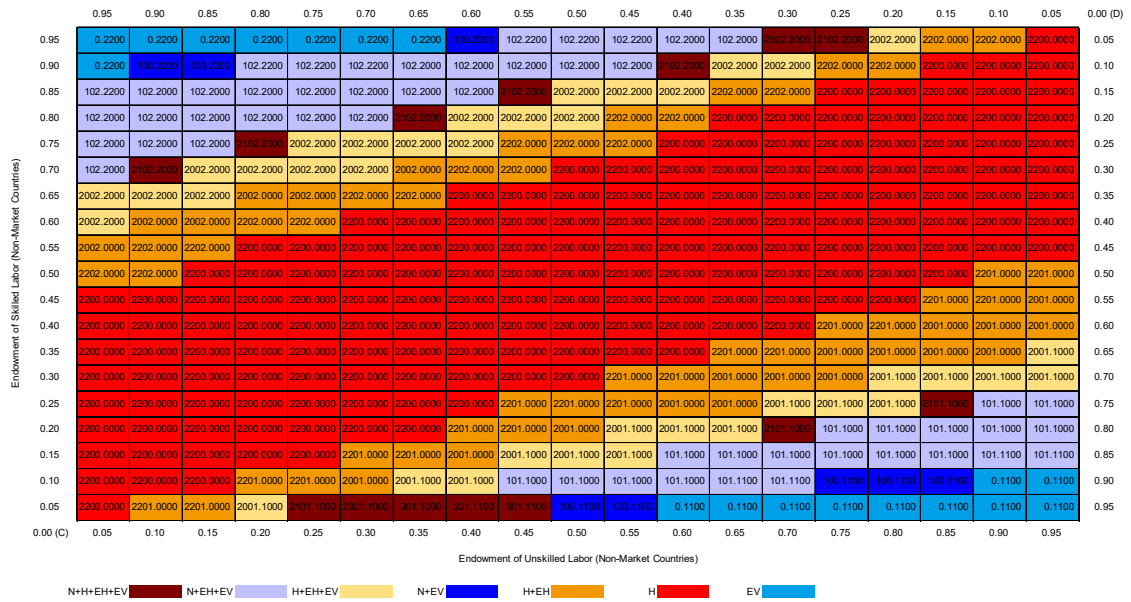


Figure 13: EPA with Country D

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

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, in addition to 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 lies in the fact that it may increase income through affecting factor prices via 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 a FTA by country D never affects either the welfare level or the factor prices in country C , as mentioned before.

Figure 14 shows how implementing a FTA between country D and one of the market countries affects 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 zero, from negative, if we trace the values from the NW corner to the center. In contrast, the effects on the price of unskilled labor changes from positive to zero (picture at the bottom). As seen previously, the number of the 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 , according to the assumption mentioned in Subsection 3.1 that the plant-level production of the type-Y good is less skilled-labor intensive than is that of the type-Z composite. As a result, relative wage of skilled/unskilled labor falls/rises.

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 non-market 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 in factor prices per unit increase of assembly plant becomes large in a small-sized country. Welfare losses can be avoided by increasing 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 the 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.

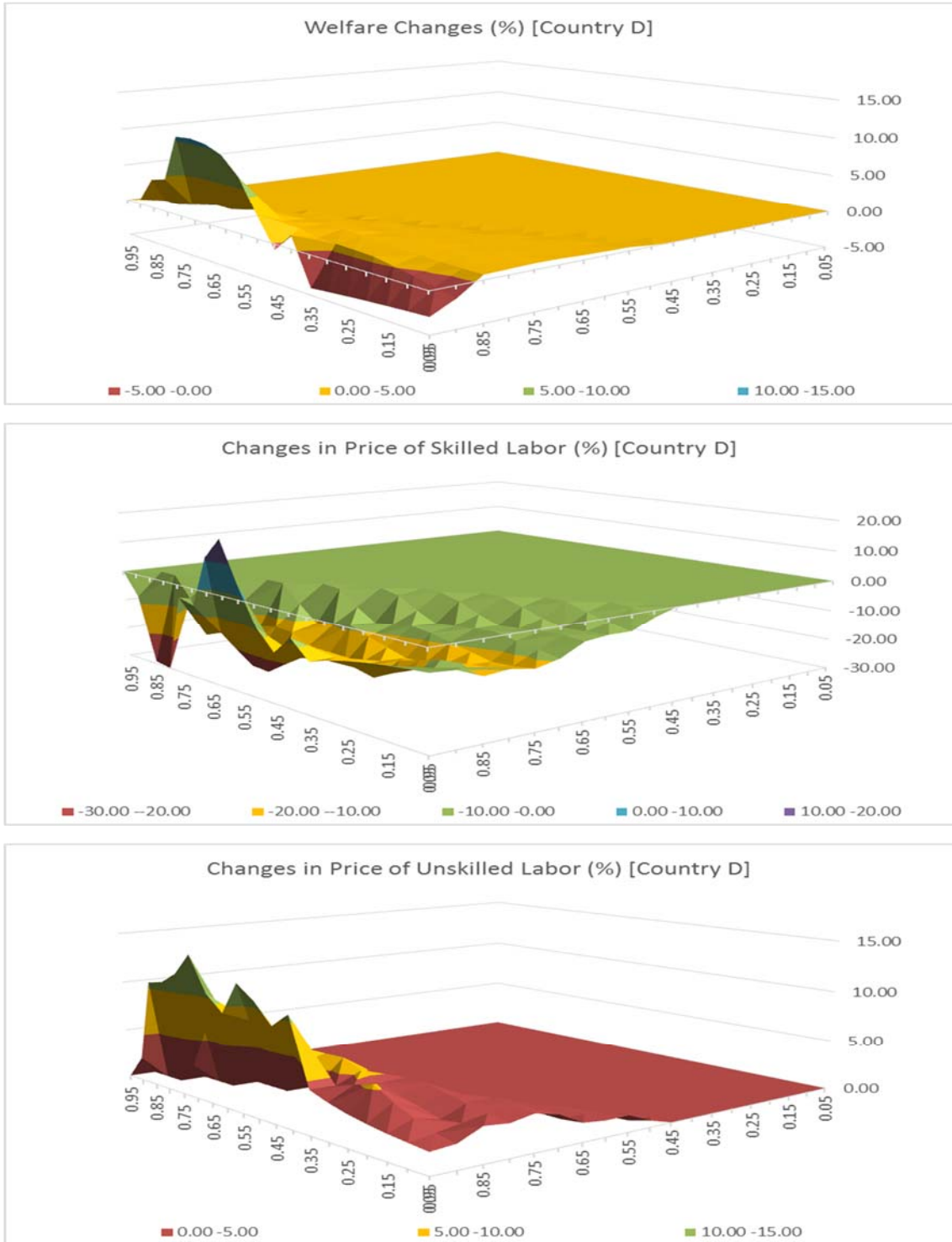


Figure 14: Effects of Implementing FTA with Country *D*

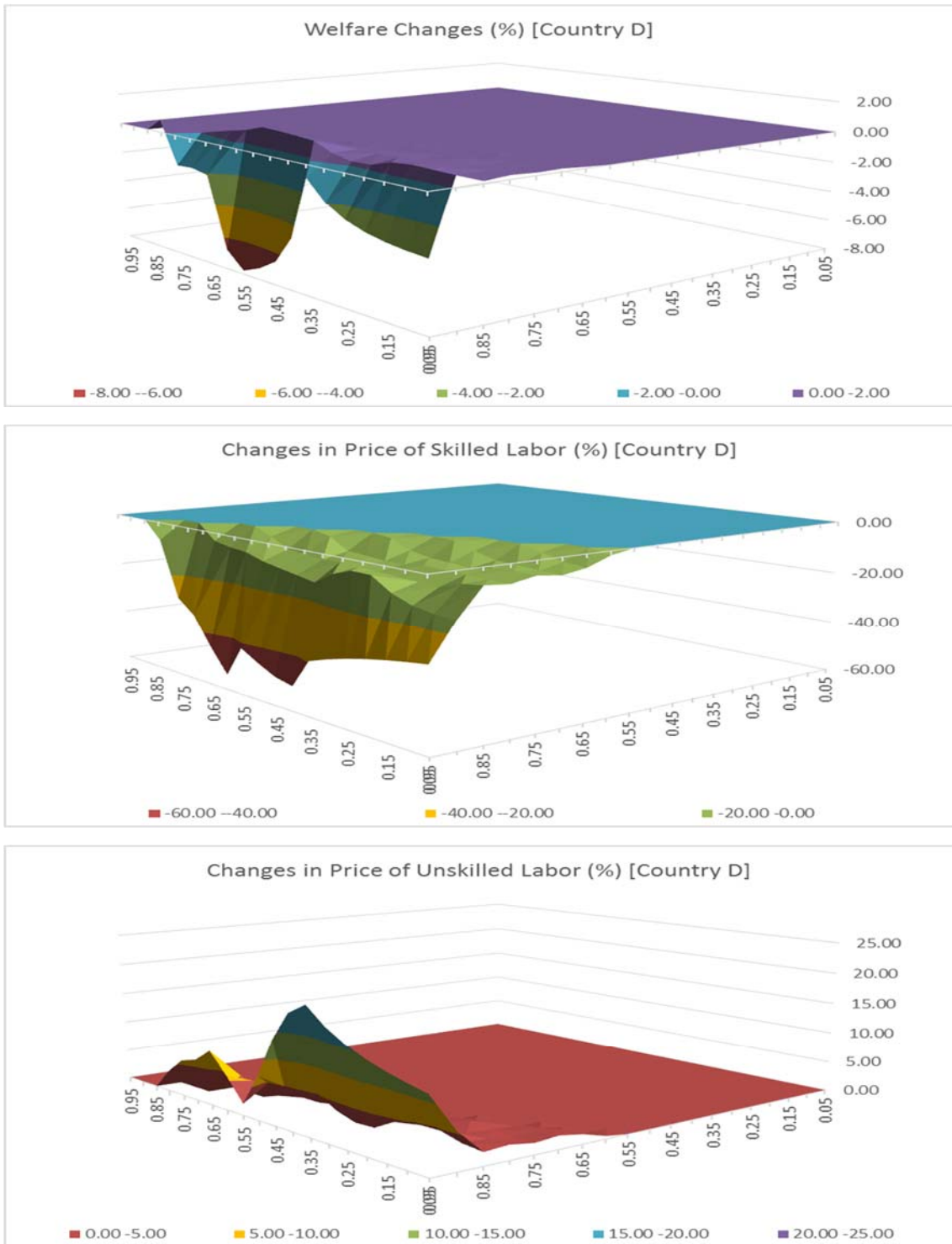


Figure 15: Effects of Additional Implementation of Cost-Saving Policies

One point to be noted is that the assumption of the factor intensity will not affect very much other than the changing directions of factor prices. Suppose we assume more skilled-labor intensive type-Y production relative to that of the type-Z. In such a case, effects on the total income from both skilled and unskilled labor will show the same kind of changes, because of the generally increased factor demand, even though the relative price of skilled/unskilled labor tends to rise/fall. Thus, the welfare effects show a similar pattern.

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 of recovering the welfare effects from negative to positive around the neighborhoods surrounding the NW corner, where the type-EV firms may extend their influence. This tendency becomes strong when the total endowments for the non-market countries are large.

The effects of the additional cost-saving policies on the factor prices are mainly elicited by the partial release of the skilled labor, which used to be hired for local administration and management. This is why the price of skilled labor tends to fall. As the increase in the availability of relatively cheap skilled labor calls over additional setup of local affiliates, the price of unskilled labor rises. This direction of price changes will not be affected by the assumption of the factor intensity. This implies that the additional cost-saving policies can also be used to either reduce the wage gap between skilled and unskilled labor or prevent price falls in the unskilled-labor market when the plant-level type-Y production is more skilled-labor intensive than is that of the type-Z.

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. The paper utilized an extended version of the knowledge-capital model that includes six types of firms and four countries grouped into market (developed) and non-market (developing) countries in a general equilibrium framework. Simulations with the model revealed conditions under which type of firm would be active in a given economic environment. With a special focus on the effects of FTA/EPA between a pair of market and non-market countries, the key findings can be summarized as follows.

1. When two non-market countries differ in size and relative factor endowment, lowering the trade costs (transportation cost or import tariff) of finished products sold on a trade-link between a pair of market and non-market countries motivates firms in a country "not" on the link to be an export-platform MNE operating in the non-market country on the link.
2. Complexly integrated MNEs emerge in a special case when a pair of market and non-market countries liberalize trade in the environment where transportation cost of components is low while the cost of finished products sold on the trade-link between market countries are substantially high.
3. MNEs will not setup plants in non-market countries, but will go straight to a foreign market country if non-market countries are similar in relative factor endowments, even when some of those non-market countries liberalize trade with a market country. To attract inward FDI, a non-market country must have a substantial amount of cheap unskilled labor based on its rich relative endowment of the factor.
4. In the present setting, wherein two market countries are perfectly symmetric, the choice of a FTA partner from market countries by a non-market country will not affect either the production pattern of firms, welfare levels, or factor prices in the non-market countries. On the other hand, the welfare level in the market country that settles a FTA with a non-market country improves, whereas the market country being excluded from the FTA will be worse off.
5. Although FTA/EPA generally tends to increase FDI to a non-market country, the possibility of improving 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 in factor prices per unit increase of assembly plant becomes small in a large country.
6. A non-market 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. As 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 non-market country, in which skilled labor is relatively scarce but not extremely scarce, can enhance welfare gains from a FTA. Moreover, it is even possible to recover the welfare effects from negative to positive, by making the arrangement an EPA. This tendency becomes strong when the total endowments for the non-market countries are large.

There are several potentially important issues that we have not yet considered 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, in the real economy, the production of components is not limited to taking place in developed countries but is also implemented in developing countries. Although such a model must be highly complicated, it is worth challenging.

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