Specialization, Trade in Intermediate Goods, and Wage Inequality

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Abstract – Using a model that recognizes the prevalent cross-country specialization in production and the intermediate nature of all traded products, we investigate the effect of observed trends in the prices of ordinary intermediate and semi-final imports on the wage differential between skilled and unskilled labor in the United States. Contrary to earlier findings, our results suggest that decreases in import prices compress this differential. Sources of wage inequality are however found in skill-biased economy-wide dynamic processes of capital accumulation and technical change. The paper offers a simple theoretical model that features endogenous specialization, trade in intermediate products, trade costs, and sources of comparative advantage that derive from both factor endowments and technology that reconciles our findings with related stylized facts

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1. Introduction

The role of trade in the dramatic expansion of relative wage inequality between skilled and unskilled labor in the United States that was observed during the 1970s and 1980s has attracted considerable interest in the literature.[1, 2] Early research in this area relied heavily on the well known Heckscher-Ohlin (HO) channels to investigate the potential link between trade and labor markets. However, in light of little evidence of a substantial increase in the relative price of skilled to unskilled-intensive goods it was soon concluded that the HO mechanism was an unlikely culprit.[3]

The potential relevance of trade in the wage inequality debate was re-introduced in the literature by the pioneering work of Feenstra and Hanson (1996a, 1996b, 1999). These authors argue that preoccupation with HO dynamics that emphasize trade in final goods obfuscates the full range of channels through which import competition impacts labor markets. They explain that imports of intermediate goods have the potential to have a significant impact on wages by fragmenting the set of production processes that typically take place within individual manufacturing industries into distinct sub-activities which are then re-allocated across countries.[4] In this context, Feenstra and Hanson show that to the extent that intermediate imports in

[1] See figure 1.

[2] Surveys can be found in Richardson (1995), Burtless (1995), Slaughter (2000), and Feenstra and Hanson (2003). See also Sachs and Shatz (1994).

[3] Slaughter (1998).

[4] Feenstra and Hanson (1996b, p. 240).

the US are low-skill intensive, they shift employment away from low-skill labor and contribute to wage inequality.

Recently, in an effort to shed light on how trade can facilitate inequality not only in developed but also in developing countries, Zhu and Trefler (2005)[5] extended the general framework of Feenstra and Hanson by introducing Ricardian sources of comparative advantage in the analysis. This innovation further facilitates global fragmentation of production[6]. Yet, despite the evolving importance of how trade in intermediate goods promotes specialization, relevant research continues to rely on the regularities of a globally diversified production. For example, research in this area typically reconciles 4-digit SITC classifications of imports into the US with 4-digit SIC figures irrespectively of the source of these imports[7]. Of course, the potential for aggregation bias in such studies that may derive from the extent of specialized production is well known and has been extensively discussed in the literature[8]. However, it was not until the recent findings of Davis and Weinstein (2001) and Schott (2003) that the true potential magnitude of this bias was revealed. These authors show that traditional product categorizations hide fundamental and profound cross-country specific product differences. They further demonstrate that when these

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[5] See also the working edition of this article (Zhu and Trefler, 2001, Section 9).

[6] As shown by Chipman (1971) and Ferguson (1978), at least in the context of a $2\times2\times2$ HO model of trade that also incorporates Ricardian comparative advantage and allows for at least one of the two factors to be mobile, production will never prevail within the cone of diversification.

[7] See for example Zhu and Trefler (2005, p. 33).

[8] See for example Feenstra and Hanson (1996a, 2000)

differences are considered, cross-country specialization in largely exclusive subsets of goods is significant.

Aggregation bias aside, the prevalence of specialization can have profound implications on the study of trade and wages. For example, an increase in non-competing intermediate imports can potentially stimulate demand for all domestic labor with uncertain effects on wage inequality. Furthermore, to the extent that increases in imports facilitate further fragmentation of production and lead to new structures of specialization, they can set in motion substitutions between skilled and unskilled labor that can have significant effects on relative wages.

In this article we extend our earlier work in this area (Tombazos, 2003) in an effort to investigate the role of imports disaggregated by kind in wage inequality using an economy-wide production theory approach that relies on a flexible functional representation of aggregate US production. This approach has a number of advantages over competing methodologies. By not requiring "matching" imports with domestic output it is not susceptible to the aggregation bias associated with such reconciliations[9]. In addition, by assuming an economy-wide perspective that does not depend on, or require, fully diversified production, this approach can investigate potential substitutions between different types of labor that may ensue from a process of trade induced fragmentation of domestic production. Moreover, the flexible representation of production used in this approach is very much unlike the Cobb-Douglass and the CES in that it does not restrict, *a priori*, the signs or sizes of

[9] Of course, this approach is as vulnerable as other methodologies to other forms of aggregation bias, such as those that may derive from extensive changes in the structure of the US economy over time that change the composition of aggregate output.

estimated coefficients. Hence, relevant estimations can capture potential complementarities between non-competing imports and domestic labor which are likely to prevail in any highly specialized setting.

The empirical model proposed in this article disaggregates imports by kind on the basis of their degree of "intermediateness". This facilitates a study of the special role of traded inputs in promoting fragmentation that has been highlighted in the "outsourcing" literature. In addition, disaggregation of imports on this basis will also shed light on the results of a host of studies, including Aw and Roberts (1985), Tombazos (1998, 1999b), and others, that have identified substantial differences in the role of intermediate and final imports in domestic production. In particular, these authors find that imports of final goods, or more precisely goods not subject to *extensive* domestic handling, typically lead to net substitutions with aggregate domestic labor, while imports of ordinary intermediate products generally complement aggregate labor demand. While such studies suggest that the degree of import "intermediateness" is likely to impact differentially on the demand for different types of labor, they do not employ frameworks that can relate such effects directly to wages.

As far as we know, the only previous effort to disaggregate imports by kind in a model of the U.S. economy that also disaggregates labor in skilled and unskilled categories using the production theory approach was undertaken by Harrigan (2000).[10] This contribution relates closely to issues examined in this paper, but does not shed light on the potential link between the degree of intermediateness of a particular category of imports and wage inequality. As we show in the appendix, this

[10] Harrigan and Balaban (1999) also examine wage inequality between skilled and unskilled labour using the GNP function approach, but do not examine imports.

study falls in a category of contributions in the general area of production theory that employ a modeling approach that purges the flexibility of the functional form that is used to represent aggregate production. The implications are significant as the resulting model relinquishes its potential to correctly identify potentially complementary relationships between imports and domestic labor. Yet, such possible complementarities underlie a key reason for adopting the proposed framework of analysis.

The remainder of this paper is organized as follows. The econometric model is examined in section 2. The construction of the data and estimation issues are discussed in section 3, and the results in section 4. Section 5 offers a simple theoretical framework that reconciles our findings with related stylized facts. Concluding remarks are reserved for section 6.

2. The Model

The production theory approach to modeling international trade was originally proposed by Burgess (1974, 1976), and further developed by Kohli (1978, 1991). A derivative of this framework was applied to the study of trade and wages by Tombazos (1999a), and was subsequently extended in a number of relevant applications by Falk and Koebel (2002), Tombazos (2003), Hijzen, Görg, and Hine (2005), and others. This approach requires the specification of a model that treats imports as an input in the domestic economy on the premise that *all* imports, including those of so-called "final" goods, are subject to extensive domestic "downstream handling" [11] before reaching the consumer. This is reflected in the well

[11] This may involve a host of domestic channels including assembly, finishing, transportation, insurance, storage, repackaging, marketing, and retailing.

known observation that a significant portion of the "shelf price" of imported commodities reflects value added domestically[12].

Given our objectives, labor is disaggregated in high-skill (S) and low-skill (U) categories (henceforth, for convenience, skilled and unskilled categories, respectively) and imports in ordinary intermediate (I) and semi-final (F) goods. While the model treats all imports as inputs in domestic production this disaggregation captures the significant differences in the extent to which different categories of imported commodities are subjected to domestic handling. [13]

Following Krugman (1995, p. 355) and Kohli (1991, p. 76, 170, 198), the prices of capital (K), skilled labor (S), and unskilled labor (U), together with the quantities of ordinary intermediate imports (I), semi-final imports (F), and aggregate output (Y) are treated as variable. In this context, production technology is represented using the symmetric normalized quadratic (SNQ) variable profit function developed by Kohli (1993). This functional form allows the required non-uniform statistical treatment of inputs, and is given by

$$\pi = \tfrac{1}{2}(\mathbf{g}'\mathbf{x})\mathbf{p}'\mathbf{A}\mathbf{p}/(\mathbf{v}'\mathbf{p}) + \tfrac{1}{2}(\mathbf{v}'\mathbf{p})\mathbf{x}'\mathbf{B}\mathbf{x}/(\mathbf{g}'\mathbf{x}) + \mathbf{p}'\mathbf{C}\mathbf{x} + \mathbf{p}'\mathbf{D}\mathbf{x}\, t + \tfrac{1}{2}(\mathbf{v}'\mathbf{p})(\mathbf{g}'\mathbf{x})\,\xi\, t^2 \quad (1)$$

[12] According to Rousslang and To (1993, p. 214), domestic value-added increases the final price of US imports by a greater margin than the combined effect of import tariffs and international transportation costs in the case of about half of all import categories, and for the overall average of all sectors examined by these authors.

[13] My disaggregation of imports in ordinary intermediate and semi-final categories roughly follows Aw and Roberts (1985) and Tombazos (1998) and is discussed in detail in the next section. More detailed disaggregations of imports were initially attempted, but abandoned as they did not allow the econometric implementation to converge.

where and $\mathbf{x} = (x_U, x_S, x_K)'$ and $\mathbf{p} = (p_Y, p_F, p_I)'$ collect the quantities of fixed inputs and the prices of "outputs", respectively; $\mathbf{A} \equiv [a_{ih}]$, $\mathbf{B} \equiv [b_{jk}]$, and $\mathbf{C} \equiv [c_{ij}]$ denote unknown symmetric parameter matrices of dimensions 3×3, $\mathbf{D} \equiv [d_{ij}]$ represents an unknown parameter matrix of dimensions 3×3, $\mathbf{g} \equiv [g_j]$ and $\mathbf{v} \equiv [v_i]$ represent vectors of preselected parameters of order 3, $\forall i, h \in (Y, F, I)$ and $j, k \in (U, S, K)$; ξ denotes an unknown scalar parameter; $\sum_h^{(Y,F,I)} a_{ih} = 0 \;\; \forall i \in (Y, F, I)$; $\sum_k^{(U,S,K)} b_{jk} = 0$ $\forall j \in (U, S, K)$; $\sum_i^{(Y,F,I)} v_i = 1$ and $\sum_j^{(U,S,K)} g_j = 1$. Equation (1) is a fully flexible functional form and it is neither necessarily concave in fixed input quantities, nor necessarily convex in the prices of the variable quantities.

Using the Gorman-Diewert adaptation of Hotelling's[14] lemma, in the context of the *variable* profit function, differentiation of $\pi(\cdot)$ with respect to input prices yields the supply of output and the demand for variable inputs (i.e., imports) given by:

$$\begin{aligned}\mathbf{y} = (\mathbf{g}'\mathbf{x})\mathbf{A}\mathbf{p}/(\mathbf{v}'\mathbf{p}) - \tfrac{1}{2}\mathbf{v}(\mathbf{g}'\mathbf{x})\mathbf{p}'\mathbf{A}\mathbf{p}/(\mathbf{v}'\mathbf{p})^2 + \tfrac{1}{2}\mathbf{v}\mathbf{x}'\mathbf{B}\mathbf{x}/(\mathbf{g}'\mathbf{x}) \\ + \mathbf{C}\mathbf{x} + \mathbf{D}\mathbf{x}t + \tfrac{1}{2}\mathbf{v}(\mathbf{g}'\mathbf{x})\xi t^2\end{aligned} \qquad (2)$$

where $\mathbf{y} = (y_Y | y_F, y_I)'$ collects the quantities of "outputs".[15]

If, under competitive conditions, producers also optimize with respect to fixed inputs[16], the inverse fixed input demand functions for capital and the two types of labor can be derived from the "marginal product" conditions and are given by:

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[14] See Diewert (1974, p. 137).

[15] Note that variable inputs, such as imports, are treated as negative outputs in the model.

[16] See Diewert (1974, p. 140) for a relevant discussion.

$$\mathbf{w} = \tfrac{1}{2}\mathbf{g}\,\mathbf{p}'\mathbf{A}\mathbf{p}\big/\left(\mathbf{v}'\mathbf{p}\right)+\left(\mathbf{v}'\mathbf{p}\right)\mathbf{B}\mathbf{x}\big/\left(\mathbf{g}'\mathbf{x}\right)-\tfrac{1}{2}\mathbf{g}\left(\mathbf{v}'\mathbf{p}\right)\mathbf{x}'\mathbf{B}\mathbf{x}\big/\left(\mathbf{g}'\mathbf{x}\right)^2 + \mathbf{C}'\mathbf{p}+\mathbf{D}'\mathbf{p}t+\tfrac{1}{2}\left(\mathbf{v}'\mathbf{p}\right)\mathbf{g}\xi t^2 \tag{3}$$

where $\mathbf{w} = \left(w_U, w_S, w_K\right)'$ represents the prices of the fixed inputs.

Substitution possibilities between inputs and outputs can be using the elasticity matrix given by:

$$\mathbf{E}=\begin{bmatrix} \left[\left\{\mathbf{diag}\left(\nabla_{\mathbf{p}}\pi(\cdot)\right)\right\}^{-1}\cdot\left(\nabla^2_{\mathbf{pp}}\pi(\cdot)\right)\cdot\left(\mathbf{diag}(\mathbf{p})\right)\right] & \left[\left\{\mathbf{diag}\left(\nabla_{\mathbf{p}}\pi(\cdot)\right)\right\}^{-1}\cdot\left(\nabla^2_{\mathbf{px}}\pi(\cdot)\right)\cdot\left(\mathbf{diag}(\mathbf{x})\right)\right] \\ \left[\left\{\mathbf{diag}\left(\nabla_{\mathbf{x}}\pi(\cdot)\right)\right\}^{-1}\cdot\left(\nabla^2_{\mathbf{xp}}\pi(\cdot)\right)\cdot\left(\mathbf{diag}(\mathbf{p})\right)\right] & \left[\left\{\mathbf{diag}\left(\nabla_{\mathbf{x}}\pi(\cdot)\right)\right\}^{-1}\cdot\left(\nabla^2_{\mathbf{xx}}\pi(\cdot)\right)\cdot\left(\mathbf{diag}(\mathbf{x})\right)\right] \end{bmatrix} \tag{4}$$

where, given $\mathbf{m},\mathbf{n}\in\left(\mathbf{p},\mathbf{x}\right)$, $\nabla_{\mathbf{m}}\pi\left(\cdot\right)$ represents the gradient of $\pi(\cdot)$ with respect to **m** and $\nabla^2_{\mathbf{mn}}\pi\left(\cdot\right)$ denotes the sub-hessian of $\pi(\cdot)$ with respect to **m** and **n**. Similarly, the impact of technical change, made possible by the passage of time, on the prices of the fixed inputs can be captured by the time semi-elasticity

$$\mathbf{E}_{\mathbf{x}t} = \left[\mathbf{diag}\left(\nabla_{\mathbf{x}}\right)\pi\left(\cdot\right)\right]^{-1}\cdot\left(\nabla^2_{\mathbf{x}t}\pi\left(\cdot\right)\right) \tag{5}$$

3. Data and estimation

The model employed in this paper requires data on prices and quantities for skilled and unskilled labor, capital, intermediate and semi-final imports, and aggregate output. The raw data that was used to construct these variables was obtained from the *National Income and Product Accounts of the United States* (NIPA), the *Survey of Current Business*, and the *Occupations by Industry Subject Reports* of the 1970 *Census of Population.*

To generate price and quantity indexes corresponding to economy-wide output, capital, skilled labor, and unskilled labor, in accordance with the requirements of the model discussed in the previous section, we followed the approach used by Tombazos (2003). In the context of this approach, construction of economy-wide output entails a Tornqvist aggregation of all categories of income listed in the NIPA. These include fourteen categories of private consumption, nine categories of private investment, six categories of consumption by the state and federal governments, six categories of investment by the state and federal governments, three categories of exports (including services), and the changes in durable and nondurable business inventories. Given that my model treats imports as an input of domestic production, nominal capital expenditure for any given year corresponds to the nominal value of economy-wide output net of the wage bill and expenditures on imports. To determine, the implicit rental rate of capital for each year we divided nominal capital expenditures by capital stock which we define as the sum of the net stock of fixed non-residential equipment and structures and the net stock of residential capital.

Economy-wide data on employment and wages for skilled and unskilled labor is not currently available for the United States. To produce representative indexes we relied on the definition for skilled labor used by Tombazos (2003) who classifies skilled occupations to include professionals and managers as well as sales, clerical, and precision production labor. Using this definition, and the occupational breakdown across industries that appears in the *Occupations by Industry Subject Reports* of the 1970 *Census of Population*, we calculated the percentage of skilled workers over total employment in each of the fifty-four industries identified in the NIPA. We then proceeded to classify industries as either high-skill intensive or low-skill intensive. An industry is considered to be high-skill intensive if it employs a higher percentage of skilled labor than the average of all industries under examination (which approximates the economy’s skilled labor - aggregate labor ratio). Otherwise, an industry is classified as low-skill intensive. Representative wages and employment levels for the clusters of high skill intensive and low skill intensive industries were derived using Tornqvist aggregations. These employment and wage figures are used as proxies for the representative economy-wide employment and wage rate of "skilled" and "unskilled" labor, respectively.

Disaggregation of imports in intermediate and semi-final groupings was guided by the NIPA's *end-use* classification of imports that corresponds to the following categories: Foods, feeds, and beverages (I_1); durable industrial supplies and materials (I_2); non-durable industrial supplies and materials (I_3); petroleum and products (I_4); capital goods except autos (I_5); autos and parts (I_6); durable consumer goods (F_1); nondurable consumer goods (F_2); and other consumer goods (F_3). Following Tombazos (1998), we classify categories I_1, I_2,…, I_6 as *intermediate imports* and categories F_1, F_2, and F_3 as *semi-final imports*. With the exception of incorporating category I_6 in intermediate imports, which is necessitated by the significant similarities between this category and category I_5, my disaggregation is otherwise identical to the one suggested by Aw and Roberts (1985). The data used covers the period 1968-1994.

The econometric model consists of six equations: the aggregate output supply function, the two variable input demand functions pertaining to ordinary intermediate and semi-final imports, and the three inverse demand functions of capital and the two types of labor. Simultaneous estimation of these equations was performed using an autocorrelation-adjusted nonlinear three-stage-least-squares (AN3SLS) method[17] that accounts for the likely endogeneity of import prices.

[17] The instrumental variables employed are: excise taxes, sales taxes, and personal savings as percentages of personal disposable income; the budget deficit, net foreign

Following preliminary estimation of the model the curvature conditions were checked[18]. Table 1 reports the relevant eigenvalues. As can be seen from this table, while convexity was satisfied in the first round of estimations, concavity was not. This necessitated global enforcement of this condition, and subsequent re-estimation of the model[19]. The method used relies on the approach originally proposed by Wiley, Schmidt and Bramble (1973).

In their well known contribution, Wiley, Schmidt and Bramble (1973) prove that a sufficient condition for a matrix $\mathbf{Q}$ to be negative semidefinite is that it can be expressed as $\mathbf{Q} = -\mathbf{Z} \cdot \mathbf{Z}$ where $\mathbf{Z} \equiv \left[z_{jk} \right]$ is a lower triangular matrix. Building upon the work of these authors, Diewert and Wales (1987) showed that this condition is also necessary.

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investment, and the government wage bill as percentages of GDP; the discount rate; the producer price indices of Canada, Japan, the United Kingdom and Germany; the population of the US, Canada, Japan, Germany and the United Kingdom; the time trend and the time trend squared; and a constant.

[18] Convexity with respect to output and variable input prices requires the estimated parameter matrix $\mathbf{A} \equiv \left[a_{ih} \right]$ to be positive semidefinite, and concavity with respect to the quantities of the fixed factors requires the coefficient matrix $\mathbf{B} \equiv \left[b_{jk} \right]$ to be negative semidefinite.

[19] It should be noted that, unlike the case of the Translog (see the appendix), external imposition of curvature does not compromise the flexibility of the SNQ functional form.

We define:

$$\mathbf{z} = \begin{bmatrix} z_{1,1} & 0 & \cdots & 0 \\ z_{2,1} & z_{2,2} & \cdots & 0 \\ . & . & . & . \\ . & . & \cdots & . \\ . & . & . & . \\ z_{J,1} & z_{J,2} & \cdots & z_{J,J} \end{bmatrix} \tag{6}$$

Hence, the negative product of this lower triangular matrix with its transpose gives:

$$\mathbf{Q} = \begin{bmatrix} -z_{1,1}^2 & -z_{1,1} \cdot z_{2,1} & \cdots & -z_{1,1} \cdot z_{J,1} \\ -z_{1,1} \cdot z_{2,1} & -z_{2,1}^2 \cdot z_{2,2}^2 & \cdots & -z_{2,1} \cdot z_{J,1} - z_{2,2} \cdot z_{J,2} \\ . & . & . & . \\ . & . & \cdots & . \\ . & . & . & . \\ -z_{1,1} \cdot z_{J,1} & -z_{2,1} \cdot z_{J,1} - z_{2,2} \cdot z_{J,2} & \cdots & -z_{J,1}^2 - z_{J,2}^2 - \cdots - z_{J,J}^2 \end{bmatrix} \tag{7}$$

As previously noted, a sufficient condition for the variable profit function to be concave, with respect to the quantities of the fixed factors, is that the estimated parameter matrix $\mathbf{B} \equiv \left[b_{jk} \right]$ is negative semidefinite. Hence, imposition of concavity requires the reparametrization of the model equations by replacing each element of matrix **B** with its corresponding expression in $\mathbf{Q}$. However, given the constraint of linear homogeneity in the fixed input quantities **x** which requires $\sum_k b_{j,k} = 0$, matrix **B** is not of full rank. Hence, in the context of the proposed reparametrization, this constraint must also be imposed on (7)[20]. Using the procedure outlined above,

[20] See Tombazos (2003) for a discussion of linear homogeneity in fixed input quantities in the context of curvature enforcing reparametrisations.

concavity was imposed globally before re-estimating the model. The eigenvalues of the final edition of the model are given in parentheses in the second row of Table 1.

4. Empirical results

The resulting parameter estimates of the final edition of the model are reported in Table 2 together with the associated t-statistics, degrees of freedom (DOF), and Berndt's generalized $\tilde{R}^2$ (1991, p. 468)**.** The overall fit of the model as reflected by the $\tilde{R}^2$ is quite good, and monotonicity is satisfied for all observations with the exception of the first observation in the case of intermediate imports.

Table 3 reports selected annual and average elasticities derived from the parameter estimates of Table 1 using equations (4) and (5). The first part of Table 2 reports what Appelbaum and Kohli (1997, p. 627) refer to as the "Stolper-Samuelson" elasticities. As can be noted, sign reversals are common. However, the average elasticities given by $\varepsilon_{U,F}$, $\varepsilon_{U,I}$, $\varepsilon_{S,F}$ and $\varepsilon_{S,I}$, are all negative with values given by -0.093, -0.112, -0.052, and -0.064, respectively. This result suggests that the downward trend in the relative price of imports observed in recent years, discussed in the literature, has stimulated wages. This result is consistent with the findings of Appelbaum and Kohli (1997) as well as Tombazos (1998, 1999b) who account for both the potentially positive downstream effects of non-competing intermediate imports as well as the effects of output substitution. However, it contradicts the findings of studies that concentrate on the latter either in the context of the HO mechanism, such as Wood (1998), or through a process of outsourcing, such as Feenstra and Hanson (1999). Still, this observation alone does not preclude some congruity between my results and those of studies that only consider the output-substitution quality of imports – at least to the extent that the results of those studies suggest that a decrease in import prices augments wage inequality. Given the qualitative nature of my results, such a decrease in the price of imports may contribute to the trend in wage inequality if it generates a disproportional *increase* in the demand for skilled labor. However, such a relationship does not find support in the evidence. At least in the post 1980 period[21], the relative magnitudes of corresponding Stolper-Samuelson elasticities across the two types of labor examined by my model are consistently characterized by inequalities $\varepsilon_{U,F} < \varepsilon_{S,F}$ and $\varepsilon_{U,I} < \varepsilon_{S,I}$. Hence, contrary again to the results of mainstream studies in this area, trade liberalization schemes which decrease the relative price of ordinary intermediate or semi-final imports, such as uniform tariff reductions, are found to compress, rather than augment, the prevailing wage inequality. Of course, given the relative magnitudes of these elasticities it is clear that this effect is very small. However, it is significantly different from the consensus that has so far emerged in the literature that trade is responsible for about 20% of the increase in wage inequality (see Zhu and Trefler, 2005, p. 21).

The different impact of changes in the prices of intermediate and semi-final imports on the wages of skilled and unskilled labor partly confirms relevant *a priori* expectations. As we noted in an earlier paper, "…other things equal, imports with a high intermediate (final) content are more likely to exhibit complementarity (substitutability) with domestic labor" [Tombazos (1999b, p. 355)]. In the context of the model employed in this paper, this statement would be consistent, other things equal, with corresponding import-price – wage-rate Stolper-Samuelson elasticities that are smaller in the case of ordinary intermediate as compared to semi-final

[21] It should be noted that, as pointed out by Bhagwati and Dehejia (1994, p. 37), 1980 marks the beginning of the era in which the wage differential increased most noticeably.

imports. At least in the post 1985 period the expected pattern emerges in the results. A comprehensive interpretation of the pre 1985 results is beyond the scope of this paper. However, it should be noted that these results reflect, amongst other factors, the nature of the synergy of negative and positive labor demand effects that ensue from output substitution and downstream production processes, respectively, as well as differences in the skill intensity of domestic industries competing with intermediate and semi-final imports. In short, “other things” are not always equal.

Bhagwati and Dehejia (1994) and many others argue that, rather than trade, the observed trend in wage inequality is likely to be driven by the *economy-wide* impact of potentially skill-biased dynamic processes of technical change and capital accumulation (p. 52-55; 69-71). The impact of technical change on wages, made possible by the passage of time, is captured in our model in the form of a residual by the time semi-elasticities $\varepsilon_{U,t}$ and $\varepsilon_{S,t}$ which are both statistically significant at the 1% level with averages of 0.083 and 0.157 respectively. As can be noted, $\varepsilon_{S,t} > \varepsilon_{U,t}$ for all observations. This suggests that technological advancements are more (less) likely to complement (substitute) demand for skilled rather than unskilled labor. Given that $\varepsilon_{S,t}$ is, on average, about two times as large as $\varepsilon_{U,t}$, and given that the two elasticities assume fairly large values[22], technical change is likely to be an important contributor

[22] To place these figures in perspective, it should be noted that the time variable, *t*, that appears in the model was originally assigned values 1, 2,…, 27 for years 1968, 1969, …, 1994, respectively. However, to promote convergence, and together with all prices and instruments, *t* was normalised to the value of 1 for 1987 which necessitated dividing the original value of *t* corresponding to each year in the data by the number 20. Hence, the normalised edition of *t* corresponds to 0.05 for 1968, 0.1 for 1969, 0.15

to the prevailing trend in wage inequality. This result is also consistent with the findings of studies that investigate this issue at the micro level such as Berman *et al.* (1994). Examination of the capital-labor elasticities suggests that capital accumulation strongly reinforces the role of technical change in wage inequality with $\varepsilon_{S,K}$ assuming an average value of 0.494 that is more than seven times larger than the corresponding value of 0.062 for $\varepsilon_{U,K}$, both of which are statistically significant at the 1% level.

5. A Theoretical View of Endogenous Specialization

To shed further light on the potential positive impact of intermediate imports on the relative demand for unskilled labor we propose a model of endogenous specialization that incorporates trade costs and sources of comparative advantage that derive from both factor endowments and technology. This model differs substantially from similar models that have been recently proposed in the literature. For example, unlike Beaulieu *et al.* (2004) that do not consider trade in intermediate goods, such trade features prominently in our analysis. Also, by endogenizing the extend of the global division of labor with respect to liberalization our model is also different from Trefler and Zhu (2005) who do not consider liberalization at all. Also unlike Trefler and Zhu (2005), in our model comparative endowment advantage opposes comparative technological advantage. While our results rely heavily on this alternative specification of comparative advantage, this is by all accounts a peripheral difference between the two models. As shown by Ferguson (1978), in the presence of

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for 1970, and so on. In this light, the average value of, say, $\varepsilon_{S,t}$ that corresponds to 0.157 implies that the passing of each year increases the wage rate of skilled workers by an average of 0.79% $\left[=\left(0.157/20\right)\times 100\right]$.

trade in intermediate goods, Ricardian comparative advantage always supersedes factor endowments in determining the pattern of trade.

5.1 A simple $2\times2\times2$ *model of endogenous specialization*

Consider a world economy consisting of two countries, 1 and 2. Each country *i* is endowed with L_{is} and L_{iu} units of skilled and unskilled labor, respectively. We require full employment and assume that migration between countries prohibitively expensive. We consider two types of outputs X and Y, and require X to also serve as an input in the production of Y. Finally, trade costs take the form of iceberg transaction costs similar to those discussed by Samuelson (1952) and Norman and Venables (1995). Specifically, for each unit of consumer good X or Y imported by country *i* a fraction $1-k_i$ disappears in transit due to costs of international exchange. k_i represents the transaction efficiency coefficient of international exchange that prevails in country *i* and is required to assume a value between zero and one.

We assume that preferences are Cobb-Douglas, and identical across countries and different types of labor. In this setting, the decision problem of a representative consumer of type *m* $\left[m\in\left(s,u\right)\right]$ in country *i* is summarized below:

$$\begin{aligned}&Max \quad U_{im}=(y_{im}+k_i y_{jim})^{\alpha}(x_{im}+k_i x_{jim})^{1-\alpha}\\&s.t.\ p_{iy}y_{im}+p_{jy}y_{jim}+p_{ix}x_{im}+p_{jx}x_{jim}=w_{im}\end{aligned} \tag{8}$$

where $x_{im}\left(y_{im}\right)$ corresponds to the amount of good X (Y) produced in country *i* and consumed by an individual of type *m* in the same country; $x_{jim}\left(y_{jim}\right)$ represents the amount of good X (Y) delivered from country *j* to country *i* where it is consumed by an individual of type *m*; $p_{ih}\left(p_{jh}\right)$ is the price of good *h* $\left[\forall h\in\left(x,y\right)\right]$ in country $i\left(j\right)$; and w_{im} corresponds to the wage rate of labor of type *m* in country *i*.

Production functions are assumed to be constant returns to scale Cobb-Douglas with identical production elasticities across countries (but different across the two outputs). To introduce Ricardian comparative advantage each production function is assigned a total factor productivity coefficient that is assumed to be different across countries. The decision problems of representative firms in country *i* producing X and Y assume the following forms, respectively:

$$\underset{K_{ih},L_{ih}}{Max}\,\pi_{ix} = p_{ix}a_{ix}L_{iux}{}^{\beta}L_{isx}{}^{1-\beta} - w_{iu}L_{iux} - w_{is}L_{isx} \qquad \forall\, i, j = 1, 2 \tag{9}$$

$$\begin{aligned} \underset{K_{ih},L_{ih},x_{iy},x_{jiy}}{Max}\,\pi_{iy} = {} & p_{iy}a_{iy}\left(x_{iy} + k_i x_{jiy}\right)^{\delta} L_{isy}{}^{\varepsilon}L_{iuy}{}^{1-\delta-\varepsilon} - w_{is}L_{isy} - w_{iu}L_{iuy} \\ & - p_{ix}x_{iy} - p_{jx}x_{jiy} \\ & \forall\, i, j = 1, 2; i \neq j \end{aligned} \tag{10}$$

where L_{imh} is the amount of labor of type *m* employed in country *i* in the production of good *h*, where $m \in (s,u)$ and $h \in (x, y)$; $a_{ih}\ (i = 1, 2; h = x, y)$ represents the total factor productivity coefficient of producing good *h* in country *i*; p_{ih} corresponds to the price of good *h* in country *i*; and $x_{iy}\,(x_{jiy})$ the amount of good X produced domestically (imported from country *j*) and used as an input in the production of Y in country *i*. The aggregate output of X(Y) produced in country *i* is given by $x_i\left(y_i\right)$.

5.2 Possible equilibrium structures

Possible equilibrium market structures, representing potentially optimum combinations of cross-country patters of production, consumption, and trade, are outlined in Figure 2. The notation used in this Figure designates production profiles in parentheses – where the first profile corresponds to country 1 – and employs subscripts to denote exports. In what follows we concentrate on three of the nine structures corresponding to “1” (autarky), “3” (production within the cone of diversification with country 1 exporting X and importing Y), and “8” (complete specialization with country 1 exporting X and importing Y). The remaining structures are either symmetric to those that we examine, or correspond to incomplete specialization and do not add much to the story.

In the context of these structures our first objective is to identify the conditions under which each structure prevails. This entails a two step inframarginal approach. In the first step we identify the price-transaction efficiency relationships relevant to each structure. In the second, we solve for the prices that would prevail within each structure. Substitution of these prices in the conditions identified in the first step demarcates the parameter space[23] in exclusive parameter value subsets within which each of the three structures that we examine represents the general equilibrium.

The price constraints required for autarky, diversification and trade, and complete specialization are given below by conditions (11), (12), and (13) respectively.

$$k_2 < \frac{p_{1y}}{p_{2y}} < \frac{1}{k_1} \quad \text{or} \quad k_2 < \frac{p_{1x}}{p_{2x}} < \frac{1}{k_1} \tag{11}$$

$$\frac{p_{1y}}{p_{2y}} = \frac{1}{k_1}, \frac{p_{1x}}{p_{2x}} = k_2 \tag{12}$$

$$\frac{p_{1y}}{p_{2y}} > \frac{1}{k_1}, \frac{p_{1x}}{p_{2x}} < k_2 \tag{13}$$

We first consider the case of production within the cone of diversification in which country 1 exports X, given by $\left(xy\right)_x \left(xy\right)_y$. The demand functions for X and Y by each consumer of type *m* in countries 1 and 2 are given by:

[23] This is defined on the basis of the fourteen exogenous variables of the model given by α, k_1, k_2, L_{1s}, L_{1u}, L_{2s}, L_{2u}, a_{1y}, a_{1x}, a_{2y}, a_{2x}, δ, ε, β.

$$y_{1m} + k_1 y_{21m} = \frac{\alpha w_{1m}}{p_{1y}}, \qquad x_{1m} = \frac{(1-\alpha) w_{1m}}{p_{1x}} \tag{14}$$

$$y_{2m} = \frac{\alpha w_{2m}}{p_{2y}}, \qquad k_2 x_{12m} + x_{2m} = \frac{(1-\alpha) w_{2m}}{p_{2x}} \tag{15}$$

The decision problem of the representative firm producing Y in country 1 is given by:

$$\underset{x_{1y}, L_{1uy}, L_{1sy}}{Max} \ \pi_{1y} = p_{1y} a_{1y} x_{1y}^{\delta} L_{1sy}^{\varepsilon} L_{1uy}^{1-\delta-\varepsilon} - p_{1x} x_{1y} - w_{1u} L_{1uy} - w_{1s} L_{1sy} \tag{16}$$

Rearranging the first order conditions gives:

$$\frac{\delta}{\varepsilon} \frac{L_{1sy}}{x_{1y}} = \frac{p_{1x}}{w_{1s}} \tag{17}$$

$$\frac{\varepsilon}{1-\delta-\varepsilon} \frac{L_{1uy}}{L_{1sy}} = \frac{w_{1s}}{w_{1u}} \tag{18}$$

Similarly, the decision problems of producing X in country 1, Y in country 2, and X in country 2 are given below by (19), (20), and (21) respectively:

$$\underset{L_{1ux}, L_{1sx}}{Max} \ \pi_{1x} = p_{1x} a_{1x} L_{1ux}^{\beta} L_{1sx}^{1-\beta} - w_{1u} L_{1ux} - w_{1s} L_{1sx} \tag{19}$$

$$\begin{aligned} \underset{L_{2uy}, L_{2sy}, x_{2y}, x_{12y}}{Max} \ \pi_{2y} = p_{2y} a_{2y} (k_2 x_{12y} + x_{2y})^{\delta} L_{2sy}^{\varepsilon} L_{2uy}^{1-\delta-\varepsilon} - w_{2u} L_{2uy} \\ - w_{2s} L_{2sy} - p_{1x} x_{12y} - p_{2x} x_{2y} \end{aligned} \tag{20}$$

$$\underset{L_{2ux}, L_{2sx}}{Max} \ \pi_{2x} = p_{2x} a_{2x} L_{2ux}^{\beta} L_{2sx}^{1-\beta} - w_{2u} L_{2ux} - w_{2s} L_{2sx} \tag{21}$$

Combining the first order conditions of (19) gives:

$$\frac{\beta}{1-\beta} \frac{L_{1sx}}{L_{1ux}} = \frac{w_{1u}}{w_{1s}} \tag{22}$$

Similarly, from (20):

$$\frac{\delta}{\varepsilon} \frac{L_{2sy}}{k_2 x_{12y} + x_{2y}} = \frac{p_{2x}}{w_{2s}} \tag{23}$$

$$\frac{\varepsilon}{1-\delta-\varepsilon} \frac{L_{2uy}}{L_{2sy}} = \frac{w_{2s}}{w_{2u}} \tag{24}$$

and (21):

$$\frac{\beta}{1-\beta}\frac{L_{2sx}}{L_{2ux}}=\frac{w_{2u}}{w_{2s}} \tag{25}$$

The market clearing conditions for good Y produced in country 1, X in 1, Y in 2, X in 2, and the different types of labor in the two countries are given by:

$$y_{1u}L_{1u}+y_{1s}L_{1s}=a_{1y}x_{1y}^{\delta}L_{1sy}^{\varepsilon}L_{1uy}^{1-\delta-\varepsilon} \tag{26}$$

$$x_{1u}L_{1u}+x_{1s}L_{1s}+x_{12u}L_{2u}+x_{12s}L_{2s}+x_{12y}+x_{1y}=a_{1x}L_{1ux}^{\beta}L_{1sx}^{1-\beta} \tag{27}$$

$$y_{21u}L_{1u}+y_{21s}L_{1s}+y_{2u}L_{2u}+y_{2s}L_{2s}=a_{2y}(k_2x_{12y}+x_{2y})^{\delta}L_{2sy}^{\varepsilon}L_{2uy}^{1-\delta-\varepsilon} \tag{28}$$

$$x_{2u}L_{2u}+x_{2s}L_{2s}+x_{2y}=a_{2x}L_{2ux}^{\beta}L_{2sx}^{1-\beta} \tag{29}$$

$$\begin{aligned}&L_{1ux}+L_{1uy}=L_{1u},\quad L_{1sx}+L_{1sy}=L_{1s},\quad L_{2ux}+L_{2uy}=L_{2u},\\&L_{2sx}+L_{2sy}=L_{2s}\end{aligned} \tag{30}$$

Normalizing the wage rate of unskilled labor in country 1, given by w_{1u}, to unity and using (14)-(30), generates the equilibrium prices and wages:

$$w_{1s}=\frac{\alpha\varepsilon+(1-\beta)(1-\alpha+\alpha\delta)}{1-\alpha\varepsilon-(1-\beta)(1-\alpha+\alpha\delta)}\frac{L_{1u}+\left[\left(\frac{a_{1x}}{a_{2x}}\right)^{\varepsilon}\left(\frac{a_{2y}}{a_{1y}}\right)^{1-\beta}k_2^{\varepsilon+\delta(1-\beta)}k_1^{1-\beta}\right]^{\frac{1}{(1-\delta)(1-\beta)-\varepsilon}}L_{2u}}{L_{1s}+\left[\left(\frac{a_{2x}}{a_{1x}}\right)^{1-\delta-\varepsilon}\left(\frac{a_{1y}}{a_{2y}}\right)^{\beta}k_2^{\delta(1-\beta)+\varepsilon-1}k_1^{-\beta}\right]^{\frac{1}{(1-\delta)(1-\beta)-\varepsilon}}L_{2s}} \tag{31}$$

$$w_{2u}=\left[\left(\frac{a_{1x}}{a_{2x}}\right)^{\varepsilon}\left(\frac{a_{2y}}{a_{1y}}\right)^{1-\beta}k_2^{\varepsilon+\delta(1-\beta)}k_1^{1-\beta}\right]^{\frac{1}{(1-\delta)(1-\beta)-\varepsilon}} \tag{32}$$

$$w_{2s}=\left[\left(\frac{a_{2x}}{a_{1x}}\right)^{1-\delta-\varepsilon}\left(\frac{a_{1y}}{a_{2y}}\right)^{\beta}k_2^{\delta(1-\beta)+\varepsilon-1}k_1^{-\beta}\right]^{\frac{1}{(1-\delta)(1-\beta)-\varepsilon}}w_{1s} \tag{33}$$

$$p_{1x}=a_{1x}^{-1}\beta^{-\beta}(1-\beta)^{\beta-1}w_{1u}^{\beta}w_{1s}^{1-\beta} \tag{34}$$

$$p_{2x}=a_{2x}^{-1}\beta^{-\beta}(1-\beta)^{\beta-1}w_{2u}^{\beta}w_{2s}^{1-\beta} \tag{35}$$

$$p_{1y} = a_{1y}^{-1}\delta^{-\delta}\varepsilon^{-\varepsilon}(1-\delta-\varepsilon)^{\delta+\varepsilon-1} p_{1x}^{\delta} w_{1s}^{\varepsilon} w_{1u}^{1-\delta-\varepsilon} \tag{36}$$

$$p_{2y} = a_{2y}^{-1}\delta^{-\delta}\varepsilon^{-\varepsilon}(1-\delta-\varepsilon)^{\delta+\varepsilon-1} p_{2x}^{\delta} w_{2s}^{\varepsilon} w_{2u}^{1-\delta-\varepsilon} \tag{37}$$

Assuming $(1-\beta)(1-\delta) > \varepsilon$, substituting (31)-(33) in (34)-(37), the result of this substitution in (12), and combining this with the resource constraints corresponding to fully diversified production given by $0 < L_{1ux}, L_{1uy} < L_{1u}$, $0 < L_{1sx}, L_{1sy} < L_{1s}$ generates the conditions corresponding to the parameter value subset for this structure given by:

$$\frac{\beta}{1-\beta}\frac{L_{1s}}{L_{1u}} < A\frac{L_{1s}+BL_{2s}}{L_{1u}+CL_{2u}} < \frac{1-\delta-\varepsilon}{\varepsilon}\frac{L_{1s}}{L_{1u}} \tag{38}$$

and

$$\frac{\beta}{1-\beta}\frac{L_{2s}}{L_{2u}} < A\frac{B^{-1}L_{1s}+L_{2s}}{C^{-1}L_{1u}+L_{2u}} < \frac{1-\delta-\varepsilon}{\varepsilon}\frac{L_{2s}}{L_{2u}} \tag{39}$$

where $A = \frac{1-\alpha\varepsilon-(1-\beta)(1-\alpha+\alpha\delta)}{\alpha\varepsilon+(1-\beta)(1-\alpha+\alpha\delta)}$, $B = \left[\left(\frac{a_{2x}}{a_{1x}}\right)^{1-\delta-\varepsilon}\left(\frac{a_{1y}}{a_{2y}}\right)^{\beta} k_2^{\delta(1-\beta)+\varepsilon-1}k_1^{-\beta}\right]^{\frac{1}{(1-\delta)(1-\beta)-\varepsilon}}$

and $C = \left[\left(\frac{a_{1x}}{a_{2x}}\right)^{\varepsilon}\left(\frac{a_{2y}}{a_{1y}}\right)^{1-\beta} k_2^{\varepsilon+\delta(1-\beta)}k_1^{1-\beta}\right]^{\frac{1}{(1-\delta)(1-\beta)-\varepsilon}}$.

Using (31)-(37) it can be shown that the relative wage rates between skilled and unskilled labor in countries 1 and 2 are given by:

$$\frac{w_{1s}}{w_{1u}} = A^{-1}\frac{L_{1u}+CL_{2u}}{L_{1s}+BL_{2s}} \tag{40}$$

$$\frac{w_{2s}}{w_{2u}} = A^{-1}\frac{C^{-1}L_{1u}+L_{2u}}{B^{-1}L_{1s}+L_{2s}} \tag{41}$$

Following a similar approach, the parameter value subset corresponding to autarky, denoted as structure $(xy)(xy)$, is given by the following conditions[24]:

$$k_2 < \frac{a_{2x}}{a_{1x}}\left(\frac{L_{1u}}{L_{1s}}\frac{L_{2s}}{L_{2u}}\right)^{1-\beta} < \frac{1}{k_1} \tag{42}$$

$$k_2 < \frac{a_{2y}}{a_{1y}}\left(\frac{a_{2x}}{a_{1x}}\right)^{\delta}\left(\frac{L_{1u}}{L_{1s}}\frac{L_{2s}}{L_{2u}}\right)^{(1-\beta)\delta+\varepsilon} < \frac{1}{k_1} \tag{43}$$

Normalizing the wage rate of unskilled labor, given by w_{iu}, to unity the corresponding relative wage rate between skilled and unskilled labor in country *i* is given by:

$$w_{is} = \frac{(1-\beta)[1-\alpha(1-\delta)]+\varepsilon\alpha}{(1-\beta)\alpha(1-\delta)+\beta-\varepsilon\alpha}\frac{L_{iu}}{L_{is}} \tag{44}$$

To ensure that $w_{is} > 0$ we require $(1-\beta)\alpha(1-\delta)+\beta > \varepsilon\alpha$.

Finally, the parameter value subset corresponding to complete specialization $(x)_x(y)_y$ is given by:

$$\frac{a_{2y}}{a_{1y}}k_2^{\delta}\left(\frac{1-\beta}{\varepsilon}\right)^{\varepsilon}\left(\frac{\beta}{1-\delta-\varepsilon}\right)^{1-\delta-\varepsilon}\left(\frac{1-\alpha+\delta\alpha}{\alpha}\right)^{1-\alpha}\left(\frac{L_{2s}}{L_{1s}}\right)^{\varepsilon}\left(\frac{L_{2u}}{L_{1u}}\right)^{1-\delta-\varepsilon} > \frac{1}{k_1} \tag{45}$$

$$\frac{a_{2x}}{a_{1x}}\left(\frac{1-\beta}{\varepsilon}\right)^{1-\beta}\left(\frac{\beta}{1-\delta-\varepsilon}\right)^{\beta}\left(\frac{1-\alpha+\delta\alpha}{\alpha}\right)\left(\frac{L_{2s}}{L_{1s}}\right)^{1-\beta}\left(\frac{L_{2u}}{L_{1u}}\right)^{\beta} < k_2 \tag{46}$$

Recalling that the wage rate of unskilled labor in country 1, given by w_{1u}, is normalized to unity, the relative wage rates between skilled and unskilled labor in countries 1 and 2 are given by:

$$w_{1s} = \frac{1-\beta}{\beta}\frac{L_{1u}}{L_{1s}} \tag{47}$$

[24] At least one of these conditions must hold for autarky to prevail.

$$\frac{w_{2s}}{w_{2u}} = \frac{\varepsilon}{1-\delta-\varepsilon}\frac{L_{2u}}{L_{2s}} \tag{48}$$

5.3 Simulations of inframarginal comparative statics

Given the complexity of the parameter value subsets corresponding to the different structures under examination, analytical comparisons of relative wages across the various structures are not possible and we therefore opt for a computational approach. Our interest is in the skill abundant country that we represent in the analysis with country 2 by selecting $L_{1s} = 400$, $L_{1u} = 4000$, $L_{2s} = 4000$, $L_{2u} = 400$.

It is easy to show that the constant of proportionality, d, corresponding to the ratio of skilled to unskilled labor in sector Y as a percentage of the same ratio in sector X, or $L_{isy}/L_{iuy} = d\left(L_{isx}/L_{iux}\right)$, is given by:

$$d = \frac{\varepsilon\beta}{(1-\beta)(1-\delta-\varepsilon)} \tag{49}$$

To ensure that, in the presence of diversified production, sector Y is the unskilled labor intensive sector, i.e. $d < 1$, we select $\delta = 0.4$, $\varepsilon = 0.1$, $\beta = 0.6$ (corresponding to $d = 0.3$)[25].

Unlike similar models recently proposed in the literature, such as Zhu and Trefler (2005), in our model comparative endowment advantage opposes Ricardian comparative advantage as reflected by our selection of total factor productivity coefficients for the production functions for X and Y given by $a_{1y} = 1$,

[25] Our analysis does not depend on the production elasticity of unskilled labour being greater than the production elasticity of skilled labour in sector X. The same results still follow when we assume $\beta = 0.4$.

$a_{1x} = 5$, $a_{2y} = 3$, $a_{2x} = 1$. Given these coefficients, country 2 has a comparative technological advantage in good Y.

To investigate the inframarginal comparative statics that may ensue from successive waves of liberalization we consider symmetric transaction efficiency coefficients corresponding to $k_1 = k_2 = 0.0001$, $k_1 = k_2 = 0.5$, and $k_1 = k_2 = 1$. The results are summarized in Table 4. As it may be noted from this table, when transaction efficiency is given by $k_1 = k_2 = 0.0001$ the potential benefits of international trade are neutralized and autarky necessarily prevails. A decrease in trade costs from almost 100% down to 50% corresponding to an increase in transaction efficiency to $k_1 = k_2 = 0.5$ is sufficient to move the economy across the parameter value subsets that demarcate autarky and production within the cone of diversification. Finally, elimination of trade costs, corresponding to transaction efficiency given by $k_1 = k_2 = 1$ causes a discontinuous jump from the cone of diversification to complete specialization. As it may be noted from the table, each successive exogenous decrease in trade costs decreases the relative wage rate of skilled workers in the skill abundant country from a normalized figure of 1 corresponding to autarky, to a figure of 0.83 corresponding to diversified production and trade, down to 0.5 in complete specialization. The intuition of this result is straightforward. Comparative technological advantage in the skilled labor abundant country is in the unskilled labor intensive commodity Y. As liberalization decreases the cost of international trade, country 2 outsources X to country 1, and labor in country 2 shifts from sector X to sector Y. Given the selected production elasticities, relative productivity of skilled labor to unskilled labor is lower in sector Y than in sector X. Hence, as global division of labor intensifies the relative wage rate of skilled workers decreases. Of course, given complete specialization the factor of proportionality (49) ceases to hold and the skilled labor abundant country's exports are, relative to its imports, skilled labor intensive.

Clearly, outsourcing plays an important role in the model. In the absence of the possibility to outsource, complete specialization could not prevail and the relative wage of skilled labor would settle at the higher levels of diversified production.

6. Concluding remarks

The recent findings of Davis and Weinstein (2001) and Schott (2003) suggest that cross-country specialization in the production of different goods is significant. Yet specialization has not received much attention in the literature on trade and wage inequality. And this despite the fact that the prevalence of extensive specialization can have profound implications in the study of trade and wages. An increase in non-competing intermediate imports has the potential to stimulate demand for all domestic labor with uncertain effects on wage inequality. Furthermore, to the extent that increases in imports facilitate further fragmentation of production and lead to new structures of specialization, they can set in motion substitutions between skilled and unskilled labor that can have significant, and not easily predictable, effects on relative wages.

To investigate the potential role of imports in stimulating domestic demand for labor we use an economy-wide production theory approach that relies on a Symmetric Normalized Quadratic (SNQ) flexible functional representation of the US economy. Unlike similar studies that utilize the Translog (see the appendix), the SNQ retains its flexibility in the estimation process and can therefore correctly measure potential complementarities between imports and domestic labor.

Deviating from other studies in this area, our estimations generate the first evidence that imports, and particularly those subject to extensive downstream handling, stimulate the relative wage of unskilled labor. While this is the first study to identify this result, this finding fits nicely with earlier evidence by Aw and Roberts (1985), Appelbaum and Kohli (1997), and Tombazos (1998, 1999b) that imports, and particularly those subject to extensive domestic processing, have the potential to stimulate the aggregate demand for domestic labor.

Interest in our finding that imports can decrease wage inequality, does not derive from the size of this effect which, at any rate, is very small and does not correspond to more than a few percentage points during the period under examination. Instead, it derives from the theoretical plausibility that, in the context of specialized production and trade in intermediate goods, the impact of imports on the relative wages of unskilled labor may be considerably smaller than the -20% consensus that has emerged in the literature (see Zhu and Trefler, 2005, p. 21), and possibly even be positive.

Our theoretical model, featuring endogenous specialization driven by changes in trade costs, sheds light on our empirical results. When Ricardian comparative advantage opposes comparative endowment advantage industries that begin as unskilled labor intensive expand and those that begin as skilled labor intensive contract thereby decreasing wage inequality[26]. As we show, the possibility of outsourcing facilitates this process.

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[26] Difficulties to match trade and production data more accurately than what is possible by 4-digit level SIC/SITC classifications may disguise such resource transfers.

We suspect that our theoretical framework may be viewed as heretical on a number of grounds. How could it be that the US exports goods not characterized by comparative skilled labor advantage? After all, is it not the case that US exports are skilled labor intensive compared to its imports? We address the second question first. In the aggregate, US exports may very well be more skill intensive than its imports. And this is exactly what the final, and inevitable when trade costs are eliminated, structure of complete specialization in our model predicts. What we challenge is not the revealed factor content of trade. What we challenge is the extent to which this factor content is in the case of every sector of the economy *the* key determinant of the observed pattern of trade. It is important to note that there is neither theoretical nor empirical justification for the assumption made by similar models in this area, including Zhu and Trefler (2005), Beaulieu *et al.* (2004) and others, that factor endowments reinforce technology in determining the pattern of trade. Our model illustrates that when comparative factor endowment advantage opposes Ricardian comparative advantage the latter may occasionally prevail, a result that is more likely than the alternative when intermediate goods are traded.[27]

A lot more work is required in this area both on the theoretical and particularly on the empirical front. However, at the very last, our results suggest that in the presence of a trade induced-process that facilitates global division of labor and specialization in production, the role of trade in wage inequality is perhaps less clear than what has been so far suggested by models concentrating on the assumption of global diversification.

[27] See Ferguson (1978).

Appendix

A new trend in econometric methodology entails *indirect* global enforcement of curvature (IGEC)[28] in the case of the popular Translog variable profit function when curvature fails in the first round of estimations. See for example, Ziari and Azzam, (1999), Harrigan and Balaban (1999), and Harrigan (2000). Curvature conditions are, of course, necessitated by economic theory and must hold for a variable profit function to be meaningful (Kohli, 1991). However, enforcing these conditions in the case of the Translog purges the flexibility of this functional form relinquishing its potential to correctly identify potentially complementary relationships between inputs such as imports and domestic labor.

To illustrate this result consider the translogarithmic variable (restricted) profit function originally introduced by Diewert (1974) given by:

$$\begin{aligned}\ln\pi &= \alpha_0 + \sum_i a_i \cdot \ln(p_i) + \sum_j b_j \cdot \ln(x_j) + \tfrac{1}{2}\cdot\sum_i\sum_h c_{i,h}\cdot\ln(p_i)\cdot\ln(p_h) \\ &+ \tfrac{1}{2}\cdot\sum_j\sum_k f_{j,k}\cdot\ln(x_j)\cdot\ln(x_k) + \tfrac{1}{2}\cdot\sum_i\sum_j d_{i,j}\cdot\ln(p_i)\cdot\ln(x_j) \\ &+ \sum_i \delta_{i,t}\cdot\ln(p_i)\cdot t + \sum_j \phi_{j,t}\cdot\ln(x_j)\cdot t + \beta_t\cdot t + \tfrac{1}{2}\cdot\xi_{t,t}\cdot t^2\end{aligned} \tag{50}$$

Denote $\mathbf{y}\equiv[y_i]$ and $\mathbf{p}\equiv[p_h]$ $\left(\mathbf{x}\equiv[x_j] \text{ and } \mathbf{w}\equiv[w_j]\right)$ as the $I\times 1$ $(J\times 1)$ vectors of quantities and prices of the "outputs" [29] (fixed inputs), respectively. Note that index *i* is partitioned in two subspaces. The first, corresponds to $i=1,...,M$, and runs across positive outputs. The second, given by $i=M+1,...,I$, pertains to variable inputs. Symmetry of (50) requires (i) $c_{i,h}=c_{h,i}$ and $f_{k,j}=f_{j,k}$. It can be easily shown that $\pi(\mathbf{p},\mathbf{x},t)$ is homogeneous of degree one in $\mathbf{p}\equiv[p_h]$ if and only if (ii) $\sum_i a_i = 1$, (iii) $\sum_i d_{i,j}=0$ for $j=1,...,J$, and (iv) $\sum_i c_{i,h}=0$ for $h=1,...,I$. Similarly, $\pi(\mathbf{p},\mathbf{x},t)$ is homogeneous of degree one in $\mathbf{x}\equiv[x_j]$ if and only if (v) $\sum_j b_j = 1$, (vi) $\sum_j d_{i,j}=0$ for $i=1,...,I$, and (vii) $\sum_j f_{j,k}=0$ for $k=1,...,J$.

It should be noted that (50) is neither necessarily concave (for a given **p**) in the fixed input quantities **x**, nor necessarily convex (for a given **x**) in the prices, **p**, of the variable quantities**.** Yet, a variable profit function must necessarily be convex in prices, and, as long as the underlying technology set is convex it must also be concave in the fixed input quantities.

In the interest of brevity, the predominance of our analysis concentrates on concavity, rather than both curvature conditions. However, analogous implications in the case of convexity are, for the most part of the discussion, implicit.

A necessary and sufficient condition for a twice continuously differentiable variable profit function to be concave in the fixed input quantities **x,** over the positive orthant, is negative semidefiniteness of the Hessian matrix of this function with respect to **x** given by $\nabla^2_{\mathbf{x},\mathbf{x}}\pi(\mathbf{p},\mathbf{x},t)$ $\equiv\left[\partial^2\pi(\mathbf{p},\mathbf{x},t)/\partial x_j\partial x_k\right]$. To derive a useful formulation for this matrix, I derive the logarithmic second order derivative of the variable profit function given by $\partial^2\ln\pi(\mathbf{p},\mathbf{x},t)/\partial\ln(x_j)\cdot\partial\ln(x_k)$. It can be shown that[30]:

[28] *Indirect* global enforcement of curvature entails the global enforcement of those conditions that are necessary and sufficient for all resulting demand and supply curves to assume slopes with signs consistent with the underlying curvature.

[29] These include variable inputs which are represented in the model as negative outputs.

[30] Here I follow a similar approach to that used by Diewert and Wales (1987) in an analogous cost function setting.

$$\frac{\partial^2 \ln \pi(\mathbf{p},\mathbf{x},t)}{\partial \ln(x_j)\cdot\partial \ln(x_k)} = x_j \cdot \left[\frac{\partial^2 \pi(\cdot)}{\partial x_j \cdot \partial x_k}\cdot\frac{x_k}{\pi(\cdot)} + \frac{\partial \pi}{\partial x_k}\cdot\frac{\partial\left(x_k \cdot \pi(\cdot)^{-1}\right)}{\partial x_j} \right] \tag{51}$$

Clearly, if $j = k$ then $\frac{\partial\left(x_k \cdot \pi(\cdot)^{-1}\right)}{\partial x_j} = \frac{1}{\pi(\cdot)} - \frac{x_k}{\pi(\cdot)^2}\cdot\frac{\partial \pi(\cdot)}{\partial x_j}$, otherwise $\frac{\partial\left(x_k \cdot \pi(\cdot)^{-1}\right)}{\partial x_j} = \frac{x_k}{\pi(\cdot)^2}\cdot\frac{\partial \pi(\cdot)}{\partial x_j}$. Hence, (51) may be written as:

$$\frac{\partial^2 \ln \pi(\mathbf{p},\mathbf{x},t)}{\partial \ln(x_j)\cdot\partial \ln(x_k)} = \begin{cases} \dfrac{x_j \cdot x_k \cdot \left(\dfrac{\partial^2 \pi(\cdot)}{\partial x_j \cdot \partial x_k}\right)}{\pi(\cdot)} + \dfrac{x_j \cdot \dfrac{\partial \pi(\cdot)}{\partial x_k}}{\pi(\cdot)} - \dfrac{x_j \cdot x_k \cdot \dfrac{\partial \pi(\cdot)}{\partial x_k}\cdot\dfrac{\partial \pi(\cdot)}{\partial x_j}}{\pi(\cdot)^2} \\ \forall \quad j = k \\ \dfrac{x_j \cdot x_k \cdot \left(\dfrac{\partial^2 \pi(\cdot)}{\partial x_j \cdot \partial x_k}\right)}{\pi(\cdot)} - \dfrac{x_j \cdot x_k \cdot \dfrac{\partial \pi(\cdot)}{\partial x_k}\cdot\dfrac{\partial \pi(\cdot)}{\partial x_j}}{\pi(\cdot)^2} \\ \forall \quad j \neq k \end{cases} \tag{52}$$

From (50):

$$\frac{\partial^2 \ln \pi(\mathbf{p},\mathbf{x},t)}{\partial \ln(x_j)\cdot\partial \ln(x_k)} = f_{j,k} \tag{53}$$

Hence, the expression in (52) can be rewritten in a more compact form as:

$$f_{j,k} = \frac{x_j \cdot x_k \cdot \left(\dfrac{\partial^2 \pi(\cdot)}{\partial x_j \cdot \partial x_k}\right)}{\pi(\cdot)} + \frac{\gamma_{j,k} \cdot x_j \cdot \dfrac{\partial \pi(\cdot)}{\partial x_k}}{\pi(\cdot)} - \frac{x_j \cdot x_k \cdot \dfrac{\partial \pi(\cdot)}{\partial x_k}\cdot\dfrac{\partial \pi(\cdot)}{\partial x_j}}{\pi(\cdot)^2} \tag{54}$$

where $\gamma_{j,k} = 1$ if $j = k$ and $\gamma_{j,k} = 0$ otherwise.

The elasticities that capture the impact of an exogenous change in the quantity of fixed factor *k* on the price of fixed factor *j* can be readily derived from (54). Rearranging the terms of equation (54) and dividing both sides by the share of GNP of fixed-factor *k*, given by s_k {i.e. $s_k = w_k(\mathbf{p},\mathbf{x},t)\cdot x_k / \pi(\cdot)$}, renders:

$$\varepsilon(w_j, x_k) = \frac{\partial \ln(w_j)}{\partial \ln(x_k)} = \frac{\dfrac{x_j \cdot x_k \cdot \left(\dfrac{\partial^2 \pi(\cdot)}{\partial x_j \cdot \partial x_k}\right)}{\pi(\cdot)}}{s_k}$$
$$= \frac{f_{j,k}}{s_k} - \frac{\dfrac{\gamma_{j,k} \cdot x_j \cdot \dfrac{\partial \pi(\cdot)}{\partial x_k}}{\pi(\cdot)}}{s_k} + \frac{\dfrac{x_j \cdot x_k \cdot \dfrac{\partial \pi(\cdot)}{\partial x_k}\cdot\dfrac{\partial \pi(\cdot)}{\partial x_j}}{\pi(\cdot)^2}}{s_k} \tag{55}$$

Under competitive conditions the following "marginal product" requirement holds:

$$w_j = \frac{\partial \pi(\mathbf{p}, \mathbf{x}, t)}{\partial x_j} \tag{56}$$

Using (56), the expression outlined in (55) may simplify in the case of the "own" inverse demand elasticities (corresponding to $j = k$) to:

$$\varepsilon(w_j, x_j) = \frac{f_{j,j}}{s_j} - 1 + s_j \tag{57}$$

As implemented by Harrigan and Balaban (1999) and Harrigan (2000) global enforcement of curvature entails the global enforcement of those conditions that are necessary and sufficient for all resulting *ordinary* demand and supply functions to assume slopes with signs that are consistent with the underlying curvature. In what follows we refer to this approach as *Indirect Global Enforcement of Curvature* (IGEC). To investigate the implications of this approach we consider the variable profit function in (50) with $M \geq 2$ (i.e., a minimum of two final outputs), $I \geq M + 3$ (i.e., a minimum of three variable inputs) and $J \geq 4$ (i.e., a minimum of 4 fixed factors of production)[31].

As implemented by enforcement of concavity requires the own fixed-factor inverse demand elasticities, given by (57), to satisfy the following inequality:

$$\varepsilon(w_j, x_j) = \frac{f_{j,j}}{s_j} - 1 + s_j \leq 0 \quad \forall \quad j = 1, ..., J \tag{58}$$

Correspondingly, indirect global enforcement of convexity with respect to output prices, **p,** requires the own price elasticity of output (variable input) supply (demand)[32] to satisfy the following restrictions:

$$\varepsilon(y_i, p_i) = \frac{c_{i,i}}{r_i} - 1 + r_i \geq 0 \quad \forall \quad i = 1, ..., M \tag{59}$$

$$\varepsilon(y_i, p_i) = \frac{-c_{i,i}}{r_i} - 1 - r_i \leq 0 \quad \forall \quad i = M + 1, ..., I \tag{60}$$

where $\mathbf{r} \equiv [r_1, ..., r_I]'$ represents the vector of shares of the *I* final outputs and variable inputs.

Given the input-output disaggregation employed in this model; the assumption of linear homogeneity of (50) [which, given (i), entails conditions (ii)-(vii)] on the one hand; and restrictions (58)-(60) outlined above, on the other, indirect global enforcement of curvature requires that the following restrictions hold when evaluated using the estimated parameters of (50):

$$f_{1,1} \leq (1 - s_1) \cdot s_1, \tag{61}$$

$$f_{2,2} \leq (1 - s_2) \cdot s_2, \tag{62}$$

.
.

[31] Harrigan's (2000) specification corresponds to $M = 2$, $I = 5$, and $J = 4$.

[32] These elasticities can be easily derived using an approach similar to that employed in the case of (57) . An appropriate point of departure requires evaluation of the Hessian given by $\nabla^2_{\mathbf{q},\mathbf{q}} \ln\left[\pi(\mathbf{p}, \mathbf{x}, t)\right]$ where $\mathbf{q} \equiv \left[\ln(p_1), ..., \ln(p_{M3})\right]'$. In such derivations it is important to remember that variable inputs are represented in the variable profit function as negative outputs.

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$$f_{J-1,J-1} \leq (1-s_{J-1}) \cdot s_{J-1} \tag{63}$$

$$-\left(\sum_j \sum_k f_{j,k}\right) \leq (1-s_J) \cdot s_J \tag{64}$$

and

$$c_{1,1} \geq (1-r_1) \cdot r_1, \tag{65}$$

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$$c_{M,M} \geq (1-r_M) \cdot r_M, \tag{66}$$

$$c_{M+1,M+1} \geq -r_{M+1} \cdot (1+r_{M+1}), \tag{67}$$

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.
.

$$-\left(\sum_i \sum_h c_{i,h}\right) \geq -r_I (1+r_I) \tag{68}$$

Implementation of IGEC entails the inclusion of inequalities (61)-(68) in the relevant framework of analysis in order to restrict the values of relevant parameter estimates, and consequently elasticities, accordingly. In the majority of studies that employ IGEC, the relevant inequalities are incorporated directly in the estimation process after *substitution of the minimum [maximum] sample values* of the expressions on the right-hand side of inequalities (61)-(64) [(65)-(68)] (see for example Harrigan, 2000, p. 189-190).

The method of IGEC, outlined above, is subject to two important shortcomings that are neglected by the relevant literature:

First, inequalities (61)-(68) represent necessary, not sufficient conditions for the relevant curvature requirements to hold. Consider for example the case of concavity. If, similarly to the model outlined in this section, there are more than one fixed components, this condition does not merely require the own quantity elasticities of the inverse demand functions represented by equation (57) to be non-positive. In addition, concavity calls for all principal minors of the Hessian $\nabla^2_{\mathbf{x},\mathbf{x}}\pi(\mathbf{p},\mathbf{x},t)$ that are of an odd-numbered order to be non-positive, and all principal minors that are of an even-numbered order to be non-negative. Hence, concavity requires not only the restrictions on coefficients $f_{j,k}\ \forall\ j,k$ outlined in (61)-(64), but the host of all additional restrictions that are necessary for matrix $\nabla^2_{\mathbf{x},\mathbf{x}}\pi(\mathbf{p},\mathbf{x},t)$ to be negative semidefinite. Such constraints are not reflected in the inequalities outlined above, and are therefore subject to violations. Accordingly, despite implementation of the restrictions outlined in (61)-(68), the generated parameter estimates may violate both convexity as well as concavity, rendering elasticities that are incongruous with economic theory, and of modest informational content.

Second, in addition to the failure of the method of IGEC to produce necessary *and sufficient* conditions for global curvature to hold, this approach destroys the flexibility of the translogarithmic functional form casting further doubt on the values of estimated parameters and, consequently, elasticities. A relevant proof in the case of indirect global enforcement of concavity follows.

Consider again the case of the elasticity given in (57). Adding a time subscript, *t*, to this equation renders:

$$\varepsilon_t\left(w_{j,t}, x_{j,t}\right) = \frac{f_{j,j}}{s_{j,t}} - 1 + s_{j,t} \tag{69}$$

Generalization of (61)-(64) gives:

$$f_{j,j} \leq \left(1-s_{j,t}\right)\cdot s_{j,t} \tag{70}$$

Let $s_{j,m}$ represent the sample value corresponding to the share of factor j in year m and assume that[33]:

$$s_{j,m} \text{ minimizes } \left(1-s_{j,t}\right)\cdot s_{j,t} \tag{71}$$

Following the method outlined above, indirect global enforcement of concavity requires substitution of $s_{j,m}$ for the fixed factor shares that appear in expression (70). This substitution imposes the following constraint on the econometric estimate for $f_{j,j}$ denoted by $\hat{f}_{j,j}$:

$$\hat{f}_{j,j} \leq \left(1-s_{j,m}\right)\cdot s_{j,m} \tag{72}$$

Hence:

$$\hat{f}_{j,j} = \left(1-s_{j,m}\right)\cdot s_{j,m} - \lambda \text{ where } \lambda \in \mathbb{R}^1_+ \tag{73}$$

Consider now elasticity (69) in year $v\ \forall\ v \neq m$ given by:

$$\varepsilon_v\left(w_{j,v}, x_{j,v}\right) = \frac{f_{j,j}}{s_{j,v}} - 1 + s_{j,v} \tag{74}$$

and assume that its *true value* is zero.

Substitution of (73) in equation (74) renders the estimated value for this elasticity:

$$\hat{\varepsilon}_v\left(w_{j,v}, x_{j,v}\right) = \frac{\left(1-s_{j,m}\right)\cdot s_{j,m} - \lambda}{s_{j,v}} - 1 + s_{j,v} \tag{75}$$

This expression will be forced to assume a value that is *strictly* less than zero when:

$$\frac{\left(1-s_{j,m}\right)\cdot s_{j,m} - \lambda}{s_{j,v}} - 1 + s_{j,v} < 0 \tag{76}$$

Rearranging terms, and allowing $\lambda \to 0$ renders:

$$\left(1-s_{j,m}\right)\cdot s_{j,m} < \left(1-s_{j,v}\right)\cdot s_{j,v} \tag{77}$$

[33] I assume that that the sample variation of $s_{j,t}$ is such that expression $\left(1-s_{j,t}\right)\cdot s_{j,t}$ is characterized by a single global minimum. As this is a concave expression, it is possible that it may incorporate up to two (but not more than two) identical global minima corresponding to different values of $s_{j,t}$ (that, when added, sum to one). In this context, it is important to note that allowing for such potential multiplicity of identical global minima to prevail would complicate the analysis somewhat, but would not alter the results of this paper.

Given (71), expression (77) always holds. This implies that even though the true value of $\varepsilon_v\left(w_{j,v}, x_{j,v}\right)$ is zero, the econometric estimate for this elasticity will be forced to assume the arbitrary negative value generated by (75). Hence, the relevant estimate will be negatively biased.

By way of a numerical illustration of this result assume that $s_{j,m} = 0.12$ and $s_{j,v} = 0.19$. In this instance the relevant estimate for $\varepsilon_v\left(w_{j,v}, x_{j,v}\right)$ is given by -0.25, whereas its true value corresponds to zero.

Similar results can be derived in the case of all remaining own and cross-price elasticities that are affiliated with constraints dictated by either concavity or convexity. This implies that IGEC destroys the flexibility of this functional form and has the potential to generate significant and systematic biases on the estimated values pertaining to parameters $f_{j,k}$ and $c_{i,h}$, which, via the estimation process, will permeate in the case of all remaining coefficients.

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*Table 1. Eigenvalues of matrices **A** and **B** of estimated Symmetric Normalized Quadratic variable profit function*

Eigenvalues (Cholesky Values)	
Matrix **A**	Matrix **B**
0.0590, 0.0176, 0.0000	-0.6695, 0.0055, 0.0000
(0.0585, 0.0173, 0.0000)	(-0.6694, 0.0000, 0.0000)

Notes: Convexity requires matrix **A** to be positive semidefinite, and concavity requires matrix **B** to be negative semidefinite. Eigenvalues of curvature-corrected models in parentheses.

Table 2. Estimated Symmetric Normalized Quadratic variable profit function parameters

$a_{Y,Y}$	0.31066×10^{-1}	(0.561)	$c_{I,S}$	0.91344×10^{-1}	(1.107)
$a_{Y,F}$	-0.26298×10^{-1}	(-0.461)	$c_{I,K}$	-0.12844[c]	(-1.697)
$a_{F,F}$	0.33123×10^{-1}	(0.458)	$d_{Y,U}$	0.17182	(0.885)
$z_{1,1}$	0.10932×10^{-1}	(0.005)	$d_{Y,S}$	0.11645	(0.710)
$z_{2,1}$	0.56631	(0.005)	$d_{Y,K}$	0.39909[a]	(2.798)
$z_{2,2}$	-0.87744×10^{-1}	(0.000)	$d_{F,U}$	0.31962	(1.342)
$c_{Y,U}$	1.0492[a]	(6.397)	$d_{F,S}$	0.31941	(1.533)
$c_{Y,S}$	0.88090[a]	(6.378)	$d_{F,K}$	-0.34426[b]	(-2.006)
$c_{Y,K}$	0.75751[a]	(5.772)	$d_{I,U}$	-0.39780[a]	(-2.932)
$c_{F,U}$	-0.32238[c]	(-1.791)	$d_{I,S}$	-0.26798[b]	(-2.267)
$c_{F,S}$	-0.25873	(-1.635)	$d_{I,K}$	0.17322	(1.576)
$c_{F,K}$	0.27054[b]	(2.058)	ξ	-0.87850×10^{-1}	(-0.413)
$c_{I,U}$	0.17727[c]	(1.920)			
DOF	131				
$\tilde{R}^2$	0.9998137				

Notes: t-statistics in parentheses. Superscripts "a", "b" and "c" denote significance at the 1%, 5% and 10% level with a two-tailed test, respectively. The data used corresponds to 1968-1994 with the first observation lost because of the autocorrelation correction discussed in the estimation section. Given that all equations estimated simultaneously incorporate the same right-hand-side variables, the degrees of freedom (DOF) of the model are given by the number of observations (26) multiplied by the number of equations (6) minus the number of estimated coefficients (25). Hence there are 131 degrees of freedom.

Table 3. Selected annual and average elasticities of the Symmetric Normalized Quadratic variable profit function

Elasticity	Year 1970	1980	1985	1994	Average	
Price elasticities of inverse factor demands (Stolper-Samuelson Elasticities) $\varepsilon_{ji} = \partial \ln w_j / \partial \ln p_i$						
$\varepsilon_{U,Y}$	1.259	1.256	1.210	1.180	1.202[a]	(18.695)
$\varepsilon_{U,F}$	-0.291	-0.137	-0.033	0.092	-0.093[c†]	(-1.708)
$\varepsilon_{U,I}$	0.091	-0.116	-0.187	-0.275	-0.112[a†]	(-3.479)
$\varepsilon_{S,Y}$	1.043	1.100	1.051	0.983	1.024[a]	(18.491)
$\varepsilon_{S,F}$	-0.250	-0.095	0.003	0.130	-0.052[†]	(-0.934)
$\varepsilon_{S,I}$	0.059	-0.066	-0.117	-0.172	-0.064[c†]	(-2.304)
$\varepsilon_{K,Y}$	0.815	1.105	1.093	1.171	1.028[a]	(17.745)
Quantity elasticities of inverse factor demands $\varepsilon_{jk} = \partial \ln w_j / \partial \ln x_k$						
$\varepsilon_{U,K}$	0.044	0.071	0.061	0.059	0.062	(0.775)
$\varepsilon_{S,K}$	0.429	0.610	0.491	0.425	0.494[a]	(4.561)
Time semi-elasticities of inverse factor demands $\varepsilon_{jt} = \partial \ln w_j / \partial t$						
$\varepsilon_{U,t}$	0.231	-0.028	0.026	0.109	0.083[c†]	(1.836)
$\varepsilon_{S,t}$	0.255	0.102	0.106	0.153	0.157[a]	(4.476)
$\varepsilon_{K,t}$	0.201	0.254	0.244	0.163	0.205[a]	(3.789)

Notes: t-statistics in parentheses. Superscripts "a", "b" and "c" denote significance at the 1%, 5% and 10% level with a two-tailed test, respectively. Superscript "†" Indicates sign reversals.

Table 4. Inframarginal comparative statics

Structure	Parameter Value Subset	Within subset with $k_1 = k_2 = 0.0001$	Within subset with $k_1 = k_2 = 0.5$	Within subset with $k_1 = k_2 = 1$	Relative skilled-unskilled labor wage rate in skill-abundant country 2 normalized to unity in the case of autarky
$(xy)(xy)$	$k_2 < \frac{a_{2x}}{a_{1x}}\left(\frac{L_{1u}}{L_{1s}}\frac{L_{2s}}{L_{2u}}\right)^{1-\beta} < \frac{1}{k_1}$ and/or $k_2 < \frac{a_{2y}}{a_{1y}}\left(\frac{a_{2x}}{a_{1x}}\right)^{\delta}\left(\frac{L_{1u}}{L_{1s}}\frac{L_{2s}}{L_{2u}}\right)^{(1-\beta)\delta+\varepsilon} < \frac{1}{k_1}$	Yes	No	No	1
$(xy)_x(xy)_y$	$\frac{\beta}{1-\beta}\frac{L_{1s}}{L_{1u}} < A\frac{L_{1s}+BL_{2s}}{L_{1u}+CL_{2u}} < \frac{1-\delta-\varepsilon}{\varepsilon}\frac{L_{1s}}{L_{1u}}$ and $\frac{\beta}{1-\beta}\frac{L_{2s}}{L_{2u}} < A\frac{B^{-1}L_{1s}+L_{2s}}{C^{-1}L_{1u}+L_{2u}} < \frac{1-\delta-\varepsilon}{\varepsilon}\frac{L_{2s}}{L_{2u}}$	No	Yes	No	0.83
$(x)_x(y)_y$	$\frac{a_{2y}}{a_{1y}}k_2^{\delta}\left(\frac{1-\beta}{\varepsilon}\right)^{\varepsilon}\left(\frac{\beta}{1-\delta-\varepsilon}\right)^{1-\delta-\varepsilon}\left(\frac{1-\alpha+\delta\alpha}{\alpha}\right)^{1-\alpha}\left(\frac{L_{2s}}{L_{1s}}\right)^{\varepsilon}\left(\frac{L_{2u}}{L_{1u}}\right)^{1-\delta-\varepsilon} > \frac{1}{k_1}$ and $\frac{a_{2x}}{a_{1x}}\left(\frac{1-\beta}{\varepsilon}\right)^{1-\beta}\left(\frac{\beta}{1-\delta-\varepsilon}\right)^{\beta}\left(\frac{1-\alpha+\delta\alpha}{\alpha}\right)\left(\frac{L_{2s}}{L_{1s}}\right)^{1-\beta}\left(\frac{L_{2u}}{L_{1u}}\right)^{\beta} < k_2$	No	No	Yes	0.5

Notes: $A = \frac{1-\alpha\varepsilon-(1-\beta)(1-\alpha+\alpha\delta)}{\alpha\varepsilon+(1-\beta)(1-\alpha+\alpha\delta)}$, $B = \left[\left(\frac{a_{2x}}{a_{1x}}\right)^{1-\delta-\varepsilon}\left(\frac{a_{1y}}{a_{2y}}\right)^{\beta} k_2^{\delta(1-\beta)+\varepsilon-1}k_1^{-\beta}\right]^{\frac{1}{(1-\delta)(1-\beta)-\varepsilon}}$, $C = \left[\left(\frac{a_{1x}}{a_{2x}}\right)^{\varepsilon}\left(\frac{a_{2y}}{a_{1y}}\right)^{1-\beta} k_2^{\varepsilon+\delta(1-\beta)}k_1^{1-\beta}\right]^{\frac{1}{(1-\delta)(1-\beta)-\varepsilon}}$,

$\alpha = 0.8$, $L_{1s} = 400$, $L_{1u} = 4000$, $L_{2s} = 4000$, $L_{2u} = 400$, $a_{1y} = 1$, $a_{1x} = 5$, $a_{2y} = 3$, $a_{2x} = 1$, $\delta = 0.4$, $\varepsilon = 0.1$, $\beta = 0.6$.

Figure 1. Wage dispersion between skilled and unskilled labor

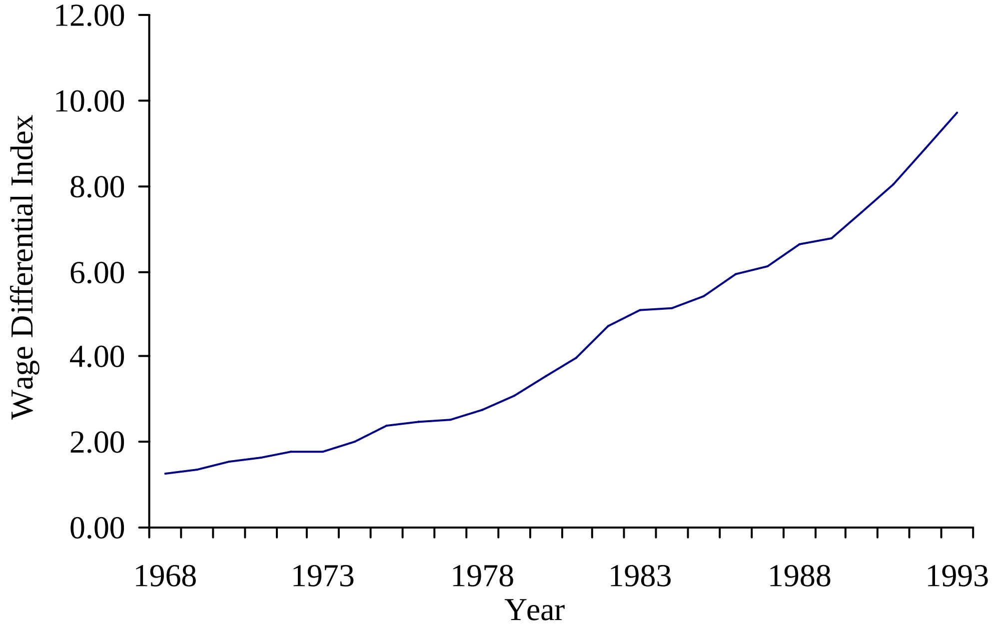

Figure 2. Possible trade structures