

**TRADE LIBERALIZATION, SKILL-LINKED INTERMEDIATE
AND TWO-SIDED WAGE GAP**

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Abstract

An interesting contemporary research question in trade theory deals with the possibility of rising wage inequality across the globe. A few possible explanations have been provided so far. We provide a natural explanation and a rigorous proof of the phenomenon by arguing that liberalizing trade in skill-linked intermediate product is likely to increase skilled-unskilled wage gap across the globe. Our model has the feature that a trade-induced shock can reduce the price of the skill-intensive traded good and raise the skilled-unskilled wage gap at the same time.

Key Words: Wage gap; Liberalization; Skill-linked Intermediate; North-South Trade.
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1. Introduction

The topic of trade and wage inequality has already featured as an important research agenda in contemporary trade theory. One intriguing aspect of the problem has to do with the phenomenon of so-called two-sided wage gap. If liberal trade policies affect both the North and the South, the standard Heckscher-Ohlin type prediction is that the wage gap will increase in the North and reduce in the South as the North exports relatively skilled labour intensive goods and the South has a comparative advantage in unskilled labour intensive products. However, a wide range of empirical evidence suggest that the wage gap between the skilled and unskilled workers has been on the rise both in the North and in the South¹. Therefore, a natural theoretical investigation is not out of context. The task has been sought to be accomplished mainly by three major papers. Feenstra and Hanson (1996,1997) provide interesting analyses based on NAFTA and foreign investment. They demonstrate that wage inequality can rise in USA and in Mexico simultaneously by increasing the relative demand for skilled input across the board. In a way definition of skill changes from one region to another. What is relatively skill-intensive production activity in Mexico can be interpreted as relatively unskilled-intensive activity in the US. This actually echoes a broader interpretation of Heckscher-Ohlin-Samuelson model with multiple skills as elegantly constructed in Davis (1996) and used in Marjit and Acharyya (2003)². In a recent paper, Acemoglu (2003) argue that trade induced pro-active technological change creates increasing demand for skill across the globe and as a consequence the wage gap should be on the rise. He stresses the need for building a trade model with the capacity to explain such two-sided wage gap.

In the simple model we propose in the paper, global wage gap turns out to be an outcome of liberalizing trade in skilled-linked intermediate good. The crux of the matter has a close resemblance with the computer industry. It is well recognized that some of the

¹ For a survey on the empirical evidence refer to Marjit and Acharyya (2003).

² Broader interpretation of the Heckscher-Ohlin-Samuelson framework can take care of apparent paradoxes involving endowment and trade patterns. For a discussion on related issue refer to Jones, Beladi and Marjit (1999). In a recent paper Xu (2003) explains rising wage gap in the North by considering endogenous range of non-traded goods in the Ricardian continuum framework.

Southern countries such as India have emerged as a phenomenal exporter of software related products. Software sectors depend on hardware capabilities. If computers are imported from the North, a decline in import tariff in the South must help the skilled labour in the software processing industries in the South. But lower tariff on hardware implies that such items which are skill-intensive will be more profitable to produce in the North. This tends to increase skilled wage across the globe. Our simple model clearly captures this mechanism and supplements the existing analyses in the literature. What is even more interesting to observe is that the wage inequality in the South grows despite a fall in the world price of its skill-intensive exports. The two key factors in our analysis are asymmetric responses of local prices of intermediate good following a tariff cut in the South and the production and use of such intermediate in the skill-intensive sectors in the two countries. We highlight the point that the pricing of the skill-linked intermediate across the globe is a natural element to cause rising wage gap for both trading partners. Liberal trade policies reduce the price of the skill generated intermediate which is *used* by the skilled workers locally, raising their return. In the global market such liberal policy makes skill-intensive intermediates more profitable to produce, raising the wage of skilled labor *used* to produce such products.

Section 2 builds up the basic model of a two-region world economy where all prices adjust instantaneously and traces out the impact of a liberal trade policy in the South on wage inequality in the two regions. A simple example of the case is provided in section 3. Section 4 concludes the paper.

2. Trade and Wage Inequality

2.1 Framework of a Two-Region World Economy

Consider a world economy consisting of two economies: a home and a foreign country. The home country produces two goods, a final consumption good X and an intermediate good M, using skilled and unskilled labour. We assume that good X is relatively unskilled labour intensive. The foreign country, on the other hand, produces a final good Y using the locally produced as well as imported intermediate good (which are of same

quality or variety) and skilled labour. Thus, the two countries are completely specialized in the two final consumption goods, and produce the same intermediate good.

From these production structures it immediately follows that the home country exports good X and the foreign country good Y. Moreover, since the intermediate good is used only in production of good Y, which is not produced in the home country, entire production of intermediate good in the home country is being exported to the foreign country. The software exports by India best exemplifies the above production structure of our foreign country: highly skilled and trained Indian software experts and programmers use state-of-the-art computers, either locally produced or imported from elsewhere, to write and export software packages³. Of course, in most of the cases local and imported varieties of computers differ, but we are not interested in this paper with the implication of differences in variety of the locally produced and imported intermediate good.

Initially our foreign country has a non-prohibitive ad-valorem tariff on imports of the intermediate from the home country. All markets everywhere are assumed to be perfectly competitive and the production functions for the intermediate good and for final good Y are assumed to exhibit constant returns to scale and diminishing marginal productivity. Moreover, we assume that production technologies for the intermediate good in the two countries are the same.

The Following conditions specify our global economy. All variables with asterisk represent the foreign country. First of all, perfect competition with free mobility of factors within countries imply the following zero-profit conditions:

$$1 = a_{SX}W_S + a_{LX}W \quad (1)$$

$$P_M^w = a_{SM}W_S + a_{LM}W \quad (2)$$

$$P_Y^* = a_{SY}W_S^* + a_{MY}(1 + t)P_M^w \quad (3)$$

³ An alternative interpretation particularly relevant in the USA-Mexico context would be that hardware components constitute the import of intermediate which are then assembled by Mexican skilled workers to produce (and export) personal computers.

$$TP_M^w = a_{SM}W_S^* + a_{LM}W^* \quad (4)$$

where, $T = (1 + t)$; P_M^w = world price of the intermediate good.

There are, of course, the least-cost input choices captured through the coefficients a_{ij} which are not written here explicitly. Note that all prices are expressed in terms of good X.

All factors of production are assumed to be fully employed:

$$\bar{L} = a_{LX}X + a_{LM}M \quad (5)$$

$$\bar{S} = a_{SX}X + a_{SM}M \quad (6)$$

$$\bar{L}^* = a_{LM}M^* \quad (7)$$

$$\bar{S}^* = a_{SM}M^* + a_{SY}Y^* \quad (8)$$

where \bar{S} and \bar{L} (\bar{S}^* and \bar{L}^*) denote endowment of skilled and unskilled labour respectively in the home (foreign) country.

Finally, the world market clearing conditions close the model:

$$a_{MY}Y^* = M + M^* \quad (9)$$

$$\frac{Y_d^w}{X_d^w} = f(P_Y^*) = \frac{Y^*}{X} \quad (10)$$

Given our assumption of the intermediate good being produced by both the countries, and its only use in production of good Y, which, in turn, is produced only in the foreign country, eq. (9) describes equilibrium in global market for this intermediate good. On the other hand, (10) describes equilibrium in the global market for final goods. Here we

assume that tastes are homothetic and identical across the globe so that relative world demand for good Y depends only on its (relative) price. This standard Heckscher-Ohlin assumption is employed here to rule out any real income or country-size effect and to keep the analysis simple.

It is instructive at this point to look at the determination of the prices and output levels. For any given set of prices of the intermediate good and the final good Y, competitive conditions (1) - (4) determine the skilled and unskilled wages (measured in terms of good X) in the two countries. The consequent choice of techniques at such factor prices then help us determine the output levels given the endowments of skilled and unskilled workers in the two regions. Figure 1 illustrates the equilibrium output levels in the foreign country corresponding to the point E^* , for any given set of wages.

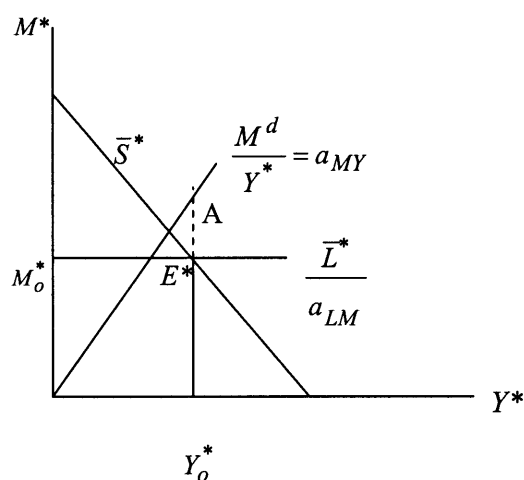


Figure 1: Output Determination in the Foreign Country

Once we arrive at the supply levels, equilibrium conditions (9) and (10) determine the two relative prices, P_M^* and P_Y . What is to be noted is that flexibility of all wages and prices of intermediate and final good ensure that at such equilibrium the demand for the intermediate good produced in the home country is strictly positive. To see this, suppose initially there had been excess supply of intermediate good in the world market: $a_{MY}Y^* \equiv M^d < M + M^*$. The world price of the intermediate good thus falls. In the foreign country, for any given world price of good Y, the skilled wage increases as

evident from the zero-profit condition (3). Production of good Y thus becomes relatively less skilled-labour intensive. On the other hand, unskilled money wage in the foreign country falls to make production of the intermediate good viable. With wage of the skilled workers rising relative to that of the unskilled workers, factor substitution effect makes production of intermediate good more unskilled-labour intensive, which, in turn, lowers its production for a given endowment of foreign unskilled workers [see eq. (7)]. What follows from these effects is that the demand for skilled labour per unit of production of both good Y and M falls. This coupled with contraction of the volume of intermediate output M^* enables an increase in the output of good Y for the same endowment of skilled labour [see eq. (8)]. Therefore, by both the technique and scale effects in sector Y, the (world) demand for intermediate good increases to accommodate for the initial excess supply and, hence, production of intermediate good in the home country.

Thus, referring back to Figure 1, the ray through the origin $\frac{M^d}{Y^*}$, which indicates the demand for intermediate good for any given level of output of good Y, should pass through a point like A above point E^* .

2.2 Liberal trade policy in the Foreign Country

How does a liberal trade policy in our foreign country, a reduction in T , affect wage inequality in the two countries? The answer depends primarily on how world prices change. Note that in the home country the production structure is Heckscher-Ohlin. That is the wages are determined by the relative world price of the intermediate good. In particular, by the standard price magnification effect, changes in relative wage in the home country equals:

$$(\hat{W} - \hat{W}_S) = \frac{-\hat{P}_M^w}{|\theta|} \quad (11)$$

where, $|\theta| = \theta_{LX} - \theta_{LM}$.

Thus, the wage inequality increases there if the world price of the intermediate good rises as a consequence of trade liberalization in the foreign country provided, of course, the final good X is unskilled-labour intensive relative to the intermediate production ($|\theta| > 0$). In the foreign country, on the other hand, changes in relative wages following an increase in the world price of the intermediate good, for example, will not depend upon factor intensity condition but on how the world price of good Y and the tariff-inclusive price of the intermediate good there, $P_M^* = TP_M^w$, change. Since we can expect the tariff-inclusive price of the intermediate good to fall after the tariff cut (for similar reason as in the case known as the non-Metzler result in the standard trade literature), $\hat{T} + \hat{P}_M^w < 0$, the foreign skilled wage increases unambiguously if the world price of good Y increases or remains constant. This is evident from simple manipulation of the zero-profit condition (3) which yields,

$$\hat{W}_S^* = \frac{1}{\theta_{SY}} \hat{P}_Y^* - \frac{\theta_{MY}}{\theta_{SY}} (\hat{T} + \hat{P}_M^w) \quad (12)$$

The skilled wage can increase even when the world price of good Y falls provided, of course, it is less than proportionate to the fall in the tariff-inclusive price of the intermediate good: $\theta_{MY}(\hat{T} + \hat{P}_M^w) < \hat{P}_Y^* < 0$. If the foreign skilled wage increases, for reasons spelled out just now, the unskilled wage must fall as evident from the zero-profit condition (4). As a consequence, the wage gap increases in the foreign country as well. Note that Y is naturally more intensive in use of skilled labor relative to M since M is used as an intermediate and only skilled labor is used along with it. Even if we do not make any assumption on the relative intensities, the underlying production structure automatically assigns such ranking. This was explored in detail in Jones and Marjit (1985).

The lesson that emerges from the above informal discussion is that, to trace out the exact effect of trade liberalization in the foreign country on relative wages there and in the home country, we must first of all examine how and to what extent the world prices of

good Y and the intermediate good change. This is what we turn to in the following subsection.

2.2.1 Changes in commodity prices

Let us begin with the world market for intermediate good. Trade liberalization in the foreign country, as spelled out earlier, changes both the demand for and supply of intermediate good in the world market. Depending on the consequent excess demand or supply, *at initial price*, the world price of the intermediate good rises or falls. This in turn induces further changes in demand and supply. However, taking into account both these initial and induced changes, *at the new equilibrium* demand and supply must match. This means,

$$\hat{Y}^* + \hat{a}_{MY} = \gamma \hat{M} + \gamma^* \hat{M}^* \quad (13)$$

where, $\gamma \equiv \frac{M}{a_{MY}Y^*}$ = share of the home country in total production of the intermediate good and $\gamma^* = (1 - \gamma)$ = share of the foreign country in total production of the intermediate good.

As evident from the left-hand side expression in (13), the change in demand for the intermediate good has two components: First is the additional demand due to expansion of the physical production of good Y, which can be obtained from a little manipulation of the full-employment conditions (7) and (8), as elaborated in the appendix:

$$\hat{Y}^* = -\frac{\lambda_{SM}}{\lambda_{SY}} \sigma_M^* (\hat{W}^* - \hat{W}_S^*) + \theta_{MY} \sigma_Y^* (\hat{W}_S^* - \hat{P}_M^*) \quad (14)$$

where, $\sigma_Y^* = \frac{(\hat{a}_{MY} - \hat{a}_{SY})}{(\hat{W}_S^* - \hat{P}_M^*)}$ is the factor-substitution elasticity in production of good Y and $\sigma_M^* = \frac{(\hat{a}_{SM} - \hat{a}_{LM})}{(\hat{W}^* - \hat{W}_S^*)}$ is factor-substitution elasticity in the (foreign) production of the intermediate good.

The second source of the change in demand for intermediate good is the change in the technique of production, which by the cost minimization condition $\theta_{SY}\hat{a}_{SY} + \theta_{MY}\hat{a}_{MY} = 0$, equals

$$\hat{a}_{MY} = \theta_{SY}\sigma_Y^*(\hat{W}_S^* - \hat{P}_M^*) \quad (15)$$

On the other hand, change in the foreign supply of the intermediate good can be obtained from a little manipulation of the full employment condition for the foreign unskilled workers, eq. (7), and the cost minimization condition in production of the intermediate good $\theta_{SM}^*\hat{a}_{SM}^* + \theta_{LM}^*\hat{a}_{LM}^* = 0$:

$$\hat{M}^* = -\hat{a}_{LM}^* = -\theta_{SM}^*\sigma_M^*(\hat{W}^* - \hat{W}_S^*) \quad (16)$$

Interpretation of the above equation is simple. Since foreign unskilled labour is used only in production of the intermediate good and initially all such workers were fully employed in such production, it is only through the factor substitution effect (or the change in intensity of the use of unskilled labour) that the production of intermediate good in the foreign country can change.

But in the home country, since unskilled workers are employed both in the intermediate as well as the final good (X) productions, the production and supply of the intermediate good by the home country changes through both the sectoral resource allocation effect and the technique effect. Formally, as shown in the appendix,

$$\hat{M} = \beta_M \hat{P}_M^w \quad (17)$$

where, $\beta_M = \frac{\theta_{LM}\sigma_M}{|\theta|} + \frac{\lambda_{LX}\lambda_{SX}\sigma_X + \lambda_{SX}\lambda_{LM}\sigma_M}{|\lambda||\theta|}$. Note that, β_M are positive if $|\theta| >$

0, i.e., good X is relatively unskilled-labour intensive in the home country.

Substitution of (14) – (17) in (13) then yields, using (12) and the value of change in the foreign unskilled wage (see appendix), the change in the world price of the intermediate good required to clear its world market as,

$$(\alpha + \gamma\beta_M)\hat{P}_M^w = \alpha\hat{P}_Y^* - \alpha\hat{T} \quad (18)$$

$$\text{where, } \alpha \equiv \left[\sigma_M^* \left(\frac{\lambda_{SM}}{\lambda_{SY}} + \gamma^* \theta_{SM} \right) \frac{1}{\theta_{LM}} + \frac{1}{\theta_{SY}} \sigma_Y^* \right] > 0.$$

It is immediate from the above expression that the change in the world price of the intermediate good depends not only on the extent of trade liberalization in the foreign country, \hat{T} , but also on the change in the world price of good Y.

Before looking at the direction of the change in the world price of good Y, it is instructive to draw the implication of trade liberalization at the initial level of such a price. From (18) it follows that if β_M is positive, a sufficient condition for which is that good X is relatively unskilled-labour intensive in the home country, trade liberalization in the foreign country raises the world price of the intermediate good. In such a case, by the price magnification effect expressed in (11), the wage gap increases in the home country if good X is relatively unskilled-labour intensive there. In the foreign country too the wage-gap increases at a given world price of good Y as spelled out earlier. Therefore, at the initial world (relative) price of good Y, good X being relatively unskilled-labour intensive ensures that a liberal trade policy in the foreign country raises the wage-gap in both the regions.

However, the world price of good Y need not remain unchanged. This can happen only when the trade liberalization induced changes in (relative) demand and supply in the world final goods market at the initial price are exactly matched. But if an excess demand (or supply) develops at the initial price, the world price of good Y must change. The issue then is can we still have the two-way wage gap, and if so, does it hold under more stringent condition than the requirement that good X be relatively unskilled-labour intensive in the home country? To examine this, we consider the changes in (relative) demand and supply in the world final goods market, taking into account both the initial

and induced changes and equating them which will be realized at the new equilibrium (relative) price of good Y:

$$\hat{Y}^* - \hat{X} = -\sigma_D \hat{P}_Y \quad (19)$$

where, σ_D is the (absolute) price elasticity of (relative) demand for the final goods.

Just as the change in the production of the intermediate good, production of good X in the home country changes through both the sectoral resource allocation effect and the technique effect. But, given initial full employment of both skilled and unskilled workers, an expansion of the intermediate good implies a corresponding contraction of production of the final good X:

$$\hat{X} = -\beta_X \hat{P}_M^w \quad (20)$$

$$\text{where, } \beta_X = \frac{\theta_{SX} \sigma_X}{|\theta|} + \frac{\lambda_{LM} \lambda_{SX} \sigma_X + \lambda_{SM} \lambda_{LM} \sigma_M}{|\lambda| |\theta|}.$$

Substitution of (14) and (20) in (19) yields, after simplification,

$$(\delta + \sigma_D) \hat{P}_Y^* = (\delta - \beta_X) \hat{P}_M^w + \delta \hat{T} \quad (21)$$

$$\text{where, } \delta \equiv \left[\frac{1}{\theta_{LM}} \frac{\lambda_{SM}}{\lambda_{SY}} \sigma_M^* + \theta_{MY} \sigma_Y^* \right].$$

Thus, the world price of good Y depends, among other factors, on the world price of the intermediate good and the tariff rate. This is not surprising because an increase in either of them means increase in the cost of production of good Y and a fall in supply, which in turn raises its world price.

The implication of the above discussion, summarized in the price equations (18) and (21), is that the world prices of the intermediate good and the final good Y (both measured in

terms of good X) depend on each other and, therefore, should be determined simultaneously. Such simultaneous determination yields the following changes in these prices:

$$\hat{P}_Y^* = \frac{1}{\Delta} [\alpha\beta_X + \gamma\delta\beta_M] \hat{T} \quad (22)$$

$$\hat{P}_M^w = -\frac{1}{\Delta} \alpha\sigma_D \hat{T} \quad (23)$$

where, $\Delta = \alpha(\beta_X + \sigma_D) + (\delta + \sigma_D)\gamma\beta_M$.

Once again good X being unskilled-labour intensive relative to the intermediate good ensures that $\Delta > 0$. Consequently, for such an intensity ranking, trade liberalization in the foreign country lowers the world price of the final good Y and raises that of the intermediate good. It then immediately follows that the wage-gap in the home country increases through the standard price magnification effect and the extent of such increase equals,

$$\hat{W}_S - \hat{W} = \frac{\hat{P}_M^w}{|\theta|} = -\frac{\alpha\sigma_D}{|\theta|\Delta} \hat{T} \quad (24)$$

The change in the wage-gap in the foreign country, on the other hand, equals,

$$\hat{W}_S^* - \hat{W}^* = \frac{1}{\theta_{LM}\theta_{SY}} [\hat{P}_Y^* - \hat{P}_M^w - \hat{T}] = -\frac{\gamma\beta_M\sigma_D}{\theta_{LM}\theta_{SY}\Delta} \hat{T} \quad (25)$$

Therefore, the same condition, namely good X is unskilled-labour intensive relative to the intermediate good, underlies the increase in the wage-gap in both the countries.

The wage-gap increases in the foreign country because, first of all, the tariff-inclusive price of the intermediate good falls,

$$\hat{P}_M^* = \hat{P}_M^w + \hat{T} = \frac{1}{\Delta} [\alpha\beta_X + (\delta + \sigma_D)\gamma\beta_M] \hat{T} < 0 \quad (26)$$

and, second, the consequent fall in the unit cost of the intermediate input in production of good Y, $\theta_{MY}\hat{P}_M^*$, is more than the fall in the (world) price of good Y.

4. Concluding Remarks

We have built a simple trade model where trade between two countries are linked through a skill-intensive intermediate input. Liberal trade policy in the foreign country which imports the intermediate good from the home country, raises the world price of this intermediate good but lowers its tariff-inclusive price in the foreign country. These asymmetric movements of prices of the intermediate good in the two countries, benefit skilled workers relative to the unskilled workers alike in the two countries. Asymmetric movement in the world and domestic (or tariff-inclusive) prices of an import good is the more general result that we find in a standard Heckscher-Ohlin-Samuelson model with no intermediate good. But there the corresponding movements in relative wages are also asymmetric. Herein lies the role of trade in intermediate good in generating the symmetric wage movements across countries as explained above.

APPENDIX

1. Change in production of good Y

From full employment conditions (7) and (8) in the text, we obtain:

$$0 = \hat{M}^* + \hat{a}_{LM} \quad (A.1)$$

$$0 = \lambda_{SM}(\hat{M}^* + \hat{a}_{SM}) + \lambda_{SY}(\hat{Y}^* + \hat{a}_{SY}) \quad (A.2)$$

Solving for \hat{Y}^* yields,

$$-\lambda_{SY}\hat{Y}^* = \lambda_{SM}(\hat{a}_{SM} - \hat{a}_{LM}) + \lambda_{SY}\hat{a}_{SY} \quad (A.3)$$

which, using $\hat{a}_{SY} = -\theta_{MY}(\hat{a}_{MY} - \hat{a}_{SY}) = -\sigma_Y^*(\hat{W}_S^* - \hat{P}_M^*)\theta_{MY}$ and $\sigma_M^*(\hat{W}^* - \hat{W}_S^*) = (\hat{a}_{SM} - \hat{a}_{LM})$, boils down to eq. (14) in the text.

2. Change in production in the home country.

From the full employment conditions (5) and (6) for the home country, we can arrive at,

$$0 = \lambda_{LX}(\hat{X} + \hat{a}_{LX}) + \lambda_{LM}(\hat{M} + \hat{a}_{LM}) \quad (\text{A.4})$$

$$0 = \lambda_{SX}(\hat{X} + \hat{a}_{SX}) + \lambda_{SM}(\hat{M} + \hat{a}_{SM}) \quad (\text{A.5})$$

By Cramer's rule these two solve for changes in the two output levels as:

$$\hat{X} = \frac{1}{|\lambda|} [\lambda_{SM}(\lambda_{LX}\hat{a}_{LX} + \lambda_{LM}\hat{a}_{LM}) + \lambda_{LM}(\lambda_{SX}\hat{a}_{SX} + \lambda_{SM}\hat{a}_{SM})] \quad (\text{A.6})$$

$$\hat{M} = \frac{1}{|\lambda|} [-\lambda_{LX}(\lambda_{SX}\hat{a}_{SX} + \lambda_{SM}\hat{a}_{SM}) + \lambda_{SX}(\lambda_{LX}\hat{a}_{LX} + \lambda_{LM}\hat{a}_{LM})] \quad (\text{A.7})$$

where $|\lambda| = \lambda_{LX}\lambda_{SM} - \lambda_{SX}\lambda_{LM}$.

Cost minimization in production of these goods implies:

$$\theta_{SX}\hat{a}_{SX} + \theta_{LX}\hat{a}_{LX} = 0$$

$$\theta_{SM}\hat{a}_{SM} + \theta_{LM}\hat{a}_{LM} = 0$$

A little manipulation of these conditions yield changes in the four input coefficients as:

$$\hat{a}_{LX} = -\theta_{SX}(\hat{a}_{SX} - \hat{a}_{LX}) = -\theta_{SX}\sigma_X(\hat{W} - \hat{W}_S)$$

$$\hat{a}_{SX} = \theta_{LX}(\hat{a}_{SX} - \hat{a}_{LX}) = -\theta_{LX}\sigma_X(\hat{W} - \hat{W}_S)$$

$$\hat{a}_{SM} = \theta_{LM}(\hat{a}_{SM} - \hat{a}_{LM}) = \theta_{LM}\sigma_M(\hat{W} - \hat{W}_S)$$

$$\hat{a}_{LM} = -\theta_{SM}(\hat{a}_{SM} - \hat{a}_{LM}) = -\theta_{SM}\sigma_M(\hat{W} - \hat{W}_S)$$

where, $\sigma_X = \frac{\hat{a}_{SX} - \hat{a}_{LX}}{\hat{W} - \hat{W}_S}$ is the elasticity of factor substitution in production of the final good X; and $\sigma_M = \frac{\hat{a}_{SM} - \hat{a}_{LM}}{\hat{W} - \hat{W}_S}$ is the elasticity of factor substitution in production of the intermediate good.

Substitution of these values in (A.6) and (A.7), using $(\hat{W} - \hat{W}_S) = \frac{-\hat{P}_M^w}{|\theta|}$, yields the changes in the production in the home country as specified in eqs. (17) and 920) in the text.

3. Price Changes

From (5a):

$$\hat{Y}^* + \hat{a}_{MY} = \gamma \hat{M} + \gamma^* \hat{M}^*$$

i.e.,

$$-\frac{\lambda_{SM}}{\lambda_{SY}} \sigma_M^* (\hat{W}^* - \hat{W}_S^*) + \theta_{MY} \sigma_Y^* (\hat{W}_S^* - \hat{P}_M^*) + \theta_{SY} \sigma_Y^* (\hat{W}_S^* - \hat{P}_M^*) = \gamma \beta_M \hat{P}_M^w + \gamma^* \theta_{SM} \sigma_M^* (\hat{W}^* - \hat{W}_S^*)$$

$$\text{i.e., } -\sigma_M^* \left[\frac{\lambda_{SM}}{\lambda_{SY}} + \gamma^* \theta_{SM} \right] (\hat{W}^* - \hat{W}_S^*) + \sigma_Y^* [\hat{W}_S^* - (\hat{T} + \hat{P}_M^w)] = \gamma \beta_M \hat{P}_M^w$$

Since, $\hat{W}^* - \hat{W}_S^* = \frac{1}{\theta_{LM} \theta_{SY}} [\hat{T} + \hat{P}_M^w - \hat{P}_Y^*]$ and $\hat{W}_S^* = \frac{1}{\theta_{SY}} \hat{P}_Y^* - \frac{\theta_{MY}}{\theta_{SY}} (\hat{T} + \hat{P}_M^w)$ so this boils down to,

$$\begin{aligned} & \left[\sigma_M^* \left(\frac{\lambda_{SM}}{\lambda_{SY}} + \gamma^* \theta_{SM} \right) \frac{1}{\theta_{LM} \theta_{SY}} + \frac{1}{\theta_{SY}} \sigma_Y^* \right] \hat{P}_Y^* - \left[\sigma_M^* \left(\frac{\lambda_{SM}}{\lambda_{SY}} + \gamma^* \theta_{SM} \right) \frac{1}{\theta_{LM} \theta_{SY}} + \frac{1}{\theta_{SY}} \sigma_Y^* + \gamma \beta_M \right] \hat{P}_M^w \\ & = \left[\sigma_M^* \left(\frac{\lambda_{SM}}{\lambda_{SY}} + \gamma^* \theta_{SM} \right) \frac{1}{\theta_{LM} \theta_{SY}} + \frac{1}{\theta_{SY}} \sigma_Y^* \right] \hat{T} \end{aligned}$$

Factoring out $\frac{1}{\theta_{SY}}$ and defining $\alpha \equiv \left[\sigma_M^* \left(\frac{\lambda_{SM}}{\lambda_{SY}} + \gamma^* \theta_{SM} \right) \frac{1}{\theta_{LM}} + \frac{1}{\theta_{SY}} \sigma_Y^* \right]$, the above equality can be written as:

$$\alpha \hat{P}_Y^* - (\alpha + \gamma \beta_M) \hat{P}_M^w = \alpha \hat{T} \quad (20)$$

On the other hand, from (6a):

$$\hat{Y}^* - \hat{X} = -\sigma_D \hat{P}_Y$$

$$\text{i.e.,} \quad -\frac{\lambda_{SM}}{\lambda_{SY}} \sigma_M^* (\hat{W}^* - \hat{W}_S^*) + \theta_{MY} \sigma_Y^* (\hat{W}_S^* - \hat{P}_M^*) + \beta_X \hat{P}_M^w = -\sigma_D \hat{P}_Y^*$$

i.e.,

$$\left[\frac{1}{\theta_{LM}} \frac{\lambda_{SM}}{\lambda_{SY}} \sigma_M^* + \theta_{MY} \sigma_Y^* + \sigma_D \right] \hat{P}_Y^* - \left[\frac{1}{\theta_{LM}} \frac{\lambda_{SM}}{\lambda_{SY}} \sigma_M^* + \theta_{MY} \sigma_Y^* - \beta_X \right] \hat{P}_M^w = \left[\frac{1}{\theta_{LM}} \frac{\lambda_{SM}}{\lambda_{SY}} \sigma_M^* + \theta_{MY} \sigma_Y^* \right] \hat{T}$$

Let, $\delta \equiv \left[\frac{1}{\theta_{LM}} \frac{\lambda_{SM}}{\lambda_{SY}} \sigma_M^* + \theta_{MY} \sigma_Y^* \right]$. Hence,

$$(\delta + \sigma_D) \hat{P}_Y^* - (\delta - \beta_X) \hat{P}_M^w = \delta \hat{T} \quad (21)$$

Writing (20) and (21) in matrix form:

$$\begin{bmatrix} \alpha & -(\alpha + \gamma \beta_M) \\ (\delta + \sigma_D) & -(\delta - \beta_X) \end{bmatrix} \begin{bmatrix} \hat{P}_Y^* \\ \hat{P}_M^w \end{bmatrix} = \begin{bmatrix} \alpha \\ \delta \end{bmatrix} \hat{T} \quad (22)$$

The Jacobian determinant, denoted by Δ , equals:

$$\Delta = \alpha(\beta_X + \sigma_D) + (\delta + \sigma_D) \gamma \beta_M \quad (23)$$

Since β_X and β_M are positive if $|\theta| > 0$, hence

$$\Delta > 0 \text{ if } |\theta| > 0 \quad (24)$$

Therefore, solving the above equation system by Cramer's Rule we obtain the price changes as:

$$\hat{P}_Y^* = \frac{1}{\Delta} [\alpha\beta_X + \gamma\delta\beta_M] \hat{T} < 0 \quad (25)$$

$$\hat{P}_M^w = -\frac{1}{\Delta} \alpha\sigma_D \hat{T} > 0 \quad (26)$$

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