WP/06/155

IMF Working Paper

The Impact of Trade on Wages: What If Countries Are Not Small?

Mika Saito and Ichiro Tokutsu

INTERNATIONAL MONETARY FUND

 WP/06/155

IMF Working Paper

IMF Institute

The Impact of Trade on Wages: What If Countries Are Not Small?

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Authorized for distribution by Ling Hui Tan

June 2006

Abstract

This paper explores the effect of trade on the relative wage of less-skilled labor through its effect on world prices, which are typically exogenously given under the small open economy assumption. Using the 1995 international input-output data for APEC member countries, we numerically simulate a general equilibrium model to study the effects of abolishing existing tariffs under the assumption that each member country is large enough to affect the prices of goods and services produced in the region. We find that the responsiveness of prices plays an important role in easing a possible adverse effect of trade on relative wages.

JEL Classification Numbers: F11, F14, F16, C62

Keywords: International Trade; Wages

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I. Introduction

The literature on trade and wages, which so far has focused on the U.S. evidence, has found that the causes of increased wage inequality were mainly domestic rather than foreign. For example, Harrigan (2000) found that changes in relative domestic prices and relative factor supply, especially in the nontradables sector, affected domestic relative wages, but foreign price changes had, at most, small direct effects on relative wages. Does this mean that trade policies have negligible effects on domestic relative wages?

The answer to this question depends on whether a trade policy has any effect on domestic prices. For example, when we consider the effect of a tariff change in the Armington (1969) world (i.e., goods and services are differentiated by country of origin), we typically consider a scenario where the price of domestic goods (or of exports) of each country is determined in the world market (and equals the world price), and the price of imports is the world price plus tariffs. In this scenario, a change in tariffs should simply change the price of imports, but not the price of domestic goods (or of exports), unless it changes the world prices. The literature so far has ignored the effect of a tariff change on the world prices (and thus on domestic prices) by assuming that each country is too small to affect world prices. To fully examine the effect of a trade policy on wages, however, we need to ask whether the effect of a trade policy on world prices is indeed negligible. If it is not, the effect of a trade policy on domestic relative wages can be significant, given the strong relationship between domestic relative prices and domestic relative wages. This question is particularly relevant if a trade policy can affect a region as a whole (e.g., a free trade agreement (FTA)), and the world prices of goods and services produced in the region largely depend on the demand and supply which originate in that region.

For example, let us consider a situation where a number of countries that decide to enter an FTA reduce tariff duties on intraregional trade. There are a several ways in which such a change affects the supply of, and the demand for, goods and services in the region. First, a tariff cut lowers the cost of production and, as a result, has an expansionary effect on both the supply and the demand sides of the economy: producers, who will face lower costs of imported materials and inputs, will increase their supply of goods and services; an expansion of production will accompany an increase in demand for raw materials and intermediate inputs from both home and abroad; and, finally, an expansion of output generates additional income and, hence, increases consumption demand from both home and abroad. Second, a tariff cut lowers the relative price of imports vis-à-vis domestic goods and, hence, induces substitution effects on the relative demand for imports: consumers, who demand consumption goods both from home and abroad, will shift their demand away from domestic and toward foreign goods; and producers, who demand raw materials, intermediate inputs, and final goods for fixed capital formations from both home and abroad will shift their demand away from domestic to foreign products. Third, a tariff cut lowers the relative price of tradables vis-à-vis nontradables and, hence, induces substitution effects on the relative demand for tradables: consumers and producers will shift their demand from nontradables to tradables.

Assuming that the intraregional demand, including domestic demand, is the bulk of the demand for the goods and services produced by the member countries of the FTA, the aggregate of these changes in the supply of, and the demand for, goods and services by the member countries determine whether the world market for these goods and services faces an excess supply (or an excess demand) after the tariff reduction. If the world market for these goods and services faces an excess supply, the world prices (and the corresponding domestic prices) will adjust downward, with varying magnitudes of adjustments across different goods and services. Given the strong relationship between domestic relative prices and domestic relative wages, every member country of the FTA is expected to face consequences on domestic relative wages.

This paper goes beyond previous studies in two important aspects. First, we construct a general equilibrium model for a "region" where each member country is large enough to affect prices of goods and services produced in that region. Without such a general equilibrium model, we cannot analyze the effect of trade on wages through its effect on world prices and, hence, domestic prices. Second, we use the 1995 international input-output data for 9 Asia-Pacific Economic Cooperation (APEC) member countries, including the United States. We treat these countries as large open economies within the region. The observations are rich in many dimensions; we can distinguish different types of industries, either tradables or nontradables, and different types of trade, either in final goods or in intermediate inputs. The richness of the observations in these dimensions is important in capturing the effect of a tariff change on wages through its effect on the different types of supply and demand responses discussed previously.

A simulation of abolishing existing tariff payments shows that a tariff reduction does have a non-negligible impact on wages; in particular, its impact through its effect on domestic prices plays a crucial role in offsetting possible adverse effects of a tariff cut on relative wages. The terms of trade effects on wages (i.e., the effect of a change in the price of exports relative to imports on wages) differ across countries: some gain and some lose. The overall effect of a tariff cut on relative wages can, however, be negligible across the board, since any terms of trade effect on relative wages, irrespective of its direction, can be fully offset by the effect of domestic price movements on relative wages. This result implies that the impact of trade on wages, through its effect on domestic prices, is important to the extent that any adverse effects of a tariff cut on relative wages can be wiped out by such an effect.

II. Literature Review

The recent literature on trade and wages has focused on the role of intermediate inputs trade and the role of nontradables.[2] Feenstra and Hanson (2001) distinguish intermediate inputs by the skill of labor that is most intensively used in the production of these inputs. For example, typical skill-intensive intermediate inputs are research and development (R&D), and typical less skilled-labor-intensive intermediate inputs are parts of machinery and equipment. They argue that an increase in the demand for U.S. R&D exports caused an outward shift in the demand for skilled workers while a decrease in the demand for U.S. parts exports led to an inward shift in the demand for less-skilled workers. These shifts had a similar impact on relative employment and wages as in the case of skill-biased technical progress.[3]

The caveat to Feenstra and Hanson (2001) is that it focuses on U.S. manufacturing, which is mostly

[2] The relationship between factor prices and trade patterns goes back a long way in the trade literature. According to the Stolper-Samuelson theorem, a fall in the relative wage of less-skilled workers must be accompanied by a fall in the price of less-skilled labor-intensive goods. Empirical evidence, however, did not support this evidence. For example, Lawrence and Slaughter (1993) and Lawrence (1994) found that the industries that use the most less-skilled (i.e., production) workers were those with the highest price increases.

[3] Labor economists such as Katz and Autor (1999) argued that skill-biased technical progress since the mid-1980s caused an outward shift in the demand for more-skilled workers (and an inward shift in the demand for less-skilled workers), and thus resulted in an increase in their relative employment and wages.

tradables. It misses the important fact that most of the U.S. economy is devoted to nontradables. Harrigan and Balaban (1999), Harrigan (2000), and Tokarick (2005) overcome this issue by using a general equilibrium model in which both tradables and nontradables are included.

Harrigan and Balaban (1999) and Harrigan (2000) argue that the variables that were most highly correlated with the movement in wages over the 1980s and 1990s in the United States was neither trade prices nor outsourcing, but rather a sharp increase in the relative prices of skill-intensive goods, especially those in the nontradables sector. In other words, in their view, the causes of an increased wage gap were mainly domestic rather than foreign. Tokarick (2005), using an applied general equilibrium model, also showed the importance of the price of nontradables in explaining the wage gap.

The caveat to Harrigan (2000) and Harrigan and Balaban (1999) is that the effect of foreign prices and quantities on relative wages through affecting domestic relative prices, which they have shown have an important influence on domestic relative wages, is missing. In other words, supply and demand responses to a change in trade policies discussed in the introduction are assumed to have no feedback on prices. Tokarick (2005) captures some of these effects by allowing foreign prices and quantities to affect prices. Modeling intermediate inputs demand, however, is missing in his model and therefore the supply and demand responses discussed in the introduction are only partially captured. We find that the impact of trade on wages through its effect on 'input' prices turns out to be an important element in easing a possible adverse effect of trade on relative wages.

III. The Model

A. Technology

There are M number of countries and I number of industries in our model. The $(M+1)$th country is considered the rest of the world.

The representative producer in industry $j \in \{1, \ldots, I\}$ in each country $n \in \{1, \ldots, M\}$ produces output X_j^n. Each country n produces output $\mathbf{x}^n = (X_1^n, ..., X_I^n)'$, which is a $I \times 1$ column vector. We assume that the representative producer in jth industry of nth country has the following production function:

$$X_j^n = f_j^n(\mathbf{x}_j^{1n}, \ldots, \mathbf{x}_j^{Mn}, L_j^n, H_j^n; \bar{\mathbf{x}}_j^{M+1,n}, \bar{K}_j^n), \qquad (1)$$

where vector $\mathbf{x}_j^{mn}$ is its intermediate inputs imported from mth country, L_j^n is its less-skilled labor input, H_j^n is its skilled-labor input, $\bar{\mathbf{x}}_j^{M+1,n}$ is a $I \times 1$ column vector representing its intermediate inputs imported from the rest of the world, and $\bar{K}_j^n$ is its physical capital input.[4] The last two inputs with upper bars imply that these inputs are assumed fixed.

The intermediate inputs imported from mth country $\mathbf{x}_j^{mn} = \left(X_{1j}^{mn}, ..., X_{Ij}^{mn}\right)'$ are expressed in a $I \times 1$ column vector of intermediate inputs; ith element of which represents those produced in ith industry of mth country. If $m = n$, the intermediate inputs are domestically produced. Note also

[4] In the rest of this paper, labor, less-skilled labor, and production workers will be interchangeably used to describe L. Similarly, human capital, skilled labor, and nonproduction workers will be interchangeably used to describe H.

that if $i = j$, the intermediate inputs are produced in its own industry, and therefore they represent *intra*-industry transactions that take place either within or across countries.[5]

Firms are assumed to maximize their short-run profit with a given level of capital stock and material from the rest of the world. We also assume that the production function (1) is twice differentiable with respect to factors of production and homogeneity of degree 1.

The profit maximization problem of this representative producer is as follows:

$$\begin{aligned} Max\ \pi_j^n &= p_j^n X_j^n - \sum_{m=1}^{M+1} (\mathbf{p}^{mn})' \mathbf{x}_j^{mn} - w_L^n L_j^n - w_H^n H_j^n - r^n \bar{K}_j^n, \\ s.t.\ X_j^n &= f_j^n(.) \text{ as described in equation (1),} \end{aligned} \tag{2}$$

where p_j^n is the price of its own goods, $\mathbf{p}^{mn}$ is an $I \times 1$ import price vector of goods produced in mth country by agents in country n, w_L^n and w_H^n are the wage rate of less-skilled and skilled labor, respectively. Note that the elements of the price vector $\mathbf{p}^{mn}$ are the local prices that include the tariff and the transportation costs. For example, the ith element of $\mathbf{p}^{mn}$ is $p_i^m (1 + \tau_i^{mn})$ where τ_i^{mn} is the unit import cost incurred on imports of goods produced ith industry of mth country by nth country.

The unit import costs need further explanations. First, we assume that consumers and producers face the same unit import costs. This assumption is the reason for not having an industry subscript to identify the importer's type. Second, we assume that unit import costs represent unit transportation costs and tariff rates jointly: that is, we assume that $(1 + \tau_i^{mn}) = (1 + d_i^{mn})(1 + t_i^{mn})$, where d_i^{mn} and t_i^{mn} are the rates of transportation costs and the tariff rates incurred on imports of good produced by ith industry of mth country to nth country. Finally, if $m = n$, we assume $\tau_i^{mn} = 0$, though assuming no transportation costs on domestic transactions may be more problematic than assuming no tariffs on these transactions.

Solving the profit maximization problem (2) gives us the following supply and factor demand equations for jth industry in nth country:

$$X_j^n = X_j^n(\mathbf{p}^1, \ldots, \mathbf{p}^M, w_L^n, w_H^n; \boldsymbol{\zeta}_j^n), \tag{3}$$
$$\mathbf{x}_j^{mn} = \mathbf{x}_j^{mn}(\mathbf{p}^1, \ldots, \mathbf{p}^M, w_L^n, w_H^n; \boldsymbol{\zeta}_j^n), (m = 1, ..., M) \tag{4}$$
$$L_j^n = L_j^n(\mathbf{p}^1, \ldots, \mathbf{p}^M, w_L^n, w_H^n; \boldsymbol{\zeta}_j^n), \tag{5}$$
$$H_j^n = H_j^n(\mathbf{p}^1, \ldots, \mathbf{p}^M, w_L^n, w_H^n; \boldsymbol{\zeta}_j^n). \tag{6}$$

The vector $\mathbf{p}^m = (p_1^m, ..., p_I^m)'$ is an $I \times 1$ price vector of goods produced in mth country. The vector $\boldsymbol{\zeta}_j^n$ consists of factors that shift the production function of jth industry of nth country, for example, tariff rates t_i^{mn}, the rates of transportation costs d_i^{mn}, inputs from the rest of the world $\bar{\mathbf{x}}_j^{M+1,n}$, physical capital input $\bar{K}_j^n$, tariff and transportation costs, the price of goods produced in the rest of the world $\bar{\mathbf{p}}^{M+1}$, technology level, and so on. In what follows, we call these factors *shift parameters* of the corresponding functions.

Note that since wages can be expressed as a function of prices, the supply and factor demand functions can also be expressed as functions of prices alone as in the case of a standard neoclassical

[5]The Armington assumption on intermediate inputs, i.e., to assume that intermediate inputs are differentiated by the country of origin, is relaxed in Feltenstein and Plassmann (2005).

trade models. We keep the expressions above, which will become convenient in the later section on the relative wage decomposition.

Note also that we treat the total exports to the rest of the world as a numeriare. To do so, we fix the total exports to the rest of the world in nominal term.[6] This specification of a numeriare is different from the specification in the standard neoclassical trade models (i.e., the goods produced in the first industry of the first country is treated as a numeriare). By adopting our specification of a numeriare, we can pin down the prices of all the goods and services produced in the region and thus we can trace down the effect of these price movements on relative wages, including the price movements of the first industry of the first country. To adopt the standard specification of a numeriare however is equally feasible.

B. Preference

As for the household's consumption behavior, we assume that the utility maximization problem of the representative consumer of nth country is as follows:

$$\begin{aligned} Max\ U^n &= U^n(\mathbf{c}^{1n}, \ldots, \mathbf{c}^{Mn}) && (7) \\ s.t.\ C^n &= \sum_{m=1}^{M} (\mathbf{p}^{mn})' \, \mathbf{c}^{mn}, && (8) \end{aligned}$$

where C^n is the total consumption expenditure of the representative consumer in nth country (in nominal terms), $\mathbf{c}^{mn}$ is its consumption goods imported from mth country, and $\mathbf{p}^{mn}$ is defined as above.

The consumption goods imported from mth country $\mathbf{c}^{mn} = (C_1^{mn}, ..., C_I^{mn})'$ is a $I \times 1$ column vector; ith element of which represents those produced in ith industry of mth country. As before, if $m = n$, consumption goods are domestically produced and therefore they are not imports.

We assume that a fixed proportion δ^n of nominal GDP of nth country is allocated to consumption expenditures C^n :

$$C^n = \delta^n \left(\mathbf{p}^n \mathbf{x}^n - \sum_{j=1}^{I} \sum_{m=1}^{M+1} (\mathbf{p}^{mn})' \, \mathbf{x}_j^{mn} \right), \tag{9}$$

where $\mathbf{x}^n$ is a $I \times 1$ column vector of supply of goods and services produced in nth country.

Successively substituting (4) and (3) into (9) and solving the utility maximization problem (7) give us the following consumption demand equation for the representative consumer in nth country:

$$\mathbf{c}^{mn} = \mathbf{c}^{mn}(\mathbf{p}^1, \ldots, \mathbf{p}^M, w_L^n, w_H^n; \delta^n, \boldsymbol{\zeta}_1^n, \ldots, \boldsymbol{\zeta}_I^n, \boldsymbol{\eta}^n), \tag{10}$$

where $\boldsymbol{\eta}^n$ is a vector that shifts the consumption demand function of nth country, such as tariff and transportation cost incurred on imports of consumption goods.

[6] See Section C. for more detail.

C. Competitive Equilibrium

Goods market clearing conditions

There are $M \times I$ number of markets for goods and services in this model. The MI market clearing conditions are as follows:

$$\begin{bmatrix} \mathbf{x}^1 \\ \vdots \\ \mathbf{x}^M \end{bmatrix} = \begin{bmatrix} \mathbf{x}^{11} & \dots & \mathbf{x}^{1M} \\ \vdots & \ddots & \vdots \\ \mathbf{x}^{M1} & \dots & \mathbf{x}^{MM} \end{bmatrix} \boldsymbol{\iota}_{MI} + \begin{bmatrix} \mathbf{c}^{11} & \dots & \mathbf{c}^{1M} \\ \vdots & \ddots & \vdots \\ \mathbf{c}^{M1} & \dots & \mathbf{c}^{MM} \end{bmatrix} \boldsymbol{\iota}_M + \begin{bmatrix} \bar{\mathbf{f}}^{11} & \dots & \mathbf{f}^{1,M+1} \\ \vdots & \ddots & \vdots \\ \bar{\mathbf{f}}^{M1} & \dots & \mathbf{f}^{M,M+1} \end{bmatrix} \boldsymbol{\iota}_{M+1} \tag{11}$$

where a $I \times I$ square matrix $\mathbf{x}^{mn} = (\mathbf{x}_1^{mn}, ..., \mathbf{x}_I^{mn})$ is nth country's imports of intermediate inputs from mth country; $\boldsymbol{\iota}_s = (1, ..., 1)'$ is a $s \times 1$ column vector in which all the s elements are unity; and a $I \times 1$ column vector $\bar{\mathbf{f}}^{mn} = \left(\bar{F}_1^{mn}, ..., \bar{F}_I^{mn}\right)'$ represent other final demand by the representative consumer in nth country where $\bar{F}_i^{mn}$ represents nth country's other final demand (e.g., government expenditure and investment) for goods and services produced in ith industry of mth country.[7]

Labor market clearing conditions

There are two types of labor, skilled and less-skilled, in each country. Therefore, we have $2 \times M$ number of labor markets in this model. The labor market clearing conditions are as follows:

$$\mathbf{l} = \left(\ \mathbf{l}^1, \quad \dots \quad, \mathbf{l}^M\ \right)' \boldsymbol{\iota}_I \tag{12}$$

$$\bar{\mathbf{h}} = \left(\ \mathbf{h}^1, \quad \dots \quad, \mathbf{h}^M\ \right)' \boldsymbol{\iota}_I, \tag{13}$$

where $I \times 1$ column vectors $l^m = (L_1^m, ..., L_I^m)'$ and $\mathbf{h}^m = (H_1^m, ..., H_I^m)'$ are the less-skilled and skilled labor inputs in nth country, respectively; $\bar{L}^m$ and $\bar{H}^m$ are respectively the fixed endowment of less-skilled labor and skilled labor in mth country and hence $M \times 1$ column vectors $\bar{l} = \left(\bar{L}^1, ..., \bar{L}^M\right)'$ and $\bar{\mathbf{h}} = \left(\bar{H}^1, ..., \bar{H}^M\right)'$ are respectively those for the whole region. Note that the wages of less-skilled and skilled labor in the region, expressed respectively as $M \times 1$ vectors $\mathbf{w}_L = \left(w_L^1, ..., w_L^M\right)'$ and $\mathbf{w}_H = \left(w_H^1, ..., w_H^M\right)'$, will adjust to clear these markets.

Competitive equilibrium

A competitive equilibrium of this model is defined as a set of prices $(\mathbf{p}^1, \dots, \mathbf{p}^M, \mathbf{w}_L, \mathbf{w}_H)$ and an allocation $(\mathbf{x}^1, ..., \mathbf{x}^M, \mathbf{x}^{11}, ..., \mathbf{x}^{MM}, \mathbf{c}^{11}, ..., \mathbf{c}^{MM}, l^1, ..., l^M, \mathbf{h}^1, ..., \mathbf{h}^M)$ such that (i) the allocation solves the profit maximization problem (2) for the stated prices; (ii) the allocation solves the utility maximization problem (7) for the stated prices; and (iii) all market clearing conditions (11) to (13) hold.

[7] For the exports to the rest of the world, intermediate and final demands are not distinguished. They are collectively included into the export to the rest of the world and denoted by $F_i^{m,M+1}$. It is also important to recall that to treat the total exports to the rest of the world as a numeriare, we fix them in nominal term, that is, we fix $\mathbf{p}^m \mathbf{f}^{m,M+1}$ for all m. This means that the real exports to the rest of the world, that is, $\mathbf{f}^{m,M+1} = \left(F_1^{m,M+1}, ..., F_I^{m,M+1}\right)'$, are endogenously determined (and hence denoted without upper bars in equation (11)). We let these as a function of the price of corresponding goods and services alone.

Excess supply functions

The competitive equilibrium defined above can be expressed in terms of excess supply functions E_i^m for all industry $i \in \{1, \ldots, I\}$ and E_s^m for both labor markets $s \in \{L, H\}$ in each country $m \in \{1, \ldots, M\}$.[8] Note that these excess supply functions are functions of a set of prices $(\mathbf{p}^1, \ldots, \mathbf{p}^M, \mathbf{w}_L, \mathbf{w}_H)$ and equal zero at equilibrium.

Let $\mathbf{e}^m = (E_1^m, ..., E_I^m)'$ be a $I \times 1$ vector of excess supply function for goods produced in mth country; ith element of which is that for goods produced in ith industry. Let $\mathbf{e}_L = \left(E_L^1, ..., E_L^M\right)'$ be a $M \times 1$ vector of excess supply function for less-skilled labor; mth element of which is that in mth country. Let $\mathbf{e}_H = \left(E_H^1, ..., E_H^M\right)'$ be a $M \times 1$ vector of excess supply function for skilled labor; mth element of which is that in mth country. The competitive equilibrium defined above is expressed as follows:

$$\mathbf{e}^m(\mathbf{p}^1, \ldots, \mathbf{p}^M, \mathbf{w}_L, \mathbf{w}_H; \boldsymbol{\mu}) = \mathbf{0}_I \text{ for all } m \in \{1, \ldots, M\}, \tag{14}$$

$$\mathbf{e}_L(\mathbf{p}^1, \ldots, \mathbf{p}^M, \mathbf{w}_L, \mathbf{w}_H; \boldsymbol{\mu}) = \mathbf{0}_M, \tag{15}$$

$$\mathbf{e}_H(\mathbf{p}^1, \ldots, \mathbf{p}^M, \mathbf{w}_L, \mathbf{w}_H; \boldsymbol{\mu}) = \mathbf{0}_M, \tag{16}$$

where $\boldsymbol{\mu}$ is a vector of the exhaustive list of shift parameters in the model and $\mathbf{0}_s = (0, ..., 0)'$ is a $s \times 1$ column vector in which all the s elements are zero.

D. Jacobian Matrix of Excess Supply Functions

What we are interested in is how domestic relative prices and wages change when an exogenous change, such as a change in tariff rates, occurs in the region. To obtain these changes in relative prices and wages, we differentiate excess supply equations (14) to (16) with respect to $\boldsymbol{\mu}$ (a $k \times 1$ vector of shift parameters) at the equilibrium as follows:[9]

$$\boldsymbol{\Phi}_p \cdot \boldsymbol{\Gamma}_{\boldsymbol{\mu}} + \boldsymbol{\Phi}_{\boldsymbol{\mu}} = \mathbf{0}_{(MI+2M)\times k}, \tag{17}$$

where

$$\boldsymbol{\Phi}_p = \begin{bmatrix} \frac{\partial \mathbf{e}^1}{\partial (\mathbf{p}^1)'} & \cdots & \frac{\partial \mathbf{e}^1}{\partial (\mathbf{p}^M)'} & \frac{\partial \mathbf{e}^1}{\partial \mathbf{w}_L'} & \frac{\partial \mathbf{e}^1}{\partial \mathbf{w}_H'} \\ \vdots & \ddots & \vdots & \vdots & \vdots \\ \frac{\partial \mathbf{e}^M}{\partial (\mathbf{p}^1)'} & \cdots & \frac{\partial \mathbf{e}^M}{\partial (\mathbf{p}^M)'} & \frac{\partial \mathbf{e}^M}{\partial \mathbf{w}_L'} & \frac{\partial \mathbf{e}^M}{\partial \mathbf{w}_H'} \\ \frac{\partial \mathbf{e}_L}{\partial (\mathbf{p}^1)'} & \cdots & \frac{\partial \mathbf{e}_L}{\partial (\mathbf{p}^M)'} & \frac{\partial \mathbf{e}_L}{\partial \mathbf{w}_L'} & \frac{\partial \mathbf{e}_L}{\partial \mathbf{w}_H'} \\ \frac{\partial \mathbf{e}_H}{\partial (\mathbf{p}^1)'} & \cdots & \frac{\partial \mathbf{e}_H}{\partial (\mathbf{p}^M)'} & \frac{\partial \mathbf{e}_H}{\partial \mathbf{w}_L'} & \frac{\partial \mathbf{e}_H}{\partial \mathbf{w}_H'} \end{bmatrix}, \boldsymbol{\Gamma}_{\boldsymbol{\mu}} = \begin{bmatrix} \frac{\partial \mathbf{p}^1}{\partial \boldsymbol{\mu}'} \\ \vdots \\ \frac{\partial \mathbf{p}^M}{\partial \boldsymbol{\mu}'} \\ \frac{\partial \mathbf{w}_L}{\partial \boldsymbol{\mu}'} \\ \frac{\partial \mathbf{w}_H}{\partial \boldsymbol{\mu}'} \end{bmatrix}, \boldsymbol{\Phi}_{\boldsymbol{\mu}} = \begin{bmatrix} \frac{\partial \mathbf{e}^1}{\partial \boldsymbol{\mu}'} \\ \vdots \\ \frac{\partial \mathbf{e}^M}{\partial \boldsymbol{\mu}'} \\ \frac{\partial \mathbf{e}_L}{\partial \boldsymbol{\mu}'} \\ \frac{\partial \mathbf{e}_H}{\partial \boldsymbol{\mu}'} \end{bmatrix}. \tag{18}$$

Note that the matrix $\boldsymbol{\Phi}_\mu$ captures the size of disequilibrium induced by a small change in μ . The matrix $\boldsymbol{\Gamma}_\mu$ captures the changes in prices and wages to restore an equilibrium. The matrix $\boldsymbol{\Phi}_p$ is the *Jacobian matrix* of the excess supply functions. Each element of the Jacobian matrix presents

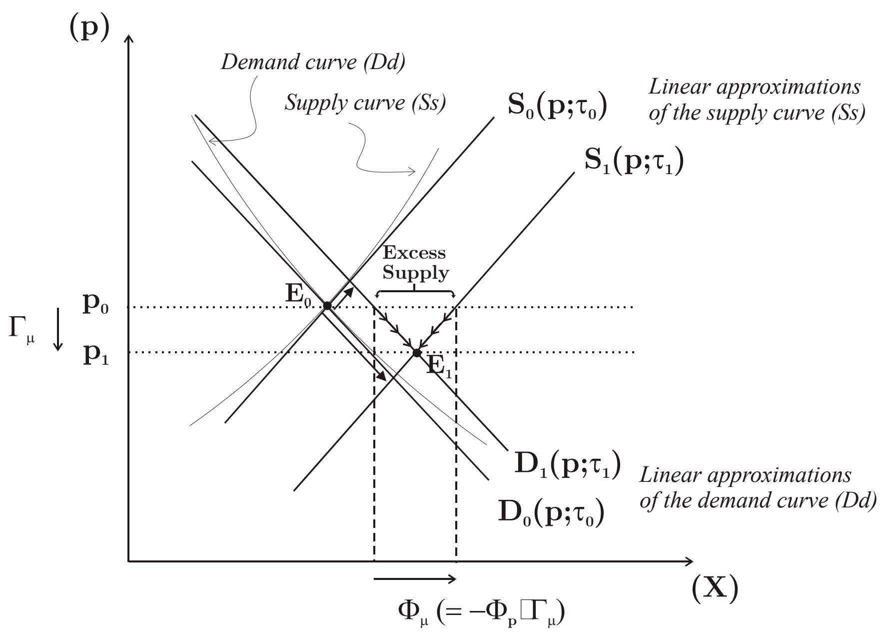
[8] This can be done by substituting each element of $\mathbf{x}^1, ..., \mathbf{x}^M$ by equation (3), each element of $\mathbf{x}^{11}, ..., \mathbf{x}^{MM}$ by equation (4), each element of $\mathbf{l}^1, ..., \mathbf{l}^M$ by equation (5), each element of $\mathbf{h}^1, ..., \mathbf{h}^M$ by equation (6), and each of $\mathbf{c}^{11}, ..., \mathbf{c}^{MM}$ by equation (10).

[9] The dimensions of $\boldsymbol{\Phi}_p$, $\boldsymbol{\Gamma}_{\boldsymbol{\mu}}$, and $\boldsymbol{\Phi}_{\boldsymbol{\mu}}$ are $(MI+2M)\times(MI+2M)$, $(MI+2M)\times k$, and $(MI+2M)\times k$, respectively.

changes in excess supply of the corresponding markets induced by infinitesimal changes in prices and wages.

What these matrices capture in a two-dimensional diagram for a small change in a shift parameter, for example a small change in a unit import price from τ_0 to τ_1, is illustrated in Figure 1. Note that $\mathbf{\Phi}_\mu$ captures the size of disequilibrium induced by a shift in supply and demand curves. $\mathbf{\Gamma}_\mu$ captures the change in prices. Finally, the Jacobian matrix $\mathbf{\Phi}_p$ together with $\mathbf{\Gamma}_\mu$ captures a movement along the supply and demand curves to reach a new equilibrium.

Figure 1. Jacobian Matrix Φ_p



What we are interested in is the effect on prices and wages (i.e., the matrix Γ_μ) for a given shift in supply and demand curves induced by a tariff reduction (i.e., the matrix $\mathbf{\Phi}_\mu$) and a given slopes of these curves (i.e., the matrix $\mathbf{\Phi}_p$). We obtain Γ_μ by solving equation (17) with respect to Γ_μ:

$$\mathbf{\Gamma}_{\boldsymbol{\mu}} = -\mathbf{\Phi}_p^{-1}\mathbf{\Phi}_{\boldsymbol{\mu}}. \tag{19}$$

We obtain the Jacobian matrix $\mathbf{\Phi}_p$ and the size of the disequilibrium $\mathbf{\Phi}_\mu$ from data, but to do so, we need to specify production technology – equation (1), and preference – equation (7). In this paper, we assume that they can be described with the Cobb-Douglas functional form (i.e., the elasticity of substitution among factors and inputs of production equals 1). The details on the specification of technology and preference and the corresponding supply and demand functions are given in Appendix I.A. The details on how to obtain the Jacobian matrix is also in Appendix I.B. It is important to note that this choice of the functional form does not affect the general direction of the impact of a tariff cut, though the magnitude of the impact may increase as the size of the elasticity of factor substitution increases (see Appendix I.E. for more detail).

E. Relative Wage Decomposition

To assess the effect of the tariff reduction on the wage rate of less-skilled relative to that of skilled labor, we take two steps. First, we compute the change in the wage gap, measured by a percentage change in the wage rate of less-skilled labor relative to that of skilled labor. Second, we decompose these changes into several components of interest.

Let us first define the semi-elasticity of prices and wages with respect to a percentage change in tariff rates as follows:

$$\begin{bmatrix} \hat{\mathbf{p}}^1 \\ \vdots \\ \hat{\mathbf{p}}^M \\ \hat{\mathbf{w}}_L \\ \hat{\mathbf{w}}_H \end{bmatrix} = \begin{bmatrix} \frac{\partial \mathbf{p}^1/\mathbf{p}^1}{\partial \boldsymbol{\mu}'} \\ \vdots \\ \frac{\partial \mathbf{p}^M/\mathbf{p}^M}{\partial \boldsymbol{\mu}'} \\ \frac{\partial \mathbf{w}_L/\mathbf{w}_L}{\partial \boldsymbol{\mu}'} \\ \frac{\partial \mathbf{w}_H/\mathbf{w}_H}{\partial \boldsymbol{\mu}'} \end{bmatrix}. \tag{20}$$

Note that since each element of $\partial \boldsymbol{\mu}'$ is a percentage change in tariff rates, the semi-elasticities $\hat{\mathbf{p}}^1, ..., \hat{\mathbf{p}}^M, \hat{\mathbf{w}}_L$, and $\hat{\mathbf{w}}_H$ can also be interpreted as elasticities. Note also that since the initial values of prices and wages $\mathbf{p}^1, ..., \mathbf{p}^M, \mathbf{w}_L$, and $\mathbf{w}_H$ are treated as unit values, the matrix above is in fact matrix $\boldsymbol{\Gamma}_{\boldsymbol{\mu}}$.

Using these elasticities, we can obtain a $M \times 1$ column vector **wgap** as follows:

$$\mathbf{wgap} = \hat{\mathbf{w}}_L - \hat{\mathbf{w}}_H. \tag{21}$$

The nth element of this vector, $\hat{w}_L^n - \hat{w}_H^n$, represents the relative increase of the less-skilled labor wage in the nth country. If $\hat{w}_L^n - \hat{w}_H^n > 0$, then an increase in the wage rate of a less-skilled worker in the nth country is higher than that of skilled labor and hence the wage gap is closing. On the other hand, if $\hat{w}_L^n - \hat{w}_H^n < 0$, then the wage gap is increasing.

The decomposition of the wage gap is based on a price equation. Suppose that at equilibrium, the price change of a good produced in jth industry in nth country can be expressed as a weighted average of the price change of all inputs and factors of production:

$$\hat{p}_j^n = \sum_{m=1}^{M} \sum_{i=1}^{I} \theta_{ij}^{mn} \hat{p}_i^m + (\theta_L)_j^n \hat{w}_L^n + (\theta_H)_j^n \hat{w}_H^n + (\theta_K)_j^n \hat{r}_j^n \tag{22}$$

where the weigths sum to 1, that is $\sum_{m=1}^{M} \sum_{i=1}^{I} \theta_{ij}^{mn} + (\theta_L)_j^n + (\theta_H)_j^n + (\theta_K)_j^n = 1$. If we assume a Cobb-Douglas functional form, these weights are simply factor cost shares (see Appendix I.D. for more detail). With a few steps of algebra, we can show that the wage gap $(\hat{w}_L^n - \hat{w}_H^n)$ for nth country can be decomposed into two components:

$$(\hat{w}_L^n - \hat{w}_H^n) = \left(\frac{\left(\hat{p}_j^n - \hat{w}_H^n\right)}{(\theta_L)_j^n} - \frac{(\theta_K)_j^n \left(\hat{r}_j^n - \hat{w}_H^n\right)}{(\theta_L)_j^n} \right) - \left(\sum_{m=1}^{M} \sum_{i=1}^{I} \frac{\theta_{ij}^{mn}}{(\theta_L)_j^n} \left(\hat{p}_i^m - \hat{w}_H^n\right) \right). \tag{23}$$

The first component captures the effect of tariff reduction on relative wages through a change in the price of goods sold (i.e., supply prices).[10] When the price of goods j in country n increases

[10] To be precise, the effect of tariff reudction on relative wages through changing the cost of capital (i.e., rental rates) relative to the cost of skilled labor is also included.

relative to the cost of skilled labor, that is, when $\hat{p}_j^n - \hat{w}_H^n > 0$, the marginal revenue increases relative to the cost of skilled labor. The producer of goods j in country n therefore increases its supply by hiring more of the less-skilled workers relative to skilled workers. As a result, the relative wage rates of less-skilled workers increases, and hence the wage gap closes.

The second component captures the effect of tariff reduction on relative wages through changing the cost of intermediate inputs (i.e., input prices). When the cost of intermediate inputs from country m and industry i falls relative to that of skilled labor, that is, $\hat{p}_i^m - \hat{w}_H^n < 0$, the marginal cost falls relative to the cost of skilled labor. The producer of goods j in country n therefore increases the supply of output by hiring more of less-skilled labor relative to skilled labor. As a result, the relative wage rates of less-skilled workers rises, and hence the wage gap falls. Note that not modeling intermediate inputs demand as in Tokarick (2005) would imply ignoring the effect on relative wages through this second component.

Both of these components are further decomposed into three subcomponents classified by the type of goods, that is, domestic tradables, nontradables, and imports. Note that the first component (i.e., the effect of supply price movements) is only decomposed into either tradables or nontradables. This second step of decomposition into subcomponents helps us see different effect of tariff reduction across countries.

IV. Data

The data used in this study are primarily taken from the Asian international input-output table, compiled by the Institute of Development Economies (IDE) (see IDE (2001)).

Table 1. Countries and Industries

m, n, i, j	Country		Industry	
1	IDN	Indonesia	AGR	Agriculture, forestry, and fishery
2	MYS	Malaysia	EGW	Energy and energy products
3	PHL	Philippines	FOD	Food, beverage, and tobacco
4	SGP	Singapore	TEX	Textile and apparel
5	THA	Thailand	PAP	Paper and pulp products
6	CHN	China	CHE	Chemicals and chemical products
7	TWN	Taiwan Province of China	BMI	Metal products
8	KOR	Korea, Republic of	MEQ	Machinery and equipment
9	JPN	Japan	SER	Trade, transportation, and services
10	USA	United States	MOT	Other manufactured products
11	ROW	Rest of the world		

The Asian international input-output table consists of 9 countries, that is, Indonesia, Malaysia, the Philippines, Singapore, Thailand, China, the Republic of Korea, Japan, the United States, and three other regions: Taiwan Province of China, Hong Kong SAR, and the rest of the world. There are 78 industries for each country or region. In this study, however, these 78 industries are aggregated into 10 industries in each country. Moreover, Hong Kong SAR is treated as part of the rest of the world. The concordance of super- or subscripts used in the previous section and the name of country and industries are shown in Table 1.

The 78 industries are aggregated into 10 industries mainly because of a constraint we face on labor data. The data described above do not distinguish production from nonproduction workers, both in terms of employment and wage rates. We therefore take labor data from each country's labor statistics, which are typically given at the 1-digit International Standard Industrial Classification (ISIC) code. The concordance between 10 industries used in this study (see Table 1) and 78 industries in the Uniform Input-Output (UIO) classification (the classification used in the international input-output table) as is available from the authors upon request, as well as the concordance between the UIO and the 4-digit 1987 U.S. Standard Industrial Classification (SIC).

Let us refer to the international input-output table for the 2-industry and 2-country case (see Table 2). Note also that the rest of the world (ROW) is also included in this table as the third country.

Table 2. Basic Accounting Scheme: International Input-Output Table

		Intermediate Demand				Final Demand					Output
		Ctry. (1)		Ctry. (2)		Cons. Demand		Other Fin. Dd		Exp.	
		Ind. (1)	Ind. (2)	Ind. (1)	Ind. (2)	Ctry. (1)	Ctry. (2)	Ctry. (1)	Ctry. (2)	to ROW	
Ctry.	Ind.(1)	$p_1^1X_{11}^{11}$	$p_1^1X_{12}^{11}$	$p_1^1X_{11}^{12}$	$p_1^1X_{12}^{12}$	$p_1^1C_1^{11}$	$p_1^1C_1^{12}$	$p_1^1F_1^{11}$	$p_1^1F_1^{12}$	$p_1^1F_1^{13}$	$p_1^1X_1^1$
(1)	Ind.(2)	$p_2^1X_{21}^{11}$	$p_2^1X_{22}^{11}$	$p_2^1X_{21}^{12}$	$p_2^1X_{22}^{12}$	$p_2^1C_2^{11}$	$p_2^1C_2^{12}$	$p_2^1F_2^{11}$	$p_2^1F_2^{12}$	$p_2^1F_2^{13}$	$p_2^1X_2^1$
Ctry.	Ind.(1)	$p_1^2X_{11}^{21}$	$p_1^2X_{12}^{21}$	$p_1^2X_{11}^{22}$	$p_1^2X_{12}^{22}$	$p_1^2C_1^{21}$	$p_1^2C_1^{22}$	$p_1^2F_1^{21}$	$p_1^2F_1^{22}$	$p_1^2F_1^{23}$	$p_1^2X_1^2$
(2)	Ind.(2)	$p_2^2X_{21}^{21}$	$p_2^2X_{22}^{21}$	$p_2^2X_{21}^{22}$	$p_2^2X_{22}^{22}$	$p_2^2C_2^{21}$	$p_2^2C_2^{22}$	$p_2^2F_2^{21}$	$p_2^2F_2^{22}$	$p_2^2F_2^{23}$	$p_2^2X_2^2$
Freight		D_1^1	D_2^1	D_1^2	D_2^2	D^1	D^2	D_F^1	D_F^2		
ROW	Ind.(1)	$p_1^3X_{11}^{31}$	$p_1^3X_{12}^{31}$	$p_1^3X_{11}^{32}$	$p_1^3X_{12}^{32}$	$p_1^3C_1^{31}$	$p_1^3C_1^{32}$	$p_1^3F_1^{31}$	$p_1^3F_1^{32}$		
	Ind.(2)	$p_2^3X_{21}^{31}$	$p_2^3X_{22}^{31}$	$p_2^3X_{21}^{32}$	$p_2^3X_{22}^{32}$	$p_2^3C_2^{31}$	$p_2^3C_2^{32}$	$p_2^3F_2^{31}$	$p_2^3F_2^{32}$		
Tariff		T_1^1	T_2^1	T_1^2	T_2^2	T^1	T^2	T_F^1	T_F^2		
Labor		$w^1L_1^1$	$w^1L_2^1$	$w^2L_1^2$	$w^2L_2^2$						
Capital		$r_1^1K_1^1$	$r_2^1K_2^1$	$r_1^2K_1^2$	$r_2^2K_2^2$						
Output		$p_1^1X_1^1$	$p_2^1X_2^1$	$p_1^2X_1^2$	$p_2^2X_2^2$						

There are four points worth making on Table 2. First, each row (except for freight, tariff, labor, capital, and output) presents the source of the demand in each market. The source of the demand can be either intermediate or final. Moreover, the final demand can be either household consumption or other final demand such as government expenditure and investment. Exports to the rest of the world include exports of both intermediate inputs and final goods, though for the sake of simplicity, they are classified as final demand in this table.

Second, each of the first four columns records the cost structure of each industry. The costs of production consist of the costs of domestic and foreign produced intermediate inputs and that of factors of production. The sum of all the costs equals the total revenue of each industry recorded in the last row.

Third, to analyze the effect of a change in tariff rates, we need data on tariff payments and transportation costs that are disaggregated by source country and industry. The international input-output table distinguishes tariff payments and transportation costs on imports within the region from those on imports from the rest of the world. It does not, however, distinguish the data by source country and industry within the region. We therefore first disaggregate the data on transportation costs (e.g., D_j^n) and then tariff payments (e.g., T_j^n). For example, we first disaggregate D_j^n (or D^n for final goods trade) in Table 2 into D_{ij}^{mn} (or D_i^{mn} for final goods trade) for all m and i where $D_{ij}^{mn} = d_{ij}^{mn} p_i^m X_{ij}^{mn}$ (or $D_i^{mn} = d_i^{mn} p_i^m X_i^{mn}$). We then disaggregate T_j^n (or T^n for final goods trade) in Table 2 into T_{ij}^{mn} (or T_i^{mn} for final goods trade) for all m and i where $T_{ij}^{mn} = t_{ij}^{mn}\left(1 + d_{ij}^{mn}\right) p_i^m X_{ij}^{mn}$ (or $T_i^{mn} = t_i^{mn}\left(1 + d_i^{mn}\right) p_i^m X_i^{mn}$). Note that the transportation cost rate d_{ij}^{mn} (or d_i^{mn}) for each m and i is estimated from U.S. bilateral trade data used in Hummels (1999) and Feenstra and others (2002). Note also that the Most-Favored-Nation (MFN) rate t_{ij}^{mn} (or t_i^{mn}) for each m and i is taken directly from the Trade Analysis and Information System (TRAINS) Version 3.0 compiled by the United Nations Conference on Trade and Development (UNCTAD) (see UNCTAD (1996)). More detail can be found in Appendixes II.A. and II.B.

Fourth, the international input-output table does not differentiate skilled and unskilled wage compensations. Since we are interested in relative wages, we compute relative wage compensation of skilled and unskilled labor. More specifically, we construct the relative wage compensation of production workers (relative to nonproduction workers) using (i) employment data by occupation and industry and (ii) wage data by occupation and industry. Employment data are collected from national labor statistics of each country in our sample (see more detail in Appendix II.C.). Wage data are taken from Freeman and Oostendorp (2000). The original data source of Freeman and Oostendorp (2000) is the October Inquiry of the International Labor Organization (ILO).[11]

V. Empirical Findings

Before assessing the effect of abolishing the existing tariff rates on relative wages in the Asia-Pacific region, we need to clarify a few points on the existing tariff rates and the specification of technology and preference.

First, in what follows, we denote tariff rates as t_{ij}^{mn} (or t_i^{mn}) instead of t_i^n to distinguish exporting

[11] It is important to note that we do not observe an obvious pattern in the relative wage compensation of production workers between industrial and emerging market economies (see more detail in Appendix II.C.). We may have been able to observe a distinctive pattern and, hence, to analyze the implications of such a pattern, if we were to use wage and employment data by education and industry, rather than by occupation and industry. Such data, however, are available for some, but not for all countries in our sample.

countries and end-users in each importing country. The MFN rate on imports of goods produced in ith industry should be irrespective of the source country m and the end-user type (either producer j or consumer) in importing country n. That is, tariff rates should be denoted by t_i^n. Due to aggregation of data, however, the tariff rates we observe are different for different source countries and end-users.

Second, we restrict the analysis to a relatively simple case where all the existing tariff rates are abolished simultaneously. In this case, the changes of the tariff rates for each commodity are simply the actual tariff rates observed in the international input-output table. We look at this relatively simple case because calculating the effect of tariff reductions becomes complex when tariff rates are treated differently for different end-users. For example, suppose that changes in the tariff rate t_{i1}^{mn} occur due to changes in the tariff rate of a specific input imported by producers in industry 1 in country n. If the same input is also imported by industry 2, the tariff rate producers in industry 2 face t_{i2}^{mn} must also change. That is, changes in t_{i1}^{mn} and t_{i2}^{mn} are not independent from each other and hence to calculate the effect of changes in t_{i1}^{mn}, we must also calculate the corresponding changes in all other tariff rates with different end-user types, that is, t_{ij}^{mn} for all $j \in \{1, \ldots, I\}$ and $n \in \{1, \ldots, M\}$ and t_i^{mn} for all $n \in \{1, \ldots, M\}$. Calculating these corresponding changes is not only complex but also infeasible unless the actual composition of individual commodities imported by each end-user type is available.

Table 3 presents the actual tariff rates in 1995. As can be seen from the table, in 1995, the total amount traded in the region was \$680.071 billion, and the amount of import duties incurred was \$40.854 billion, indicating that the corresponding tariff rate was 6.0 percent. In our simulation, these rates are set to zero.

Table 3. Import Duties and Tariff Rates on Within-Region Trade, by Country
(In billions of U.S. dollars)

Country 1/	Amount Imported (c.i.f.)	Import Duties	Tariff Rates (%)
IDN	17.585	1.571	8.9
MYS	38.096	2.149	5.6
PHL	12.896	2.125	16.5
SGP	49.110	0.320	0.7
THA	33.499	4.873	14.5
CHN	53.735	1.436	2.7
TWN	55.651	3.046	5.5
KOR	63.494	5.351	8.4
JPN	155.030	13.930	9.0
USA	200.976	6.052	3.0
Total	680.071	40.854	6.0

1/ Country abbreviations are defined in Table 1.

Let us now begin discussing our findings.

A. Direct Effect

The effect of the tariff reduction can be divided into two effects, that is, direct and indirect effects. A tariff reduction immediately reduces the price of imports that importers face. That is, it reduces the after-tax (tariff) price of imports. The effects of these changes on the economy (i.e., a shift in supply and demand curves) is referred to as *direct* effects. It should be noted that in computing these effects, we assume that the prices of goods themselves remain unchanged. Once the direct effect of tariff reduction hits the economy, excess supply (or demand) emerges and hence prices adjust to restore an equilibrium. These changes in prices themselves also have consequences on the economy. These effects on the economy (i.e., a movement along supply and demand curves) are referred to as *indirect* effects. In what follows, we analyze both of these effects.

Excess supplies in 100 goods markets are aggregated by industry and by country in Table 4.

Table 4. Direct Effect on Excess Supply
(In billions of U.S. dollars)

Ind. 1/	Supply	Intermediate Demand	Consumption Demand	Excess Supply	Ctry. 1/	Supply	Intermediate Demand	Consumption Demand	Excess Supply
AGR	0.882	2.962	1.697	-3.777	IDN	3.539	1.759	1.575	0.206
EGW	5.099	3.240	1.105	0.753	MYS	4.860	2.151	1.178	1.531
FOD	8.256	1.408	5.645	1.202	PHL	4.212	1.473	1.779	0.960
TEX	9.900	3.291	4.383	2.225	SGP	0.418	0.754	0.404	-0.740
PAP	2.105	1.663	0.292	0.149	THA	13.898	4.932	4.111	4.856
CHE	5.312	4.008	0.630	0.674	CHN	5.881	4.052	4.054	-2.225
BMI	7.899	8.108	0.232	-0.441	TWN	9.959	4.944	3.031	1.984
MEQ	38.418	13.207	4.113	21.098	KOR	16.271	8.529	4.576	3.166
SER	12.772	16.813	19.201	-23.242	JPN	37.406	23.177	11.480	2.749
MOT	20.847	6.790	1.859	12.199	USA	15.044	9.721	6.969	-1.645
Total	111.488	61.491	39.157	10.841	Total	111.488	61.491	39.157	10.841

1/ Industry and country abbreviations are defined in Table 1.

Abolishing tariffs in the region increases the supply, the intermediate demand, and the consumption demand in every goods market in the region (see the positive signs in the corresponding columns of Table 4 respectively). The main reasons are as follows. A tariff reduction lowers the marginal cost of production by reducing the cost of imported materials and thus encourages production.[12] The expansion of production explains the increase in demand: more production requires more intermediate inputs; and since prices are kept constant in measuring the direct effect, more production implies more real income of households, and therefore more consumption.

The direct effect of tariff reduction on excess supply $\Phi_{\boldsymbol{\mu}}$ is presented in the corresponding columns of Table 4. These values are computed by subtracting the increase in intermediate and consumption demand from the increase in supply. For example, abolishing tariffs in the region decreases excess supply of agricultural products by \$3.777 billion. This fall in excess supply occurs because the total demand for those products increases by \$4.659 (= \$2.962 + \$1.697) billion, while the producer of those goods increases supply only by \$882 million (with some rounding errors).

[12] The magnitude of the expansion is larger the more the industry relies on imported materials.

There are three main findings. First, excess supply is the dominant feature of tariff reduction for the region as a whole. Most countries face excess supply in some markets and excess demand in others. However, if we look at the region as a whole, we find that excess supply sums to \$10.841 billion. We can conjecture from this feature that the general price level falls as individual prices adjust to clear each market.

Second, Singapore, China, and the United States face excess demand at the aggregate level: the excess demand for these three countries are \$0.740, \$2.225, and \$1.645 billion, respectively, which are shown in the last column of the table. In fact, in Singapore, excess demand emerges in all markets except for energy and food industries. All other countries, however, face excess supply at the aggregate level.

Third, we tend to observe excess demand in nontradables and excess supply in tradables. For example, excess demand emerges in agriculture and service industry in all countries. At the aggregate level, the excess demand for these industries respectively sum to \$3.777 and \$23.242 billion for the region. Although some of the agricultural products are tradables, we consider excess demand as the main characteristic of the nontradable sector. On the other hand, in all countries except for Singapore, excess supply emerges in the machinery and other industrial products industries, both of which are typical tradables. At the aggregate level, the excess supply of these industries respectively sum to \$21.098 and \$12.199 billion for the region. In summary, abolishing existing tariff rates in the region induces an expansion in tradables, a contraction in nontradables, and a corresponding reallocation of resources between these sectors.

B. Effect on Prices

Prices adjust to clear the excess supply (or demand) discussed above. Such changes in prices $\Gamma_{\boldsymbol{\mu}}$ are calculated by equation (19) and given in Table 5 (see the upper block of the table). The last row of the upper block of the table shows changes in the Paacshe price index to represent those in the general price level in each country.[13] Since production and utility functions are assumed homogenous, a proportional price change does not affect the behavior of firms and households; what matters in production and consumption decisions is the relative price change.[14] The lower block of Table 5 therefore presents the changes in prices of each good relative to the general price level in each country.

Main findings are as follows. First, all prices except for China decline even in markets where excess demand emerges.[15] Such price movements are feasible in a general equilibrium analysis if all elements of the inverse of Jacobian matrix Φ_P^{-1} are positive. Our Jacobian matrix indeed satisfies this property (see more on the property of the Jacobian matrix in Appendix I.C.).

Second, a fall in the general price level is higher (or lower) for countries with relatively large (or small) tariff reductions. For example, in the Philippines and Thailand, the Paacshe price index

[13] The Paasche index is calculated by dividing the total nominal output by total real output after the price change.

[14] One exception in our model is the supply of goods to the rest of the world, which is assumed to depend on the absolute price change.

[15] To obtain absolute price level for all markets, our general equilibrium needs to be a nonhomogenous system. To make the system nonhomogenous, without violating the homogeneity assumptions on the production and utility functions, we assume that exports to the rest of the world are exogenous in nominal terms and thus endogenous in real terms.

Table 5. Change of Price
(In percent)

Ind. 1/	Country 1/										
	IDN	MYS	PHL	SGP	THA	CHN	TWN	KOR	JPN	USA	Total
					Price Level						
AGR	-0.985	-0.939	-2.301	-0.480	-2.808	0.919	-0.420	-1.299	-1.215	-0.209	-0.316
EGW	-0.916	-1.773	-3.009	-1.208	-4.725	0.658	-0.757	-1.622	-1.668	-0.280	-0.806
FOD	-1.003	-1.156	-2.596	-0.949	-2.958	0.852	-0.699	-1.694	-1.470	-0.214	-0.758
TEX	-0.821	-1.227	-4.799	-0.142	-3.787	0.660	-0.638	-1.327	-1.432	-0.493	-0.681
PAP	-1.237	-2.692	-6.304	-0.406	-5.328	0.549	-0.836	-1.816	-1.200	-0.266	–0.681
CHE	-2.487	-2.225	-3.720	-0.657	-5.394	0.500	-0.910	-1.904	-1.284	-0.287	-0.733
BMI	-2.050	-9.178	-5.156	-0.845	-5.764	0.540	-1.362	-1.712	-1.281	-0.336	-0.866
MEQ	-3.072	-2.109	-7.953	-1.233	-7.852	0.263	-2.331	-2.451	-1.224	-0.452	-1.064
SER	-1.026	-1.048	-2.932	-0.462	-3.496	0.835	-0.491	-1.304	-1.155	-0.278	-0.628
MOT	-1.676	-2.737	-4.545	-0.712	-4.552	0.563	-1.106	-1.756	-1.253	-0.331	-0.823
Total	-1.298	-2.121	-3.361	-0.768	-4.341	0.649	-0.977	-1.684	-1.227	-0.300	-0.725
					Relative Price to the Price Index for Each Country						
AGR	0.317	1.207	1.097	0.290	1.603	0.268	0.563	0.391	0.012	0.092	0.412
EGW	0.387	0.355	0.365	-0.443	-0.402	0.009	0.223	0.063	-0.447	0.020	-0.081
FOD	0.298	0.986	0.792	-0.182	1.446	0.201	0.281	-0.010	-0.246	0.086	-0.033
TEX	0.483	0.913	-1.488	0.631	0.579	0.011	0.342	0.362	-0.207	-0.193	0.044
PAP	0.061	-0.583	-3.045	0.365	-1.032	-0.100	0.142	-0.134	0.028	0.034	0.044
CHE	-1.205	-0.107	-0.372	0.113	-1.101	-0.148	0.067	-0.224	-0.057	0.014	-0.008
BMI	-0.762	-7.210	-1.858	-0.077	-1.488	-0.109	-0.389	-0.028	-0.055	-0.036	-0.142
MEQ	-1.798	0.012	-4.752	-0.468	-3.670	-0.384	-1.368	-0.781	0.002	-0.152	-0.342
SER	0.275	1.096	0.443	0.309	0.883	0.184	0.491	0.387	0.072	0.022	0.098
MOT	-0.383	-0.629	-1.225	0.056	-0.221	-0.086	-0.130	-0.073	-0.027	-0.031	-0.099
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

1/ Industry and country abbreviations are defined in Table 1.

falls by 3.4 percent and 4.3 percent, respectively (see the last row of the upper block of Table 5). On the other hand, the decline of the general price level is negligibly small for the United States and the general price level increases for China.

Third, relative prices of nontradables rise in all countries and those of tradables generally fall in all countries. These findings are consistent with what we observe on excess supplies of corresponding goods markets in Table 4.

C. Effect on Trade

In this section, we aggregate trade patterns only by country for two reasons. First, the main goal of our study is to analyze the effect of tariff reductions on the relative wages of skilled and less-skilled workers. Since these wages are assumed common across industries within each country, aggregation by country makes more sense. Second, we are interested in the effect of tariff reductions on wages through changing trade patterns across countries. We are therefore interested in demand for goods identified by country rather than by industry. The direct and indirect effects of tariff reduction on domestic and foreign demand are shown in Table 6.

Table 6. Change of Domestic Demand and Regional Trade, by Country
(In billions of U.S. dollars)

Ctry. 1/	Direct Effect				Indirect Effect			
	Domestic	Export	Import	Trade balance	Domestic	Export	Import	Trade balance
IDN	2.597	0.736	0.684	0.052	-1.478	-0.076	-0.294	0.218
MYS	2.457	0.872	1.479	-0.607	-1.168	0.159	-0.891	1.050
PHL	2.799	0.454	1.085	-0.632	-1.801	0.362	-0.810	1.171
SGP	0.233	0.925	0.203	0.721	0.173	-0.546	0.643	-1.188
THA	8.159	0.883	2.979	-2.096	-5.555	1.082	-3.334	4.416
CHN	4.543	3.563	0.341	3.222	-0.394	-1.542	0.839	-2.382
TWN	6.646	1.329	2.416	-1.087	-4.734	-0.169	-1.290	1.121
KOR	11.516	1.589	2.419	-0.830	-8.010	0.280	-1.568	1.848
JPN	28.985	5.672	5.433	0.239	-17.773	-2.432	-1.090	-1.342
USA	12.326	4.363	3.347	1.016	-7.452	-2.875	2.037	-4.913
Total	80.262	20.386	20.386	0.000	-48.191	-5.758	-5.758	0.000

1/ Country abbreviations are defined in Table 1.

Direct and indirect effects

There are a few points to note. First, the tariff reduction initially increases both domestic and foreign demand (see the first and third columns of Table 6). For example, the direct effects on domestic demand for the region increases by $80.262 billion, and regional trade volume increases by $20.386 billion. This increase in demand for domestic as well as foreign goods is attributed to the expansionary effect on output and income discussed earlier.

Second, trade balance initially increases for Indonesia, Singapore, China, Japan and the United States but not for the other countries (see the fourth column of Table 6). For example, trade balance for China increases by as much as $3.222 billion. On the other hand, trade balance worsens in all other countries. Particularly, in Thailand, it falls by $2.096 billion.

Third, the indirect effect on the pattern of exports is consistent with what happens to relative prices (see the sixth column of Table 6). For example, the relative price fall in Thailand and the Philippines is reflected in an increase in demand for goods produced in these countries: their exports increase by $1.082 and $0.362 billion, respectively. Similarly, the relative price increase in China and the United States is also reflected in a decrease in demand for goods produced in these countries: their exports fall by $1.542 and $2.875 billion, respectively. One exception is Japan, where the relative price fall is not accompanied by an increase in export demand.[16]

Fourth, the indirect effect on the pattern of imports is also consistent with what happens to relative prices (see the seventh column of Table 6). A relative price increase leads to output expansion while

[16] U.S. and Chinese demand for Japanese goods does increase, however; this increase in demand is more than offset by a fall in demand for Japanese goods from the rest of Asia.

a relative price fall results in output contraction. Output expansion (or contraction) increases (or reduces) intermediate inputs demand as well as consumption demand through increasing (or decreasing) real income of households. For example, the relative price fall in Thailand and the Philippines is reflected in a contraction of output and a corresponding fall in import demand: their imports fall by \$3.334 and \$0.810 billion, respectively. On the other hand, the relative price increase in China and the United States leads to an expansion of output and a corresponding increase in import demand in these countries: their imports increase by \$0.839 and \$2.037 billion, respectively.

Finally, the indirect effect on trade balance is negative for countries with relative price increase and positive for others (see the last column of Table 6). For example, the effect of the relative price increase on the trade balance of China and the United States are −\$2.382 and −\$4.913 billion, respectively. The effect on other countries is generally positive. Two exceptions are Japan and Singapore, where the relative price fall results in a drop in trade balance by \$1.342 and \$1.188 billion.

Total effects

Let us now turn to the total effect (i.e., the sum of direct and indirect effect) on trade balance for the region. Table 7 reports the initial level of exports, imports, and trade balance, and the total effect on exports, imports, and trade balance. The total effect is reported both in terms of real and nominal values.

Table 7. Change of Trade Balance

(In billions of U.S. dollars)

Ctry. 1/	Initial Level				Total Effect						
					Real				Nominal		
	Dome -stic	Ex -port	Im -port	Trade bal.	Dome -stic	Ex -port	Im -port	Trade bal.	Ex -port	Im -port	Trade bal.
IDN	173	32.1	21.7	10.4	1.119	0.660	0.390	0.270	0.228	0.143	0.085
MYS	69	48.2	51.5	-3.3	1.289	1.031	0.588	0.443	-0.018	-0.058	0.039
PHL	48	13.9	15.0	-1.1	0.997	0.815	0.275	0.540	0.188	0.112	0.076
SGP	76	45.4	53.9	-8.5	0.406	0.379	0.846	-0.467	-0.122	-0.119	-0.003
THA	132	31.5	43.0	-11.5	2.604	1.965	-0.355	2.320	0.262	-0.863	1.125
CHN	1,040	75.1	65.9	9.2	4.149	2.021	1.180	0.841	2.472	0.366	2.106
TWN	219	57.6	63.6	-6.0	1.912	1.160	1.126	0.034	0.240	0.406	-0.166
KOR	453	67.1	75.5	-8.4	3.506	1.869	0.851	1.018	0.513	0.197	0.317
JPN	4,283	279.0	172.9	106.1	11.212	3.240	4.343	-1.103	-0.205	2.780	-2.985
USA	5,892	168.2	255.2	-87.0	4.875	1.488	5.385	-3.897	0.895	1.489	-0.594
Total	12,386	818.2	818.2	0.0	32.071	14.628	14.628	0.000	4.453	4.453	0.000

1/ Country abbreviations are defined in Table 1.

There are a several interesting findings. First, the initial increase in regional trade volume by \$20.386 billion is reduced to \$14.628 billion once price adjustments are taken into account (see the sixth column of Table 7). This drop in trade volume occurs since an increase in exports by countries with relative price fall (e.g., Thailand and the Philippines) is more than offset by a fall in exports by countries with relative price increase (e.g., China and the United States).

Second, the increase in trade volume relative to the initial level is larger than that in demand for domestic goods. For example, the demand for domestic goods for the region increases by \$32.071 billion, and this increase is equivalent to a 0.26 percent increase from the initial level of \$12.386 trillion. On the other hand, the trade volume increases by \$14.628 billion, which is a 1.79 percent increase from the initial level of \$818.2 billion. The relative increase in trade volume reflects a subsitution of domestic with foregin goods.

Third, the real trade balance generally worsens (or improves) in countries with an increase (or a fall) in the general price level relative to the rest of the countries in the region. For example, trade balance in the United States falls by \$3.897 billion. On the other hand, trade balance in Thailand and the Philippines increases by \$2.320 and \$0.540 billion, respectively.

Fourth, nominal trade balance increases in Indonesia, Malaysia, the Philippines, Thailand, China, and Korea, but decreases in other countries. These changes in nominal trade balance, which are more commonly discussed in trade analysis, provide somewhat different pictures from those in real trade balance discussed above.

D. Effect on Employment

Table 8 presents the total change in the demand for skilled and less-skilled labor, respectively.

As the direct effect of tariff reductions, excess demand emerges in both skilled and less-skilled labor markets without an exception. There are two competing direct effects of tariff reduction on labor demand. First, producers substitute their labor inputs with relatively cheaper imported materials and hence labor demand falls. Second, because of the initial expansionary effect on production, the demand for labor increases. Since the latter dominates the former (and also since the supply of labor is exogenously given), excess demand emerges in labor markets.

After the relative price change, a few distinct features are observed on reallocation of resources (see Table 8). First, in many of the emerging market economies, both types of labor input fall in the tradables sectors (e.g., BMI, MEQ, and MOT) and increase in the nontradables sectors (e.g., SER). Such a pattern is less clear for industrialized economies.

Second, in many of the emerging market economies, the increase in less-skilled labor inputs tends to be larger in magnitude than that in skilled labor. See row 'Total' in the upper block of Table 8 for the average percentage increase in less-skilled labor input and see row 'Total' in the lower block of Table 8 for the average percentage increase in skilled labor input. These changes result in relative increase in the demand for less-skilled labor (see the last row of Table 8).

On the other hand, in the industrialized economies (e.g., Japan and the United States), the increase in less-skilled labor inputs tends to be smaller in magnitude than that in skilled labor, resulting in relative decrease in the demand for less-skilled labor (see the last row of Table 8).

Table 8. Change of Labor Input
(In percent)

Ind. 1/	Country 1/										
	IDN	MYS	PHL	SGP	THA	CHN	TWN	KOR	JPN	USA	Total
	Total Effect on Less-Skilled Labor										
AGR	0.019	0.034	-0.016	0.310	0.769	0.135	0.358	0.046	-0.047	0.181	0.179
EGW	0.057	-0.077	-0.055	0.043	0.044	-0.233	0.045	0.046	-0.018	0.001	-0.015
FOD	0.074	0.709	-0.035	1.289	1.561	0.194	0.715	0.124	-0.036	0.205	0.480
TEX	1.917	2.530	4.370	2.930	1.699	0.793	1.495	2.168	0.126	0.165	1.819
PAP	0.192	0.024	-0.065	0.094	0.489	-0.153	0.018	0.106	0.013	0.018	0.074
CHE	0.170	0.333	0.261	0.061	0.616	-0.096	0.298	0.422	0.122	0.048	0.224
BMI	-0.265	-0.471	-0.015	-0.200	-0.369	-0.434	-0.160	-0.071	0.086	-0.017	-0.192
MEQ	-0.355	0.277	-0.684	-0.157	-1.063	-0.411	-0.415	-0.136	0.228	-0.036	-0.275
SER	0.052	0.005	0.092	0.033	-0.146	0.031	0.003	-0.019	-0.028	-0.002	0.002
MOT	-0.415	-0.598	-1.394	-0.282	-0.733	-0.303	-0.281	-0.372	-0.098	-0.032	-0.451
Total	0.144	0.304	0.246	0.424	0.233	-0.048	0.207	0.232	0.035	0.053	0.185
	Total Effect on Skilled Labor										
AGR	-0.013	0.031	-0.039	0.309	0.850	0.120	0.353	0.062	-0.036	0.189	0.183
EGW	0.024	-0.080	-0.078	0.043	0.126	-0.248	0.039	0.062	-0.007	0.010	-0.011
FOD	0.041	0.706	-0.058	1.288	1.642	0.179	0.709	0.140	-0.026	0.213	0.484
TEX	1.885	2.527	4.347	2.929	1.781	0.778	1.490	2.184	0.137	0.173	1.823
PAP	0.160	0.021	-0.088	0.094	0.571	-0.168	0.013	0.122	0.024	0.026	0.077
CHE	0.137	0.331	0.238	0.060	0.698	-0.111	0.292	0.438	0.132	0.056	0.227
BMI	-0.298	-0.474	-0.038	-0.200	-0.287	-0.449	-0.166	-0.055	0.096	-0.009	-0.188
MEQ	-0.387	0.274	-0.707	-0.157	-0.981	-0.426	-0.421	-0.120	0.239	-0.028	-0.271
SER	0.020	0.003	0.069	0.033	-0.064	0.016	-0.003	-0.003	-0.017	0.006	0.006
MOT	-0.447	-0.601	-1.417	-0.282	-0.651	-0.318	-0.287	-0.356	-0.088	-0.024	0.447
Total	0.112	0.301	0.223	0.423	0.315	-0.063	0.202	0.248	0.045	0.061	0.189
	Relative Increase in the Demand for Less-Skilled Labor										
Total	0.032	0.003	0.023	0.001	-0.082	0.015	0.006	-0.016	-0.011	-0.008	-0.004

1/ Industry and country abbreviations are defined in Table 1.

E. Effect on Wages

The change in the real wage rate of less-skilled labor, that of skilled labor and the difference of the two (i.e., the wage gap) are shown in the first, second, and third columns of Table 9, respectively.[17] Moreover, the effect on relative wages through changing supply prices of tradables and nontradables respectively are shown in the fourth and fifth columns of the table. The effect on relative wages through changing input price of tradables, nontradables, and imports are shown in the last three columns of the table. Note that the five columns under the heading 'Sources of Change in Wage Gap' sum to 'Wage Gap.'

The main findings are as follows. First, abolishing tariff rates, the 1995 level of which are on average 6.0 percent (see Table 3), has a negligible effect on the wage gap (see the third column of Table 9).

[17] The change in the real wage rate is computed as the change in the nominal wage rate minus the change in the general price level presented in row 'Total' in the upper half of Table 5.

Table 9. Sources of Change in Wage Gap
(In percent)

Ctry. 1/	Change in Real Wage Rate		Wage Gap	Sources of Change in Wage Gap				
				Supply Prices		Input Prices		
	Less-Skilled	Skilled		Tradables	Non-tradables	Tradables	Non-tradables	Imports
IDN	0.442	0.475	-0.032	-1.219	-0.408	1.292	0.227	0.076
MYS	1.473	1.476	-0.003	-11.893	-1.673	10.047	1.506	2.011
PHL	1.576	1.600	-0.023	-6.873	-1.681	7.991	2.585	-2.044
SGP	0.551	0.552	-0.001	-7.861	-2.608	1.852	1.341	7.274
THA	1.739	1.657	0.082	-2.818	-2.090	4.577	2.819	-2.047
CHN	0.355	0.370	-0.015	-3.537	-0.878	2.806	0.552	1.042
TWN	0.697	0.702	-0.006	-2.775	-0.525	2.040	0.441	0.814
KOR	0.619	0.603	0.016	-1.640	-0.289	1.715	0.354	-0.124
JPN	0.165	0.154	0.011	-0.326	-0.163	0.294	0.219	-0.014
USA	0.056	0.048	0.008	-0.165	-0.043	0.089	0.034	0.094

1/ Country abbreviations are defined in Table 1.

Even in comparison with the percentage change in the price level, which on average falls by 0.725 percent (see Table 5), the effect on the wage gap is negligible. This finding is consistent with the findings in the literature that tariff reductions have an insignificant effect on relative wages.

Second, the effects of a tariff reduction through changes in supply prices are all negative, that is, the wage gap widens (see the fourth and fifth columns of Table 9). Recall that abolishing tariff rates leads to an excess supply in the goods market (see Table 4) and hence a reduction in prices (see Table 5). Producers facing a fall in the price of goods they supply (for a given cost of production) would reduce production by laying off less-skilled labor (for a given level of skilled labor). A fall in supply prices therefore has a negative effect on the wage gap.

Third, the effects of the tariff reduction through changes in domestic inputs prices are all positive, that is, the wage gap closes. Producers facing a fall in the price of inputs (for a given price of goods they supply) would increase production by hiring additional less-skilled labor (for a given level of skilled labor). A fall in domestic input prices therefore has a positive effect on the wage gap.

Moreover, the positive effects on the wage gap through changes in tradable input prices seem substantially large than those through changes in nontradable input prices. This is true especially for emerging market economies.

Fourth, the effect of imported input price movements on relative wages depends on the effect on terms of trade (see the last column of Table 9). Recall that countries with the largest tariff cuts are the ones with a relatively large fall in the general price level (e.g., Thailand and the Philippines). These countries suffer from a deterioration in terms of trade. That is, imports of intermediate inputs become more expensive relative to what they export. An increase in the cost of imports discourages production and hence lowers the demand for less-skilled labor (for a given level of skilled labor). An increase in the import price of inputs therefore has a negative effect on the wage gap. On the other hand, producers in countries with an improvement in terms of trade benefit from import cost reductions. A fall in the import price of inputs therefore has a positive effect on the wage gap in these countries.

Fifth, most of the effect of the change in terms of trade on relative wages is offset by the effect of domestic price movements on relative wages. For example, in Thailand and the Philippines, the cost reduction from the fall in the price of domestic inputs, in particular that of domestic tradable inputs, generates a large enough demand for less-skilled labor (for a given level of skilled labor). What is interesting is that the positive effect of domestic price movements on the wage gap is large enough to fully offset the negative effect of import price movements on relative wages. On the other hand, the domestic price movements have a negative effect on the wage gap for countries such as the United States, China, Taiwan, Singapore, and Malaysia. The extent of the negative impact of domestic price movements on relative wages is large enough to wipe out the the positive effects on the wage gap from the import price movements for these countries.

In summary, the relative wage decomposition highlights the importance of relative price movements through which a tariff cut affects relative wages. This is true for both movements in the price of imports relative to domestic goods and that in the price of tradables relative to nontradables.

VI. Concluding Remarks

We examined the effect of abolishing the existing tariff rates on wages using the 1995 Asian international input-output table. In particular, we focused on the effect of tariff reduction through its effects on domestic relative prices. We find that prices of tradables and nontradables generally fall, and this is especially true for tradables. In a cross-country comparison, countries with the largest tariff cuts face a deterioration in their terms of trade. The overall effect of these price movements on relative wages is negligible across the board. The prices of domestic tradables, nontradables, and imports individually, however, have distinctively different impact on relative wages across countries. For example, import price movements have an adverse effect on the wages of less-skilled workers relative to more-skilled workers in countries with deteriorating terms of trade. Domestic price movements, however, fully offset the negative impact from deterioration in the terms of trade, leaving the overall effect on relative wages in these countries almost negligible. The effect of trade on wages through its effect on domestic prices, especially that on input prices (which have been neglected in the literature so far), is an important element in understanding the overall impact of trade on wages.

APPENDIXES

I. Technical Notes

A. Specification of Technology and Preference

Technology

We assume that production technology (1) can be described with the Cobb-Douglas functional form.[18] That is, the representative producer in jth industry in nth country faces the following production function:

$$X_j^n = A_j^n \left[\prod_{m=1}^{M+1} \prod_{i=1}^{I} (X_{ij}^{mn})^{\alpha_{ij}^{mn}} \right] \cdot \left(L_j^n\right)^{(\beta_L)_j^n} \cdot \left(H_j^n\right)^{(\beta_H)_j^n} \cdot (\bar{K}_j^n)^{\gamma_j^n}, \tag{24}$$

where

$$\sum_{m=1}^{M+1} \sum_{i=1}^{I} \alpha_{ij}^{mn} + (\beta_L)_j^n + (\beta_H)_j^n + \gamma_j^n = 1. \tag{25}$$

Assuming that capital input and intermediate inputs from the rest of the world are exogenously given at least in the short-run, we can rewrite the production function as follows:

$$X_j^n = A_j^n Q_j^n \left[\prod_{m=1}^{M} \prod_{i=1}^{I} (X_{ij}^{mn})^{\alpha_{ij}^{mn}} \right] \cdot \left(L_j^n\right)^{(\beta_L)_j^n} \cdot \left(H_j^n\right)^{(\beta_H)_j^n}, \tag{26}$$

where $Q_j^n = \left[\prod_{i=1}^{I} (\bar{X}_{ij}^{M+1,n})^{\alpha_{ij}^{M+1,n}}\right] \cdot (\bar{K}_j^n)^{\gamma_j^n}$ is a composite of exogenous factors of production.

The (short-run) profit maximization problem of the representative producer in jth industry in nth country can therefore be described as follows:

$$\begin{aligned} Max\ \pi_j^n \quad &= \quad p_j^n X_j^n - \sum_{m=1}^{M+1} \sum_{i=1}^{I} p_i^m \left(1 + \tau_i^{mn}\right) X_{ij}^{mn} - w_L^n L_j^n - w_H^n H_j^n - r^n \bar{K}_j^n, \\ & \quad\ s.t.\ X_j^n \text{ as described in equation (26).} \end{aligned} \tag{27}$$

Note that p_j^n and p_i^m are the prices of goods (and inputs) produced in jth industry of nth country and that in ith industry of mth country, respectively. w_L^n and w_H^n are the wage rate of less-skilled and skilled labor in nth country, respectively. τ_i^{mn} is the unit cost incurred on imports of goods produced ith industry of mth country by nth country.

Solving the short-run profit maximization problem (27) gives us the following supply and factor demand equations for jth industry in nth country. The supply equation is:

$$X_j^n = \left(G_j^n\right)^{\frac{1}{\kappa_j^n}} \left(p_j^n\right)^{\frac{1-\kappa_j^n}{\kappa_j^n}} \left[\prod_{m=1}^{M} \prod_{i=1}^{I} (p_i^m)^{-\frac{\alpha_{ij}^{mn}}{\kappa_j^n}} \right] \cdot (w_L^n)^{-\frac{(\beta_L)_j^n}{\kappa_j^n}} \cdot (w_H^n)^{-\frac{(\beta_H)_j^n}{\kappa_j^n}} \tag{28}$$

[18] Note that the Jacobian matrix does not depend on the functional form we specify here; it only depends on the size of the elasticity of substitution among factors and inputs of production (see Tokutsu (2002) for more detail). Here, by assuming the Cobb-Douglas functional form, we are setting the elasticity of substitution to be 1. See below in this appendix for the impact of different elasticities on our empirical findings.

where $\sum_{i=1}^{I}\alpha_{ij}^{M+1,n}+\gamma_j^n=\kappa_j^n$ and $G_j^n=A_j^nQ_j^n\left[\prod_{m=1}^{M}\prod_{i=1}^{I}\left(\frac{\alpha_{ij}^{mn}}{1+\tau_i^{mn}}\right)^{\alpha_{ij}^{mn}}\right]\cdot(\beta_L)_j^{n(\beta_L)_j^n}\cdot(\beta_H)_j^{n(\beta_H)_j^n}$. The intermediate inputs, less-skilled labor, and skilled labor demand equations are as follows:

$$X_{ij}^{mn}=\frac{p_j^n}{p_i^m}\cdot\frac{\alpha_{ij}^{mn}X_j^n}{1+\tau_i^{mn}},\ (i=1,\ldots,I;m=1,\ldots,M) \tag{29}$$

$$L_j^n=\frac{p_j^n}{w_L^n}\cdot(\beta_L)_j^n\cdot X_j^n \tag{30}$$

$$H_j^n=\frac{p_j^n}{w_H^n}\cdot(\beta_H)_j^n\cdot X_j^n \tag{31}$$

Preference

As for the household's consumption behavior, we assume that the utility maximization problem of the representative consumer of nth country is as follows:

$$\begin{aligned} Max\ U^n &= B^n\prod_{m=1}^{M+1}\prod_{i=1}^{I}C_i^{mn\theta_i^{mn}} \\ s.t.\ C^n &= \sum_{m=1}^{M+1}\sum_{i=1}^{I}p_i^m(1+\tau_i^{mn})C_i^{mn}, \end{aligned} \tag{32}$$

where $\sum_{m=1}^{M+1}\sum_{i=1}^{I}\theta_i^{mn}=1$ and C^n is the total consumption of nth country.

Solving the utility maximization problem (32) gives us the following consumption demand equation for the representative consumer in nth country:

$$C_i^{mn}=\frac{(\theta_i^{mn})^*}{p_i^{m+1}(1+\tau_i^{mn})}\cdot C_{-ROW}^n \tag{33}$$

where $(\theta_i^{mn})^*=\frac{(\theta_i^{mn})}{\sum_{m=1}^{M}\sum_{i=1}^{I}\theta_i^{mn}}$ and C_{-ROW}^n is the nth country's total *intraregional* consumption demand, which is defined as follows:

$$C_{-ROW}^n=C^n-\sum_{i=1}^{I}p_i^{M+1}(1+\tau_i^{M+1,n})\bar{C}_i^{M+1,n}. \tag{34}$$

C_{-ROW}^n is defined as above because we assume that imports of consumption goods from the rest of the world, $\bar{C}_i^{M+1,n}$ for all $j\in\{1,\ldots,I\}$ are assumed to be exogenously given.

B. Jacobian Matrix

The actual structure of the submatrices of the Jacobian matrix $\mathbf{\Phi}_p$ are as follows: for $m, n \in \{1, \ldots, M\}$ and $s, r \in \{L, H\}$,

$$\frac{\partial \mathbf{e}^m}{\partial \left(\mathbf{p}^n\right)'} = \begin{bmatrix} \frac{\partial E_1^m}{\partial p_1^n} & \cdots & \frac{\partial E_1^m}{\partial p_I^n} \\ \vdots & \ddots & \vdots \\ \frac{\partial E_I^m}{\partial p_1^n} & \cdots & \frac{\partial E_I^m}{\partial p_{I1}^n} \end{bmatrix}, \frac{\partial \mathbf{e}^m}{\partial \mathbf{w}_s'} = \begin{bmatrix} \frac{\partial E_1^m}{\partial w_s^1} & \cdots & \frac{\partial E_1^m}{\partial w_s^M} \\ \vdots & \ddots & \vdots \\ \frac{\partial E_I^m}{\partial w_s^1} & \cdots & \frac{\partial E_I^m}{\partial w_s^M} \end{bmatrix}, \tag{35}$$

$$\frac{\partial \mathbf{e}_r}{\partial \left(\mathbf{p}^n\right)'} = \begin{bmatrix} \frac{\partial E_r^1}{\partial p_1^n} & \cdots & \frac{\partial E_r^1}{\partial p_I^n} \\ \vdots & \ddots & \vdots \\ \frac{\partial E_r^M}{\partial p_1^n} & \cdots & \frac{\partial E_r^M}{\partial p_I^n} \end{bmatrix}, \frac{\partial \mathbf{e}_r}{\partial \mathbf{w}_s'} = \begin{bmatrix} \frac{\partial E_r^1}{\partial w_s^1} & \cdots & \frac{\partial E_r^1}{\partial w_s^M} \\ \vdots & \ddots & \vdots \\ \frac{\partial E_r^M}{\partial w_s^1} & \cdots & \frac{\partial E_r^M}{\partial w_s^M} \end{bmatrix}. \tag{36}$$

Note that the submatrices $\frac{\partial \mathbf{e}_r}{\partial \mathbf{w}_s'}$ for $s, r \in \{L, H\}$ are diagonal matrices because of two underlying assumptions. First, we assume no labor mobility across countries and hence $\frac{\partial E_r^m}{\partial w_s^n} = 0$ for $m \neq n$. Second, two types of labor, skilled and less-skilled, are considered substitutes within a country and hence $\frac{\partial E_r^m}{\partial w_s^m} \neq 0$ even if $r \neq s$.

The Jacobian matrix $\mathbf{\Phi}_p$ is computed as follows. First, $\mathbf{\Phi}_p$ is decomposed into four parts,

$$\mathbf{\Phi}_p = \mathbf{\Xi}_p - \sum_{n=1}^{M} \sum_{j=1}^{I} \left(\mathbf{\Psi}_p\right)_j^n - \sum_{n=1}^{M} \left(\Upsilon_p\right)^n - \varGamma_p, \tag{37}$$

where each submatrix is obtained as follows.

First, $\mathbf{\Xi}_p$ is obtained by differentiating the supply function (28) with respect to prices and wages. Second, $\left(\mathbf{\Psi}_p\right)_j^n$ for each representative producer in jth industry of nth country is obtained by differentiating the intermediate input demand functions (29) and labor demand functions (30) and (31) with respect to prices and wages. Third, $\left(\mathbf{\Upsilon}_p\right)^n$ for each representative consumer in nth country is obtained by differentiating consumption demand functions (33) with respect to prices and wages.

Finally, $\varGamma_p$ is obtained by setting $\frac{\partial F_i^{m,M+1}}{\partial p_i^m} = -F_i^{m,M+1}$ in the diagonal entries and zero otherwise. Our assumption that nominal exports to the rest of the world is given exogenously allows us to do so. More specifically, this assumption implies that the first derivative of nominal exports from ith industry in mth country to the rest of the world with respect to p_i^m must equal zero: that is,

$$\frac{\partial \left(p_i^m F_i^{m,M+1}\right)}{\partial p_i^m} = p_i^m \frac{\partial F_i^{m,M+1}}{\partial p_i^m} + F_i^{m,M+1} = 0. \tag{38}$$

The diagonal entries of $\varGamma_p$, that is, $\frac{\partial F_i^{m,M+1}}{\partial p_i^m}$, must therefore equal $-F_i^{m,M+1}$.

C. Properties of Jacobian Matrix: Stability of Equilibrium

The main properties of the Jacobian matrix are as follows. First, our Jacobian matrix is a dominant diagonal matrix with positive diagonals; that is, the initial equilibrium in our model is stable.

More discussions on the stability of an equilibrium of this type of model, both in the context of mathematics and economics, can be found in McKenzie (1960) and Tokutsu (2002).

Second, all the elements of the inverse of the Jacobian matrix, Φ_P^{-1}, are positive (see Table 10 for the summary of the inverse of the Jacobian matrix). Note that each column of Φ_P^{-1} represents the change of prices induced by a downward shift of the excess supply function of the corresponding market by one unit. For example, the first column of Φ_P^{-1} represents changes in prices and wages when the final demand for Indonesian agricultural products increases by \$1 billion. All elements of Φ_P^{-1} being positive therefore implies that for an exogenous increase in excess demand in any markets in the region, all prices – including nominal wages – increase.

Table 10. Summary of Inverse of Jacobian Matrix
(In percent)

Ind. 1/	Country 1/									
	IDN	MYS	PHL	SGP	THA	CHN	TWN	KOR	JPN	USA
					Diagonal Elements					
AGR	4.079	7.309	10.354	58.589	5.044	0.819*	2.853	2.602	0.794	0.545
EGW	5.359	7.105	17.120	4.734	6.927	1.431	4.398	2.555	0.617	0.477
FOD	3.521	5.444	8.464	9.314	3.363	0.875	2.300	1.604	0.499*	0.429
TEX	4.600	11.405	9.875	11.393	3.189	0.791	1.950	1.401	0.643	0.519
PAP	12.439	18.982	49.093	13.158	13.742	1.990	3.865	2.733	0.620	0.487
CHE	5.070	7.471	20.461	7.326	7.892	1.048	2.059	1.605	0.588	0.470
BMI	7.732	7.435	15.322	5.591	7.943	0.987	1.941	1.566	0.567	0.463
MEQ	4.102	1.389*	7.659	0.824*	1.673	0.804	0.992*	0.895*	0.479*	0.391*
SER	3.235*	3.098	7.479*	1.785*	2.838	0.805	1.685*	1.194	0.481*	0.395*
MOT	3.484*	2.190	10.084	2.900	2.863*	0.799	1.445*	1.204	0.517*	0.422*
L	2.618	9.215	9.192	7.126	3.732	0.826	1.892	1.059	0.283	0.156
H	9.696	8.690	20.855	5.236	7.947	0.939	1.729	1.907	0.295	0.249
					Average of the Off-Diagonal Elements in the Corresponding Columns					
AGR	0.357	0.277	0.608	0.242	0.306	0.157	0.256	0.184	0.195	0.199
EGW	0.424	0.294	0.665	0.232	0.324	0.183	0.268	0.228	0.218	0.205
FOD	0.355	0.262	0.575	0.248	0.300	0.149	0.246	0.196	0.200	0.200
TEX	0.343	0.258	0.457	0.252	0.288	0.154	0.260	0.211	0.217	0.211
PAP	0.393	0.295	0.525	0.254	0.305	0.176	0.269	0.228	0.225	0.213
CHE	0.375	0.296	0.583	0.260	0.308	0.173	0.263	0.230	0.229	0.214
BMI	0.473	0.290	0.710	0.286	0.344	0.185	0.280	0.261	0.249	0.230
MEQ	0.392	0.277	0.522	0.261	0.305	0.186	0.270	0.245	0.241	0.231
SER	0.405	0.331	0.701	0.243	0.342	0.169	0.271	0.230	0.224	0.216
MOT	0.481	0.322	0.834	0.298	0.395	0.187	0.293	0.265	0.249	0.234
L	0.173	0.184	0.231	0.164	0.167	0.079	0.117	0.121	0.112	0.071
H	0.147	0.185	0.236	0.141	0.156	0.078	0.105	0.111	0.105	0.086

1/ Industry and country abbreviations are defined in Table 1.

Third, in most cases, each diagonal element of Φ_P^{-1} is the largest positive value in the corresponding column (see the upper half of Table 10); that is, the price (or wage) increase is the largest in the market where an exogenous increase in excess demand occurs. For example, when the final demand for Indonesian agricultural products increases by \$1 billion, the price of Indonesian agricultural products increases by 4.011 percent while that of other products on average increase by 0.344 percent. Note that diagonals with an asterisk are not the largest element in the corresponding column. Even in these cases, however, the average of the off-diagonal elements is smaller than the corresponding diagonal element.

D. Decomposition of Wage Gap

In our model, tariff reduction induces changes in prices, but also changes in input choices. That is, all the parameters such as α_{ij}^{mn}, $(\beta_L)_j^n$, $(\beta_H)_j^n$, and κ_j^n also change. For the sake of simplicity in explaining the method of decomposition, let us assume that these parameters remain constant.[19] From the supply function, we know that the following relationship must hold:

$$\left(1-\kappa_j^n\right)\hat{p}_j^n = \sum_{m=1}^{M}\sum_{i=1}^{I}\alpha_{ij}^{mn}\left(\hat{p}_i^m\right) + (\beta_L)_j^n\left(\hat{w}_L^n\right) + (\beta_H)_j^n\left(\hat{w}_H^n\right) + \kappa_j^n\left(\hat{X}_j^n\right). \tag{39}$$

Since we can rewrite $(\beta_H)_j^n = 1-\sum_{m=1}^{M}\sum_{i=1}^{n}\alpha_{ij}^{mn} - (\beta_L)_j^n - \kappa_j^n$, the wage gap can be decomposed into two components:

$$\left(\hat{w}_L^n - \hat{w}_H^n\right) = \left(\frac{\hat{p}_j^n - \hat{w}_H^n}{(\beta_L)_j^n} - \frac{\kappa_j^n\left(\hat{p}_j^n + \hat{X}_j^n - \hat{w}_H^n\right)}{(\beta_L)_j^n}\right) - \left(\sum_{m=1}^{M}\sum_{i=1}^{I}\frac{\alpha_{ij}^{mn}\left(\hat{p}_i^m - \hat{w}_H^n\right)}{(\beta_L)_j^n}\right). \tag{40}$$

To further analyze the channels through which the tariff reduction is transmitted to the changes in the wage gap, both components are further decomposed into three subcomponents classified by the type of intermediate inputs. For example, the second component is decomposed as follows:

$$\begin{aligned} -\left(\sum_{m=1}^{M}\sum_{i=1}^{I}\frac{\alpha_{ij}^{mn}\left(\hat{p}_i^m - \hat{w}_H^n\right)}{(\beta_L)_j^n}\right) \quad = \quad & -\left(\sum_{m=n}\sum_{i\neq 2,9}\frac{\alpha_{ij}^{mn}\left(\hat{p}_i^m - \hat{w}_H^n\right)}{(\beta_L)_j^n}\right) \\ & -\left(\sum_{m=n}\sum_{i=2,9}\frac{\alpha_{ij}^{mn}\left(\hat{p}_i^m - \hat{w}_H^n\right)}{(\beta_L)_j^n}\right) \\ & -\left(\sum_{m\neq n}\sum_{i=1}^{10}\frac{\alpha_{ij}^{mn}\left(\hat{p}_i^m - \hat{w}_H^n\right)}{(\beta_L)_j^n}\right). \end{aligned} \tag{41}$$

The first term captures the effect on the wage gap due to the price change in the domestic intermediate inputs that are tradables (i.e., if $m = n$ and $i \neq 2$ or 9). The second term captures the effect on the wage gap due to the price change in the domestic intermediate inputs that are nontradables (i.e., if $m = n$ and $i = 2$ or 9). The third term captures the effect on the wage gap due to the price change in the imported intermediate inputs (i.e., if $m \neq n$ and for all $i = 1, ...10$).

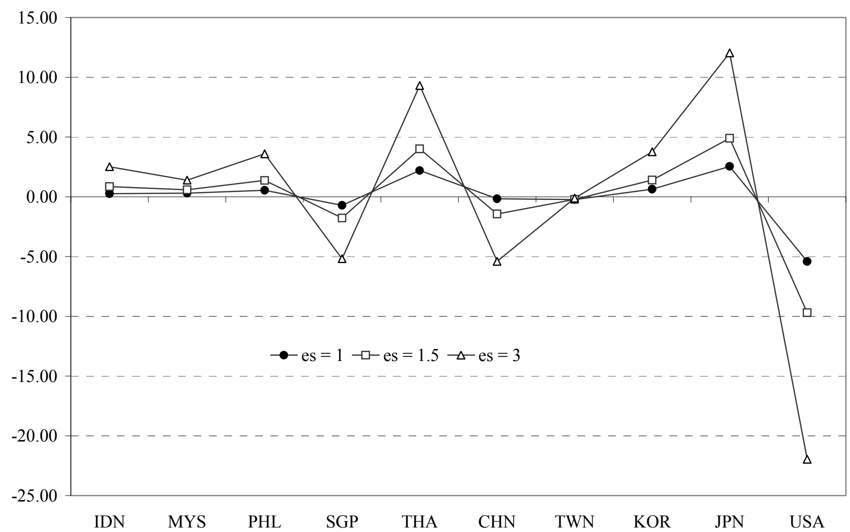
[19] In the actual decomposition, we should allow for changes in these parameters.

E. Sensitivity Analysis

This study assumes the Cobb-Douglas functional form to describe both technology and preference. The choice of the functional form does not, however, affect the general tendency in the findings of this study. For example, suppose that the production function takes a more general functional form (e.g., a constant-elasticity-of-substitution (CES)) and the elasticity of substitution among factors of production (i.e., capital, skilled and less-skilled labors) and inputs can take any value other than 1.

Our sensitivity analysis, for example on trade balance (Table 7), shows that the magnitude of the impact of tariff cut on trade balance becomes large as the elasticity (es) increases, but the direction of the impact remains the same (see Figure 2).

Figure 2. Sensitivity Analysis: Trade Balance



II. Data

A. Tariff Data

To analyze the effect of a change in tariff rates, we need data on tariff payments that are disaggregated by the type of goods imported. The international input-output table distinguishes tariff payments on imports within the region from those on imports from the rest of the world. It does not, however, distinguish the data by the type of goods imported. For example, in Table 2, tariff data for producers in jth industry in nth country is T_j^n. We need to break this into T_{ij}^{mn} for $m, n = \{1, 2\}$ and $i, j = \{1, 2\}$ so that the total tariff payments by this producer are disaggregated by the type of goods imported.

We assume that total tariff payments made by the representative producer in jth industry in nth country or the representative consumer in nth country (T_j^n or T^n) can be disaggregated as follows:

$$T_j^n = \sum_{m=1}^{M}\sum_{i=1}^{I} T_{ij}^{mn} + \sum_{i=1}^{I} T_{ij}^{M+1,n} = \sum_{m=1}^{M}\sum_{i=1}^{I} t_{ij}^{mn}\left(1 + d_{ij}^{mn}\right) p_i^m X_{ij}^{mn} + \sum_{i=1}^{I} T_{ij}^{M+1,n} \quad (42)$$

$$T^n = \sum_{m=1}^{M}\sum_{i=1}^{I} T_i^{mn} + \sum_{i=1}^{I} T_i^{M+1,n} = \sum_{m=1}^{M}\sum_{i=1}^{I} t_i^{mn}\left(1 + d_i^{mn}\right) p_i^m C_i^{mn} + \sum_{i=1}^{I} T_i^{M+1,n}, \quad (43)$$

where d_{ij}^{mn} and t_{ij}^{mn} are the rates of transportation costs and the tariff rates incurred to producer j on imports of good produced by ith industry of mth country, and d_i^{mn} and t_i^{mn} are those incurred to the consumer.

Moreover, we make three assumptions on the tariff rates. First, we assume that the tariff rates are zero if exporting country and importing country are the same, i.e., $t_{ij}^{nn} = 0$ (or $t_i^{nn} = 0$). Second, we assume that the tariff rates are specific to importing country (i.e., country n) but not to exporting country (i.e., country m). That is, we assume $t_{ij}^{mn} = t_{ij}^{m'n}$ where country m is different from country m'. This assumption is consistent with the way in which the Most-Favored-Nation (MFN) rates are applied. Third, we assume that tariff rates are specific to exporting industry (i.e., industry i), but not to importing industry (i.e., industry j). That is, we assume $t_{ij}^{mn} = t_{ij'}^{mn}$ where industry j is different from industry j'. This assumption implies that the tariff rates faced by consumers and producers are also the same.

Data on MFN rates are taken from the Trade Analysis and Information System (TRAINS) Version 3.0 compiled by the United Nations Conference on Trade and Development (UNCTAD) (see UNCTAD (1996)). The concordance between the commodity classification used in this dataset (which is the Harmonized System (HS) of commodity classification) and the industry classification used in the international input-output table (the Universal Input-Output classification (UIO)) is carried out using two concordance tables. One is the concordance table between HS and the 1987 Standard Industrial Classification (SIC) provided by Feenstra and others (2002). The other is the concordance table between the 1987 SIC and the UIO (which is available upon request). Once the tariff rates from TRAINS are classified according to the UIO, we take an average for each importing country n and for each good imported i to obtain the country- and industry-specific tariff rates $\hat{t}_i^n$.

The country- and industry-specific tariff rates $\hat{t}_i^n$ for all nth country and ith industry are used to compute the disaggregated tariff payments data as follows:

$$T_{ij}^{mn} = \hat{t}_{ij}^{mn}\left(1+d_{ij}^{mn}\right)p_i^m X_{ij}^{mn} \text{ where } \hat{t}_{ij}^{mn} = \hat{t}_i^n \tag{44}$$
$$T_i^{mn} = \hat{t}_i^{mn}\left(1+d_i^{mn}\right)p_i^m C_i^{mn} \text{ where } \hat{t}_i^{mn} = \hat{t}_i^n, \tag{45}$$

where the rates of transportation costs (d_{ij}^{mn} and d_i^{mn}) are estimated separately (see the next subsection).

Unfortunately, the difference between the sum of the estimated tariff payments $\hat{T}_j^n = \sum_{m=1}^M \sum_{i=1}^I \hat{T}_{ij}^{mn}$ (or $\hat{T}^n = \sum_{m=1}^M \sum_{i=1}^I \hat{T}_{ij}^{mn}$) and the actual $T_j^n - \sum_{i=1}^I T_{ij}^{M+1,n}$(or $T_j^n - \sum_{i=1}^I T_i^{M+1,n}$) is not negligible. There are at least two obvious reasons for this discrepancy. First, taking a simple average, which ignores the composition of goods within each industry, is certainly problematic. Second, the quality of the TRAINS data is questionable. The discrepancy between the tariff rates reported in the national statistics and in the TRAINS dataset – for example, those of the United States International Trade Commission (USITC) and those of the TRAINS data – is not negligible. A possible solution to the first problem, for example, is to take a weighted average. There is, however, no immediate solution to the second problem. We therefore compute the ratio between the estimated and the actual for each jth industry (or each consumer m) in each country and multiply the estimated by that ratio to close the gap between the estimated and the actual tariff payments.[20]

B. Transportation Data

As in the case of tariff data, the international input-output table reports only the aggregated payments on freight and insurance. We therefore assume that they can be disaggregated as follows:

$$D_j^n = \sum_{m=1}^M \sum_{i=1}^I D_{ij}^{mn} + \sum_{i=1}^I D_{ij}^{M+1,n} = \sum_{m=1}^M \sum_{i=1}^I d_{ij}^{mn} p_i^m X_{ij}^{mn} + \sum_{i=1}^I D_{ij}^{M+1,n}, \tag{46}$$
$$D^n = \sum_{m=1}^M \sum_{i=1}^I D_i^{mn} + \sum_{i=1}^I D_i^{M+1,n} = \sum_{m=1}^M \sum_{i=1}^I d_i^{mn} p_i^m C_i^{mn} + \sum_{i=1}^I D_i^{M+1,n}. \tag{47}$$

We make three assumptions on the rates of transport costs. First, we assume that there is no transport costs involved in trade among domestic industries, that is, $d_{ij}^{nn} = 0$ (or $d_i^{nn} = 0$).[21] Second, we assume that freight and insurance costs are not only specific to the importing country n and the commodity imported i, but also to the exporting country m. The only characteristic that is irrelevant here is type of importing agent (consumer and producer of each industry).

Data on freight and insurance costs are hard to obtain, especially those of developing countries. There are two ways to obtain approximations of these costs. One is to take the difference between import data reported at the cost of insurance and freight (c.i.f.) values and export data recorded at the free-on-board (f.o.b.) values. Such data, however, are rarely available, especially at the disaggregated level.

[20] This treatment to close the gap between the estimated and the actual tariff payments has its own problem; for example, it assumes that the size of the error is the same across sectors.

[21] Freight and insurance costs incur when goods are shipped within a country. In this study, such costs are ignored since what is recorded in the international input-output table only includes those costs incurred on international shipments.

The other method is to make use of trade data that report freight and insurance costs. For example, the U.S. bilateral trade data used in Hummels (1999) and Feenstra and others (2002). Once the per distant freight and insurance costs are estimated for all commodities traded, we can estimate the freight and insurance costs for bilateral trade involving countries other than the United States. This method is not perfect either since freight and insurance costs do not only depend on distance, but also on the method of transportation, the country of destination, and so on. Nevertheless, we consider this method more appropriate and accessible than the first.

More specifically, we first use data provided by Feenstra and others (2002) to estimate the following equation for each industry (where the imported goods are produced), importing country, and exporting country with the ordinary least squares (OLS) estimator:

$$\log\left(\delta_i^{mn}\right) = \alpha_i + \beta_i \log\left(dist^{mn}\right), \tag{48}$$

where δ_i^{mn} is the rate of freight and insurance for shipping goods produced in ith industry from exporting mth country to importing nth country and $dist^{mn}$ is the distance between the two countries. Given that this database includes only the U.S. bilateral trade data, nth country is always the United States. Hummels (1999) includes other right-hand side variables such as borders, languages, free-trade agreements and so on, but for this study, these variables are not included.

We then use the estimated parameters $\hat{\alpha}_i$ and $\hat{\beta}_i$ for each ith industry to estimate the rate of freight and insurance for other bilateral trade partners as follows:

$$\hat{\delta}_i^{mn} = \exp\left(\hat{\alpha}_i + \hat{\beta}_i \log\left(dist^{mn}\right)\right). \tag{49}$$

The country- and industry-specific rates of freight and insurance $\hat{\delta}_i^{mn}$ are then used as a proxy for d_{ij}^{mn} in intermediate inputs trade and d_i^{mn} in final goods trade to compute the estimated freight and insurance payments as follows:

$$\hat{D}_{ij}^{mn} = \hat{d}_{ij}^{mn} p_i^m X_{ij}^{mn} \text{ where } \hat{d}_{ij}^{mn} = \hat{\delta}_{ij}^{mn} \tag{50}$$

$$\hat{D}_i^{mn} = \hat{d}_i^{mn} p_i^m C_i^{mn} \text{ where } \hat{d}_i^{mn} = \hat{\delta}_i^{mn}. \tag{51}$$

The discrepancy between the sum of the estimated freight and insurance payments $\hat{D}_j^n = \sum_{m=1}^M \sum_{i=1}^I \hat{D}_{ij}^{mn}$ (or $\hat{D}^n = \sum_{m=1}^M \sum_{i=1}^I \hat{D}_i^{mn}$) and the actual $D_j^n - \sum_{i=1}^I D_{ij}^{M+1,n}$ (or $D_j^n - \sum_{i=1}^I D_i^{M+1,n}$) is adjusted as in the case of the discrepancy for tariff rate estimations.

C. Data on Skilled and Less-Skilled Labor

The international input-output table does not differentiate skilled and unskilled wage compensations. Since we are interested in relative wages, we compute relative wage compensation of skilled and unskilled labor. More specifically, we construct the relative wage compensation of production workers (relative to nonproduction workers) using (i) employment data by occupation and industry and (ii) wage data by occupation and industry.

Wage data are taken from Freeman and Oostendorp (2000). The original data source is the October Inquiry of the International Labor Organization (ILO). By averaging data by occupation and industry, the relative wage rate of nonproduction workers for each industry and each country is constructed (see Table 11).

Table 11. Relative Wage Rates of Nonproduction Workers, by Industry

Industry		Country 1/						
		PHL	SGP	THA	CHN	KOR	JPN	USA
2	Mining and quarrying				0.773	1.552		
31	Food, beverages, and tobacco	0.724	1.188	0.956	1.269	1.082	1.096	1.136
32	Textiles and wearing apparel							
33	Wood and wood products							
34	Paper and paper products		1.125	1.817	1.101	1.436	1.586	1.207
35	Chemicals and chemical products		1.740		1.116	1.340	1.004	2.324
36	Nonmetallic products							
37	Basic metal		2.928	2.921		1.392		
38	Metal products, machinery, and equipment		1.432	2.121	1.303	1.135		1.518

1/ Country abbreviations are defined in Table 1.

When the relative wage rate is not available, we use the average relative wage rate recorded in the last row instead. The relative wage compensation of production workers used in this study is summarized in Table 12.

Table 12. Relative Wage Compensation of Production Workers, by Industry

Ind. 1/	Country 1/									
	IDN	MYS	PHL	SGP	THA	CHN	TWN	KOR	JPN	USA
AGR	0.995	1.000	0.993	1.000	1.000	0.574	0.574	0.997	0.749	0.901
EGW	0.823	0.403	0.716	0.403	0.250	0.409	0.409	0.628	0.548	0.901
FOD	0.929	0.506	0.844	0.506	0.813	0.617	0.617	0.840	0.807	0.857
TEX	0.929	0.506	0.086	0.506	0.813	0.617	0.617	0.846	0.775	0.686
PAP	0.929	0.506	0.490	0.506	0.813	0.617	0.617	0.676	0.607	0.750
CHE	0.929	0.506	0.204	0.506	0.813	0.617	0.617	0.692	0.630	0.601
BMI	0.929	0.506	0.153	0.506	0.813	0.617	0.617	0.736	0.718	0.549
MEQ	0.929	0.506	0.076	0.506	0.813	0.617	0.617	0.769	0.671	0.384
SER	0.750	0.381	0.074	0.381	0.636	0.380	0.380	0.645	0.528	0.844
MOT	0.929	0.524	0.106	0.444	0.833	0.640	0.640	0.810	0.646	0.688

1/ Industry and country abbreviations are defined in Table 1.

Employment data by occupation and industry are collected from national labor statistics of each country in our sample (see Table 13). Different countries have different classification of occupations, but most of them can be aggregated to the 1-digit International Standard Classification of Occupations (ISCO) level: 0/1 Professional, technical and related workers; 2 Administrative and managerial workers; 3 Clerical and related workers; 4 Sales workers; 5 Service workers; 6 Agriculture, animal husbandry and forestry workers, fishermen and hunters; and 7/8/9 Production and related workers, transport equipment operators and laborers. We then further aggregate the data to obtain employment data on nonproduction workers (ISCO 0-3) and production workers (ISCO 4-9).

Table 13. Source of Employment Data

Country	Title	Source	Table
Indonesia	Population of Jawa Barat, Results of the 1995 Intercensal Population Survey	Badan Pusat Statistik (BPS-Statistics Indonesia)	Table 26-9 Population 10 Years of Age and Over who Worked During the Previous Week by Educational Attainment and Main Industry (Urban + Rural)
Malaysia	Labour Force Survey Report 1995, June 1996	Department of Statistics, Malaysia	Table A 3.5 (and A 3.9) Percentage Distribution of Employed Persons by Industry and Ethnic Group (and by Occupation and Ethnic Group)
Philippines	1990 Census of Population and Housing, Philippines	National Economic and Development Authority, National Census and Statistics Officer, Manila	Table 17 Gainful workers 15 years old and over by Occupation Group (Major), Industry Group (Major), and Region: 1990
Singapore	Report on the Labour Force Survey of Singapore 1992	Ministry of Manpower	Table 18 Employed Persons Aged Fifteen Years and Over by Occupation, Sex and Industry
Thailand	Report of the Labor Force Survey, Whole Kingdom, February 1995	National Statistics Office, Office of the Prime Minister	Level of Education Attainment, Industry and Sex (p.77)
China	Tabulation on the 1995 Population Census of the People's Republic of China, 1997	National Bureau of Statistics, People's Republic of China	Major Figures by 10 Percent Sampling (in Chinese), Table 3-11,Table 3-12
Taiwan Province of China	Monthly Bulletin of Manpower Statistics, Taiwan Area, Republic of China, December 1995	Directorate-General of Budget, Accounting and Statistics, Executive Yuan, Republic of China	Table 18 Employed Persons by Industry and Occupation in Taiwan Area (pp. 42-3)
Korea, Republic of	1990 Input-Output Tables (I), 1993	Bank of Korea	Table 3-2 Employment Matrix (pp.653-58)
Japan	1995 Input-Output Table for Japan	Statistics Bureau, Ministry of Public Management, Home Affairs, Ports and Telecommunications	
United States	Employment, Hours, and Earnings, United States, 1909-1994, Volumes I and II and March 1993 Benchmark Revision	U.S. Department of Labor Bureau of Labor Statistics	

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