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A PRODUCTION THEORY APPROACH TO THE IMPORTS AND WAGE INEQUALITY NEXUS

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Abstract – We employ a production theory approach to investigate the Stolper-Samuelson effect of fluctuations in the prices of imports, of different origin, on the wage differential between skilled and unskilled labour in the US. Challenging conventional wisdom we find that the positive, downstream-production related, effects of imports on the demand for labor are often significant enough to produce detectable *net* increases in wages. However, the overall impact of imports, including those that originate in less developed countries, on the wage differential is found to be negligible. Economy-wide dynamic processes of capital accumulation and technical change appear to be far more relevant driving forces of wage dispersion.

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A PRODUCTION THEORY APPROACH TO THE IMPORTS AND WAGE INEQUALITY NEXUS

I. INTRODUCTION

One of the most policy relevant academic inquiries in the area of international economics concerns the contribution of imports to the ever-expanding wage inequality between skilled and unskilled labor in the US[1]. Research in this area has generated considerable interest, few answers, and a plethora of conflicting results that have inspired a fierce debate. On one side of the debate, Borjas and Ramey (1994) as well as Wood (1995, 1998), among others, advocate that the rise in imports that has been observed over the last few decades can account for much of the trend in wage inequality. The retractors, including Sachs and Shatz (1994, 1996), Krugman (1995, 1997) and Lawrence and Slaughter (1993), to name a few, argue that the impact of imports on wages was negligible. To further polarise the character of the debate, there seems to be little consensus over the nature of the appropriate analytical framework for such research. As a result, a wide array of models have been recruited. These include the input-output methods of Sachs and Shatz (1994) and Wood (1995), the "behavioural" frameworks of Lawrence and Slaughter (1993) and Berman *et al.* (1994), as well as the more "descriptive" approach favoured by Krugman (1997).

One of the few unifying elements characterising empirical research in this area is the collective presumption that imports invariably displace demand for domestic labor. This notion derives from the heavy reliance of the majority of such studies on the Hecksher-Ohlin theorem of trade, and its corollary, the Stolper-Samuelson (1941), which uniformly assume that traded goods are final. An endemic methodological shortcoming of studies in this area is consequently their inability to capture, in

[1] Summaries are found in Richardson (1995) and Burtless (1995).

addition to the domestic-output-substitution labor market effects, the impact of imports on the demand for labor that is generated via *domestic factor-using downstream processes*. As noted by Burgess (1974, 1976), Appelbaum *et al* (1997) and Kohli (1991, 1993, 1994), *all* imports, including those of so-called "final" goods, are subject to extensive downstream handling[2], and a significant portion of their "shelf price" reflects value added domestically. Using a production theory approach Aw and Roberts (1985), as well as Tombazos (1998, 1999a, 1999b)[3] found that labor market effects that ensue from downstream handling of imports often assume considerable magnitudes and their omission must therefore introduce significant biases in related estimations.

Particularly susceptible to biases that arise from disregarding downstream production are studies with a more policy-relevant flavour that attempt to estimate the magnitude of the asymmetric impact of imports from less developed (LDCs) and industrialised countries (ICs) on the prevailing wage inequality[4]. Given that the mainstream views the expanding wage inequality in the US as a result that is, according to Wood (1995, p. 58), ultimately driven by the demand for unskilled labor

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[2] This may involve a host of domestic channels such as transportation, insurance, storage, finishing, repackaging, marketing and retailing.

[3] Tombazos (1999a) investigates the relevance of downstream production in a model that disaggregates labor on a skill basis. While his results are suggestive of the importance of downstream handling in the context of such labor disaggregations, they are based on a rigid wages framework and cannot be used to shed light on the impact of imports on wages. According to Krugman (1995), extrapolating the impact of imports on wage inequality using rigid-wage models is subject to "serious conceptual difficulties" (p. 355), "...that is, the same model that predicts fairly large employment effects with rigid wages *may* predict quite small effects on relative wages when they are flexible" (p. 357). Italics added for clarity.

[4] See for example Wood (1995) and Sachs and Shatz (1994, 1996).

falling substantially relative to the demand for skilled labor, this type of research has focussed primarily on the role of the low-skill imports from LDCs in domestic production. Ignoring downstream processes, that have the potential to stimulate wages if they require sufficient quantities of labor input, such imports are often viewed as the protagonist in expanding the wage inequality gap. This, as the story goes, is achieved via a typical Stolper-Samuelson chain of events, that involves displacing domestically produced, import competing, low-skill output and, consequently, demand for unskilled labor. As a *ceteris paribus* approximation, frameworks that rely on such dynamics are not entirely unreasonable. However, by neglecting the "intermediate" character of imports they miss a critical element of the story which is particularly relevant when evaluating the relative role of imports from ICs and LDCs in domestic production. A comparison of imports of such origins suggests that the latter are not only characterised by a disproportionately large low-skill factor content but also, as pointed out by Aw and Roberts (1985, p. 115-16) as well as Tombazos (1999b, p. 355), by a disproportionately large share of "down-market and raw"[5] intermediate goods which are subject to *exceptionally extensive* downstream handling. While these two authors examine the labor markets of different countries[6], they both find that this more pronounced "intermediate" nature of imports from LDCs is occasionally responsible for downstream-production induced labor-import complementarities that overshadow the labor displacement associated with the substitution of domestically produced import competing goods. Hence, studies of the imports – wage inequality nexus, such as those of Sachs and Shatz (1994, 1996) and

[5] Tombazos (1999b, p. 355)

[6] Aw and Roberts (1985) and Tombazos (1999b) examine imports from nearly identical sources but investigate the implications of import price fluctuations on the labor markets of the US and Australia, respectively.

Wood (1995), which do not account for downstream production, are likely to overestimate the significance of imports from LDCs, and underestimate the relative burden of imports from ICs, in facilitating the prevailing wage inequality.

This paper constitutes the first attempt to examine the effects of import price fluctuations on the prevailing wage inequality between skilled and unskilled labor in the US using a flexible-wage model that accounts for both the domestic-output-substitution, as well as the downstream-production effects of imports. Given that this analytical framework is particularly relevant in empirical investigations of the relative role of imports from LDC and IC origin in domestic production, imports are disaggregated accordingly.

The remainder of this paper is organised as follows. The model is examined in the following section. In section III issues of econometric implementation are discussed. The results are presented in section IV, and concluding remarks are reserved for section V.

II. THE MODEL

Imports as Inputs in Domestic Production

To capture the intermediate nature of imports, which invariably require domestic downstream processing before final consumption, we employ a model that treats imports as an input in aggregate production. This approach was originally proposed by Samuelson (1953-54), formally introduced by Burgess (1974, 1976), and further developed by Kohli (1991, 1993, 1994).

Given the nature of the adopted framework, and within the confines of the production space, imports are represented symmetrically with domestic primary factors, such as capital and labor, in the model. However, from a statistical point of view, inputs in domestic production should not be treated identically. On the one hand, as noted by Krugman (1995, p. 355) and Kohli (1991, p. 76, 198), US labour and capital markets should be modelled as flexible. On the other, as suggested by Kohli (1991, p. 76, 170), import prices are (largely) exogenous[7], at least in a statistical sense and within the context of the production theory approach. Hence, the quantity of imports should, similarly to the quantity of output, be treated as variable, whereas the endowments of capital and labour should be treated as fixed[8]. Given these considerations, conventional statistical formulations of profit, cost, revenue or production functions do not lend themselves as relevant representations of the prevailing production technology. Instead, we are required to employ a *variable profit function* which facilitates non-uniform representations of inputs in which some of these inputs may be treated as variable while others as fixed. The variable profit function is discussed in the next section.

The Variable Profit Function Approach to Modelling Imports

Let Ω^t represent a production possibilities set, or netput vector, at time *t*. Ω^t is assumed to be a closed, nonempty and convex cone that is bounded from above for all nonegative input quantities. Furthermore, assume that Ω^t is defined over three fixed inputs and three outputs. The fixed inputs are low-skill, henceforth unskilled, labor (U), high-skill, henceforth skilled, labor (S) and capital (K). The "outputs" are disaggregated in economy-wide output and two categories of variable inputs pertaining to imports from LDCs (D) and imports from ICs (I) . Denote

[7] The endogeneity of import prices that may ensue from the size of the US economy is discussed in a forthcoming section.

[8] Our treatment of the relevant variables is fairly conventional since, as pointed out by Kohli (1991), "in standard trade theory, it is customary to take trade goods prices and factor endowments as given." (p. 65).

$\mathbf{x} = (x_U, x_S, x_K)'$ as the vector of fixed input quantities and $\mathbf{y} = (y_Y | y_D, y_I)'$ as the bordered vector of variable quantities (or outputs). Let y_Y correspond to the quantity of aggregate output, and $\mathbf{y}_{\mathrm{VI}} = (y_D, y_I)'$ represent the sub-vector of variable input quantities. Note that variable inputs, such as imports in the case of our model, are treated as negative outputs. Hence, $y_Y \geq 0$ and $\mathbf{y}_{\mathrm{VI}} \leq \mathbf{0}_2$. The prices of fixed inputs are given by $\mathbf{w} = (w_U, w_S, w_K)'$ and the prices of "outputs" by $\mathbf{p} = (p_Y, p_D, p_I)'$. Finally, assuming that production decisions are made by profit maximising firms, which operate in perfectly competitive input and output markets, Ω^{t} can be represented by its dual variable profit function given by

$$\pi \equiv \pi(\mathbf{p}, \mathbf{x}, t) \equiv \max_{\mathbf{y}}\{\mathbf{p}' \cdot \mathbf{y} : (\mathbf{y}, \mathbf{x}) \in \Omega^{\mathrm{t}}\} \text{ for } \mathbf{p} > \mathbf{0}_3;\ \mathbf{x} \geq \mathbf{0}_3;\ y_Y \geq 0;\ \mathbf{y}_{\mathrm{VI}} \leq \mathbf{0}_2 \tag{1}$$

As shown by Diewert (1974, p. 136)[9], the assumptions made regarding the nature of the production possibilities set, Ω^{t}, require the variable profit function $\pi(\cdot)$ to be positive, homogeneous of degree one, continuous and convex (for a given **x**) in the prices, **p**, of the variable quantities; nondecreasing in the price of the (positive) output; nonincreasing in the prices of the variable inputs (i.e. negative outputs); and monotonically increasing, continuous, linear homogeneous and concave (for a given **p**) in the fixed input quantities **x**.

Using the Gorman-Diewert interpretation of Hotelling's[10] lemma, in the context of the *variable* profit function, differentiation of $\pi(\cdot)$ yields the supply of positive outputs and the demand for variable inputs

[9] For additional information refer to Samuelson (1953-54, p. 20), Gorman (1968, p. 141-72) and Kohli (1991, p. 36).

[10] See Gorman (1968), Diewert (1974, p. 137) and Hotelling (1932, p. 594).

(2) $$\mathbf{y} = \mathbf{y}(\mathbf{p},\mathbf{x},t) = \nabla_{\mathbf{p}}\pi(\mathbf{p},\mathbf{x},t)$$

where $\nabla_{\mathbf{p}}\pi(\cdot) \equiv \left[\partial\pi(\cdot)/\partial p_Y, \partial\pi(\cdot)/\partial p_D, \partial\pi(\cdot)/\partial p_I\right]'$ is the gradient of $\pi(\cdot)$ with respect to **p**. As noted by Kohli (1991, p. 37), given the homogeneity properties of $\pi(\cdot)$, the output supply and variable input demand functions are homogeneous of degree zero in the components of **p**, and homogeneous of degree one in **x**. Furthermore, the convexity of $\pi(\cdot)$ with respect to output (including variable input) prices require that $\partial|y_i|/\partial p_i \geq 0 \;\forall\; i \in (Y,D,I)$.

If, under competitive conditions, producers are also optimising with respect to fixed inputs[11], as well as variable inputs and outputs, then the inverse fixed input demand functions can be derived from the "marginal product" conditions via

(3) $$\mathbf{w} = \mathbf{w}(\mathbf{p},\mathbf{x},t) = \nabla_{\mathbf{x}}\pi(\mathbf{p},\mathbf{x},t)$$

where $\nabla_{\mathbf{x}}\pi(\cdot) \equiv \left[\partial\pi(\cdot)/\partial x_K, \partial\pi(\cdot)/\partial x_U, \partial\pi(\cdot)/\partial x_S\right]'$. Given the homogeneity properties of the variable profit function, the inverse fixed input demand functions are linear homogeneous in output (and variable input) prices, and homogeneous of degree zero in fixed input quantities. The concavity of $\pi(\cdot)$ further requires that the inverse input demand functions are nonincreasing in their own quantities [i.e. $\partial w_j/\partial x_j \leq 0 \;\forall\; j \in (U,S,K)$].

Substitution possibilities between inputs and outputs can be explored by estimating the elasticity matrix given by

(4) $$\mathbf{E} = \left[\varepsilon_{\lambda,\eta}\right] = \begin{bmatrix} \mathbf{E}_{\mathbf{pp}} & \mathbf{E}_{\mathbf{px}} \\ \mathbf{E}_{\mathbf{xp}} & \mathbf{E}_{\mathbf{xx}} \end{bmatrix}$$

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

As shown by Diewert (1974, p. 143), **E** can be easily derived from the variable profit function as follows

$$(5)\quad \mathbf{E}=\begin{bmatrix} \left[\left\{\mathbf{diag}\left(\nabla_{\mathbf{p}}\pi(\cdot)\right)\right\}^{-1}\cdot\left(\nabla^2_{\mathbf{pp}}\pi(\cdot)\right)\cdot\left(\mathbf{diag}(\mathbf{p})\right)\right] & \left[\left\{\mathbf{diag}\left(\nabla_{\mathbf{p}}\pi(\cdot)\right)\right\}^{-1}\cdot\left(\nabla^2_{\mathbf{px}}\pi(\cdot)\right)\cdot\left(\mathbf{diag}(\mathbf{x})\right)\right] \\ \left[\left\{\mathbf{diag}\left(\nabla_{\mathbf{x}}\pi(\cdot)\right)\right\}^{-1}\cdot\left(\nabla^2_{\mathbf{xp}}\pi(\cdot)\right)\cdot\left(\mathbf{diag}(\mathbf{p})\right)\right] & \left[\left\{\mathbf{diag}\left(\nabla_{\mathbf{x}}\pi(\cdot)\right)\right\}^{-1}\cdot\left(\nabla^2_{\mathbf{xx}}\pi(\cdot)\right)\cdot\left(\mathbf{diag}(\mathbf{x})\right)\right] \end{bmatrix}$$

where, given $\Phi,\Gamma \in (\mathbf{p},\mathbf{x})$, $\nabla_{\Phi}\pi(\cdot)$ represents the gradient of $\pi(\cdot)$ with respect to Φ and $\nabla^2_{\Phi\Gamma}\pi(\cdot)$ denotes the sub-hessian of $\pi(\cdot)$ with respect to Φ and Γ.

The elasticities which represent the impact of a change in the price of the positive output and imports (i.e. variable inputs) on the prices of the primary factors of production, including skilled and unskilled labour, are of particular interest to our analysis. Using the terminology proposed in a translogarithmic production framework by Appelbaum and Kohli (1997, p. 627), we refer to these constructs as the "Stolper-Samuelson" elasticities[12]. In the short run, these elasticities are given by $\mathbf{E}_{\mathbf{xp}}$ of equation (4). Indirect measures of the corresponding medium run values of the "Stolper-Samuelson" elasticities can be easily constructed using the estimates of $\mathbf{E}_{\mathbf{xp}}$ in conjunction with elements of $\mathbf{E}_{\mathbf{xx}}$. Finally, given that technological advancement is incorporated in the model through the inclusion of a time trend[13], the impact of technical change on variable input quantities and fixed input prices can be captured by

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[12] While the assumed production technology is not consistent with the original Stolper-Samuelson theorem, which is only valid under very restrictive conditions, the "Stolper-Samuelson elasticities" label should not be viewed as a misnomer. As shown by Kohli (1995), Stolper-Samuelson-*like* results hold for a range of alternative production structures other than the 2×2, nonjoint technology assumed in the original formulation of the theorem.

[13] See Diewert and Wales (1992, p. 705-6) for a relevant discussion.

the time semi-elasticities $\mathbf{E}_{\mathbf{p}t} = \left[\mathbf{diag}(\nabla_{\mathbf{p}})\pi(\cdot)\right]^{-1} \cdot \left(\nabla^2_{\mathbf{p}t}\pi(\cdot)\right)$ and $\mathbf{E}_{\mathbf{x}t} = \left[\mathbf{diag}(\nabla_{\mathbf{x}})\pi(\cdot)\right]^{-1} \cdot \left(\nabla^2_{\mathbf{x}t}\pi(\cdot)\right)$, respectively.

Econometric Specification of the Model

In empirical work the variable profit function is represented by flexible functional forms which, unlike the Cobb-Douglas or the CES, do not restrict a priori the signs or sizes of the estimated coefficients. While this empirical framework is hardly a recent development, it has been grossly under-utilised in research of the nature discussed in this paper. We suspect that this may be partly due to the fact that, as noted by Diewert and Wales (1987, p. 43), as well as Kohli (1994, p. 587), even modestly non-separable flexible representations of variable profit, and similar, behavioural functions, often fail the required curvature conditions[14]. Of course, these conditions can be easily imposed externally. However, in the case of the majority of flexible functional forms, curvature enforcing reparametrisations come at the expense of relinquishing flexibility, which, crudely speaking, is often analogous to the capacity of a functional form to measure complementary relationships between inputs. In the case of the translog for example, used by Aw and Roberts (1985) and Burgess (1974), Diewert and Wales (1987, p. 48) show that the imposition of concavity forces the estimated function to become Cobb-Douglas over certain portions of the data. Imposing curvature conditions on the generalised-linear-generalised-leontief flexible functional form, used by Burgess (1976), renders, according to Kohli (1991, p. 107), a more extreme bias, as the possibility for complementarity between inputs is eliminated

[14] These are conditions implied by economic theory and required for the generated results to be meaningful. In our model curvature conditions require the variable profit function to be convex with respect to output (including variable input) prices and concave with respect to the quantities of the fixed factors.

globally for all observations. Hence, the very feature of flexible functional forms that argues in favour of their wider acceptance is that which is often compromised in empirical estimations, thereby undermining their usefulness. From the perspective of this study it should be noted that, general concerns regarding flexibility violations aside, such transgressions would largely undermine our very objective: to estimate elasticities that *also* capture any downstream-production-induced "complementarities" between domestic labour inputs, and imports in aggregate production.

The unhindered path of this study, through the Scylla of curvature violations and the Charybdis of potentially input-complementarity sacrificing curvature corrections, is paved by Kohli's 1993 pioneering contribution. In that paper Kohli introduced the symmetric normalised quadratic (SNQ) flexible functional representation of a variable profit function[15]. The remarkable advantage of the SNQ over other functional frameworks is that it can accept curvature enforcing reparametrisations without endangering its flexibility[16]. This quality, which effectively protects the capacity of this functional form to identify and measure complementary net relationships between inputs under such curvature corrections, renders the SNQ the ideal choice for the purpose of the empirical investigations undertaken in this paper[17].

Using the SNQ flexible functional form developed by Kohli (1993), the variable profit function employed in this paper can be written as[18]

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[15] Kohli's (1993) SNQ representation of a variable profit function relies on the family of SNQ functional forms originally proposed by Diewert and Wales (1987).

[16] See Diewert and Wales (1992, p. 708).

[17] The presumption here is, of course, that at some stage in the course of our estimations, one or more curvature conditions will in fact be violated, as indeed they are.

[18] The manner in which time-driven technical change is incorporated in the model deviates slightly from Kohli (1993) by following Kohli (1991, p. 238-41).

(6) $\pi = \frac{1}{2}(\boldsymbol{\beta}'\mathbf{x})\mathbf{p}'\mathbf{A}\mathbf{p}/(\boldsymbol{\alpha}'\mathbf{p}) + \frac{1}{2}(\boldsymbol{\alpha}'\mathbf{p})\mathbf{x}'\mathbf{B}\mathbf{x}/(\boldsymbol{\beta}'\mathbf{x}) + \mathbf{p}'\mathbf{C}\mathbf{x} + \mathbf{p}'\Delta\mathbf{x}\,t + \frac{1}{2}(\boldsymbol{\alpha}'\mathbf{p})(\boldsymbol{\beta}'\mathbf{x})\xi_{tt}t^2$

where $\mathbf{A} \equiv [a_{ih}]$, $\mathbf{B} \equiv [b_{jk}]$, and $\mathbf{C} \equiv [c_{ij}]$ denote unknown symmetric parameter matrices of dimensions 3×3, $\Delta \equiv [\delta_{ij}]$ represents an unknown parameter matrix of dimension 3×3, and, $\boldsymbol{\alpha} \equiv [\alpha_i]$ and $\boldsymbol{\beta} \equiv [\beta_j]$ represent vectors of preselected parameters of order 3, $\forall\, i,h \in (Y,D,I)$ and $j,k \in (U,S,K)$, and ξ_{tt} denotes an unknown scalar parameter; Given the assumptions made regarding the production possibilities set $\Omega^{\mathbf{t}}$ and the characteristics of the SNQ we require that $\sum_h^{(Y,D,I)} a_{ih} = 0$ $\forall\, i \in (Y,D,I)$, $\sum_k^{(U,S,K)} b_{jk} = 0$ $\forall\, j \in (U,S,K)$, $\sum_i^{(Y,D,I)} \alpha_i = 1$ and $\sum_j^{(U,S,K)} \beta_j = 1$. Note that for estimation purposes we set the values of $\alpha_i = 1/3\ \forall\, i \in (Y,D,I)$ and $\beta_j = 1/3\ \forall\, j \in (U,S,K)$ [19]. As proven by Kohli (1993, p. 247 and p. 253-54), equation (6) is a fully flexible functional form. In addition, it is linear homogeneous in the prices of the positive output and variable inputs, and in the quantities of the fixed inputs. However, it is neither necessarily concave in fixed input quantities nor necessarily convex in the prices of the variable quantities.

Using (2) and (6) we can generate the output supply and variable input demand functions which are given by

(7)
$$\mathbf{y} = (\boldsymbol{\beta}'\mathbf{x})\mathbf{A}\mathbf{p}/(\boldsymbol{\alpha}'\mathbf{p}) - \tfrac{1}{2}\boldsymbol{\alpha}(\boldsymbol{\beta}'\mathbf{x})\mathbf{p}'\mathbf{A}\mathbf{p}/(\boldsymbol{\alpha}'\mathbf{p})^2 + \tfrac{1}{2}\boldsymbol{\alpha}\,\mathbf{x}'\mathbf{B}\mathbf{x}/(\boldsymbol{\beta}'\mathbf{x}) + \mathbf{C}\mathbf{x} + \Delta\mathbf{x}t + \tfrac{1}{2}\boldsymbol{\alpha}(\boldsymbol{\beta}'\mathbf{x})\xi_{tt}t^2$$

Similarly, (3) and (6) are used to generate the inverse fixed input demands which correspond to

(8)
$$\mathbf{w} = \tfrac{1}{2}\boldsymbol{\beta}\,\mathbf{p}'\mathbf{A}\mathbf{p}/(\boldsymbol{\alpha}'\mathbf{p}) + (\boldsymbol{\alpha}'\mathbf{p})\mathbf{B}\mathbf{x}/(\boldsymbol{\beta}'\mathbf{x}) - \tfrac{1}{2}\boldsymbol{\beta}(\boldsymbol{\alpha}'\mathbf{p})\mathbf{x}'\mathbf{B}\mathbf{x}/(\boldsymbol{\beta}'\mathbf{x})^2 + \mathbf{C}'\mathbf{p} + \Delta'\mathbf{p}t + \tfrac{1}{2}(\boldsymbol{\alpha}'\mathbf{p})\boldsymbol{\beta}\xi_{tt}t^2$$

[19] See Diewert and Wales (1992, p. 713) for a relevant discussion.

Construction of Data

The model employed in this paper requires data on prices and quantities for all primary factors, imports and aggregate output. Raw data was obtained from the *National Income and Product Accounts of the United States* (NIPA), the *Survey of Current Business*, the *Occupations by Industry Subject Reports* of the 1970 *Census of Population,* the annual and monthly editions of the *International Financial Statistics*, the *International Financial Statistics Supplement to Trade Statistics* and the *Directions of Trade Statistics Yearbook.*

Aggregate output data was constructed as a Tornqvist aggregation[20] of the changes in durable and non-durable business inventories and the twenty categories of consumption, fifteen categories of investment and three categories of exports identified in the NIPA. We consider capital expenditure to be equal to output net of the wage bill and import purchases. Thus, the implicit rental rate of capital for each year is generated by dividing 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.

Imports from thirty one countries, representing on average about 70% of aggregate US commodity imports, for which price and quantity data is complete and consistent across publications for the time period under examination, were considered. The countries considered are classified as either industrialized countries (ICs) or less developed countries (LDCs), based on their annual per capita GDP, by the International Monetary Fund[21]. Countries which cross boundaries of development during the time period examined in this study are excluded from the sample. Imports are aggregated by origin in imports from ICs and LDCs using the Tornqvist method.

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[20] See Appendix 1.

[21] See any relevant edition of the *International Financial Statistics.*

The IC category includes: Australia, Austria, Belgium-Luxembourg, Canada, Denmark, Finland, France, Germany, Iceland, Italy, Japan, the Netherlands, New Zealand, Norway, Spain, Sweden and the United Kingdom. The LDC group includes: Indonesia, Colombia, India, the Dominican Republic, Israel, Syria, Ecuador, Thailand, Honduras, Morocco, Philippines, Bolivia, Sri Lanca and Tunisia. While our country samples are far from complete, they are representative of the major geographical regions that are included in the population of their respective groupings, and are more comprehensive than either Aw and Roberts (1985) or Tombazos (1999b).

Data on employment and wages of skilled and unskilled labour respectively, is not currently available at the aggregate level. An important guideline in choosing a particular approach for the construction of "proxies" for the needed variables is that the resulting disaggregation of the labour force captures directly the impact of imports on the demand for skilled and unskilled labour. As noted by Berman, Bound and Griliches "...the increase in international trade...would work primarily by shifting the derived demand for labour between industries from those intensive in production, *or unskilled,* workers to those intensive in non-production, *or skilled,* workers." (1994, pp. 376)[22]. Hence, an appropriate labour disaggregation would allow the resulting wage and employment figures to reflect the effect of trade induced labour demand fluctuations in the high- and low-skill intensive industries. To construct the data required by our model we therefore divided the fifty-four industries identified in the subject report of the 1970 census of the population in two categories on the basis of their skill intensity[23]. We then proceeded to derive representative wages and employment levels for the high and low skill intensive industries via Tornqvist

[22] The italics are added for clarity.

[23] A statistical appendix illustrating detailed sources and construction techniques for all data employed in this paper can be supplied from the author upon request.

aggregations. We use these employment and wage figures as proxies for the corresponding data pertaining to "skilled" and "unskilled" labour respectively.

We have utilised two distinct indices of skill. Index "a" is similar to that employed by Ray (1981) and defines skilled workers to include professionals and managers as well as sales, clerical and precision production labour. Index "b" is more austere in that it defines skilled workers to include only professionals and managers. While similarly with the index employed by Adams (1999), Lawrence and Slaughter (1993) and Sachs and Shatz (1994), index "b" focuses on the distinction between white and blue collar labor, it excludes clerical workers from the skilled labor classification to "account" for the recent expansion of professional relative to clerical non-production jobs identified by Berman, Bound and Griliches (1994). As can be noted from figure 1, both skill indices capture rather symmetrically the growth of wage inequality between skilled and unskilled labour that has been observed over the last few decades.

The annual observations for the variables utilised in this study cover the period 1961-1991.

III. Estimation and Curvature Conditions

For estimation purposes the model consists of a cluster of six behavioural functions: the aggregate output supply function, the two variable import demand functions and the three inverse fixed input demands of the domestic primary factors. To improve efficiency, the six equations outlined above are estimated simultaneously using a nonlinear interpretation of Zellner's Seemingly Unrelated Regression equations (SUR) method which we label with the acronym NSUR. To account for the possibility of a statistically relevant endogenous dimension of import prices, that may arise because of the size of the US economy, the system of our model equations is also estimated using a Nonlinear Three Stage Least Squares (N3SLS) technique. The instrumental variables employed are: excise taxes, sales taxes, and personal savings as percentages of personal disposable income; the budget deficit, net foreign 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. To facilitate convergence in the system, all prices and instrumental variables were normalised to (the absolute value of) one for 1987. Variants of the model employing datasets constructed on the basis of skill indices "a" and "b" are labelled models "1a" and "1b" respectively.

Preliminary investigations using NSUR indicated that both models suffer from serial correlation. This result complicates estimation matters as there does not appear to be consensus in the econometric literature pertaining to concomitant corrections for autocorrelation and endogenous explanatory variables in a simultaneous equation setting. In applied work, empiricists often choose to correct for only one of the two problems[24], or correct for both simultaneously in a three stage least squares framework using autocorrelation coefficients generated by a (N)SUR technique[25]. In the former case the "magnitude", or relevance, of the uncorrected statistical malady inherent in the model and data is unknown. In the latter, the synergy of concomitant corrections may, under certain conditions (the presence of which is difficult to investigate), distort the final results somewhat. Our response to the dilemma of choosing a particular approach in the absence of full information is to estimate each

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[24] See for example Kohli (1993) who corrects for endogenous explanatory variables but not autocorrelation, and Kohli (1994) who corrects for serial correlation but not for endogenous explanatory variables.

[25] See for example Aw and Roberts (1985), Goss (1990) or Tombazos (1998).

variant of the model using all relevant techniques employed in the literature, and report all results. Hence models "1a" and "1b" are estimated using an autocorrelation-adjusted-nonlinear-seemingly-unrelated-regression-equations method (ANSUR), a nonlinear-three-stage-least-squares (N3SLS) technique, and an autocorrelation-adjusted-nonlinear-three-stage-least-squares approach (AN3SLS). The six resulting econometric implementations are ANSUR-1a, N3SLS-1a, AN3SLS-1a, ANSUR-1b, N3SLS-1b and AN3SLS-1b.

After a preliminary estimation of the models outlined above the curvature conditions were checked[26]. Table I reports the relevant eigenvalues pertaining to the six implementations of our framework. As can be seen from the table, convexity and concavity were satisfied in the case of all implementations of model "1a" as well as for implementation N3SLS of model "1b". However, both ANSUR-1b and AN3SLS-1b failed concavity, with the latter failing the convexity condition as well. Given the relative prevalence of concavity, relative to convexity, violations, we proceeded to investigate the option of globally imposing the former condition before re-estimating the offending models. As a point of departure we examined the technique proposed by Wiley *et al.* (1973). These authors indicate that a sufficient condition for a matrix Ψ to be negative semidefinite is that it can be expressed as: $\Psi = -\mathbf{Z} \cdot \mathbf{Z}$ 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.

[26] 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.

We define:

(9)
$$\mathbf{Z} = \begin{bmatrix} z_{1,1} & 0 & \cdots & 0 \\ z_{2,1} & z_{2,2} & \cdots & 0 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ z_{J,1} & z_{J,2} & \cdots & z_{J,J} \end{bmatrix}$$

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

(10)
$$\Psi = \begin{bmatrix} -z_{1,1}^2 & -z_{1,1}\cdot z_{2,1} & \cdots & -z_{1,1}\cdot z_{J,1} \\ -z_{1,1}\cdot z_{2,1} & -z_{2,1}^2\cdot z_{2,2}^2 & \cdots & -z_{2,1}\cdot z_{J,1} - z_{2,2}\cdot z_{J,2} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ -z_{1,1}\cdot z_{J,1} & -z_{2,1}\cdot z_{J,1} - z_{2,2}\cdot z_{J,2} & \cdots & -z_{J,1}^2 - z_{J,2}^2 - \cdots - z_{J,J}^2 \end{bmatrix}$$

As previously noted, a sufficient condition for our 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 reparametrisation of the model equations by replacing each element of matrix **B** with its corresponding expression in Ψ. However, such a reparametrisation is incompatible with the assumption that the employed variable profit function is linear homogeneous in the fixed input quantities **x**. This assumption requires that $\sum_k b_{j,k} = 0$, which implies that the last element in each row of matrix **B** is a linear combination of the remaining elements in that row. Hence, replacing matrix **B** with matrix Ψ would ensure concavity, but violate linear homogeneity as the elements of each row of matrix Ψ are not required to sum to zero. It turns out that concavity can be easily imposed without violating linear homogeneity using a simple modification of the general framework proposed by Wiley *et al.* (1973). The modification requires that matrix **Z** (and consequently matrix Ψ) is constructed so that its dimensions are given by $J \times J$, such that $J = M - 1$ where **B** is a square matrix with dimensions $M \times M$. Subsequently, concavity is imposed by replacing the elements of the leading principal minor of order $M - 1$ of matrix **B** with the corresponding elements of matrix Ψ. Clearly, the modified technique would be successful if a sufficient condition for an arbitrary square matrix of order M to be negative semidefinite is that its leading principal minor of order $M - 1$ is also negative semidefinite. A simple proof of the general validity of this proposition is provided in appendix 2.

Using the modified Wiley *et al.* (1973) procedure, outlined above, concavity was imposed globally before re-estimating the models that violated curvature conditions in the first round of estimations. There was no need to enforce convexity in the case of model AN3SLS-1b, which in the original estimation violated both curvature conditions, as the concavity-enforced implementation of the model did not suffer from convexity violations.

IV. RESULTS

The resulting parameter estimates together with their associated *t*-values, degrees of freedom (DOF), Berndt's (1991) adjusted generalised r-squared[27] ($\widetilde{R}^2$), and monotonicity violations (MV) for each of the three econometric implementations of each of models 1a and 1b are reported in tables II and III, respectively. In the case of ANSUR estimations, in which meaningful autocorrelation coefficients can be estimated, we also report the relevant Wald statistic, *W*, discussed in White (1992).

[27] Since system of equations regressions do not minimise the sum of the squared errors of each independent equation, but instead the determinant of the residual cross-product matrix, single equation R^2 measures are flawed in the equation systems' context. We therefore employ the adjusted generalised R^2 suggested by Berndt (1991, p. 468).

The values of these statistics indicate that the overall fit of the model is quite good, and that autocorrelation is rejected, at the 5% level, in the case of both autocorrelation-adjusted nonlinear seemingly unrelated regression estimations. Furthermore, where monotonicity violations are identified, they involve at the most only two of the six equations in the system, and they are strictly contained within the first few observations. Following Aw and Roberts (1985, p. 113), these violations are isolated by excluding the first few sample observations from our analysis.

Using matrix (5) and the parameters reported in tables II and III, we proceeded to calculate inverse factor demand elasticities, pertaining to the three econometric implementations of each of models 1a and 1b, which we report in tables IV and V, respectively. For each reported elasticity we provide selected annual values and, in the absence of sign reversals [28], its average together with the associated *t*-statistic. Examination of tables IV and V suggests that the majority of elasticities that do not exhibit sign-reversals are statistically significant and fairly stable over time, while, looking across the reported elasticities, there are some relatively substantial differences in magnitude.

The first part of tables IV and V presents the Stolper-Samuelson elasticities. As can be noted, the impact of an increase in the price of imports from LDCs on the wage rate of unskilled labor, as reflected by $\varepsilon_{U,D}$, often exhibits sign reversals. Where averages are provided, they are positive, with values ranging from 0.014 to 0.068. Such (absolute value) orders of magnitude, which characterise this elasticity across all annual observations, models and econometric implementations, are rather small. Hence, similarly to the findings of Sachs and Shatz (1994, 1996) as well as Krugman (1995, 1997), our results suggest that imports from developing countries only generate, in the worst case scenario, a small adverse effect on unskilled labor wages. Contrary to the case of imports from LDCs our model generates the rather startling result that, at least since 1980, which as indicated by Bhagwati and Dehejia (1994, p. 37) is the beginning of the era in which the wage differential increased most noticeably, imports from ICs stimulate the demand for unskilled labor! Specifically, an exogenous 1% decrease in the price of imports from ICs, due to say, an origin-specific but uniform across product categories tariff reduction, would increase unskilled labor wages by an amount between -0.350 and -0.063; and -0.140 and -0.057, in the case of skill definitions "a" and "b", respectively. While there is substantial variation in the values assumed by these elasticities, particularly across time, but also across the adopted definition for skill, they invariably suggest that the positive stimulus that arises from downstream processing of imports from ICs overshadows the associated downward pressure exerted upon the demand for unskilled labor via domestic output substitution, that drives the corresponding import competing domestic industries to contract. This result is consistent with the well documented high-skill content of imports from ICs[29] which implies that an increase in such imports is expected to generate a *comparatively* small negative impact on the demand for unskilled labor via the process of domestic output-substitution. Hence, other things equal, this effect is relatively easy to reverse given positive downstream-production induced pressures of some intensity.

A comparison of the relative magnitudes of the Stolper-Samuelson elasticities pertaining to the impact of price changes in imports from LDC and IC on unskilled labor wages discussed above, suggests that since 1980 (1982 for N3SLS-1b): (i)

[28] Exceptions are made in the case of elasticities that exhibit sign-reversal in the case of a single observation over the time period examined.

[29] See Trefler (1993).

$\varepsilon_{U,D} > \varepsilon_{U,I}$ and (ii) $|\varepsilon_{U,D}| < |\varepsilon_{U,I}|$, given (iii) $\varepsilon_{U,I} < 0$, with values ranging from -0.350 to -0.057 and (iv) $\varepsilon_{U,D} >,< 0$ with values ranging from -0.016 to 0.089. Inequalities (i), (ii) and (iii) hold with remarkable consistency across all relevant annual observations, models and econometric implementations and provide valuable insight into the relationship between trade and the prevailing wage differential. According to (i), imports from LDCs are more (less) likely to substitute (complement) unskilled labor than imports from ICs. The qualitative bearing of this finding is a rather common result across studies in this area, and particularly those that employ input-output frameworks, such as Sachs and Shatz (1994) and Wood (1995). However, unlike similar studies in the wage dispersion literature, we do not impose a priori restriction on Stolper-Samuelson elasticities to be positive. This renders comparisons of the absolute values of these elasticities, such as (ii), policy relevant. Given (iii) and (iv), inequality (ii) suggests that a reduction in the price of imports from ICs will increase the wage rate of unskilled labor by a larger amount than a similar reduction in the price of imports from LDCs has the potential to decrease it. Taking this analysis a step further one may be inclined to assert that a tariff reduction of identical magnitudes in imports from both ICs and LDCs may very well generate a net positive impact on unskilled wages. While the inferred result of such exogenous policy changes is consistent with our findings, it does not necessarily follow. The notional addition of the relevant elasticities, implicit in such considerations, is not, strictly speaking, meaningful as elasticities derived in partial equilibrium frameworks rely on *other things being equal.* However, the general validity of such conjectures aside, our results clearly suggest that uniform trade liberalisation schemes are not likely to play an important role in reducing unskilled labor wages.

Examination of the elasticities pertaining to skilled labor reveals that the impact of imports from LDCs is rather small, never exceeding 0.082 (in absolute value), and is often subject to sign reversals. However, in the case of imports from ICs the relevant elasticity, given by $\varepsilon_{S,I}$, exhibits sign reversal in the case of only one of the six implementations. In the majority of the remaining cases $\varepsilon_{S,I}$ is statistically significant with average values that range from –0.138 to –0.045. Even in the case of implementation AN3SLS-1b, in which this elasticity assumes positive values in pre-1980 observations, it converges by 1980 to –0.030, and by 1991 to –0.104 which is virtually identical to corresponding values found in various implementations of both models. Once again, the positive stimuli that imports have the potential to induce upon the demand for labour seem to outweigh the "displacement" effect. Our results pertaining to the impact of imports on skilled labor wages may appear to be compatible with Wood (1995) who finds that an increase in *net* imports has a small positive effect on the demand for skilled labor. However, there is little in common between the mechanisms at play that are examined by the two studies. In Wood's model the stimulus on the demand for skilled labor that is identified is induced by an increase in skill intensive exports rather than any downstream processing of imports[30].

Virtually all studies that endorse the notion that imports can account for much of the wage differential only consider their output substitution quality. This implies that any effect that increased imports may have on wage dispersion would be driven by *decreasing* the demand for unskilled labor by a larger amount than any

[30] Input-output models, such as those employed by Sachs and Shatz (1994) and Wood (1995), subtract exports from imports to determine *net imports*. In addition, these models only consider the output-displacement effect of imports and do not allow for labor demand inducing downstream processes. Hence, an increase in net imports which is found to *cause* an increase in the demand for skilled labor is likely to reflect a relatively large increase in low skill imports and a relatively small increase in high skill exports. As a result the increase in the demand for skilled labour that is identified is not related with any downstream processing of imports.

corresponding *decrease* in the demand for skilled workers. The results of this study that have been examined so far do not seem to argue in favour of such a mechanism as an explanation of the trend in wage dispersion. However, in addition to output substitution, our model also accounts for the role of imports in downstream production which, if sufficiently complementary with domestic factors, may stimulate demand for labor. Hence, imports may still be found responsible for the trend in wage dispersion if they generate a substantial (and disproportional) *increase* in the demand for skilled labor. Along these lines we now turn our attention to the *relative* magnitudes of corresponding Stolper-Samuelson elasticities across the two labor classifications employed in each of the two models.

While not much consistency can be established in the relationship between $\varepsilon_{U,I}$ and $\varepsilon_{S,I}$, we note that by 1980 the relative values of elasticities $\varepsilon_{U,D}$ and $\varepsilon_{S,D}$ assume congruity across the majority of the econometric implementations. Specifically, in the case of all implementations of model-1b, and two of the three implementations of model-1a, we find that by 1980 $\varepsilon_{U,D} > \varepsilon_{S,D}$. This relationship suggests that a decrease in the price of imports from LDCs augments wage dispersion. The trend in the average price of imports from LDCs, which dropped by a staggering 19.93% from 1980 to 1991, seems to provide additional circumstantial support to the notion that imports from LDCs are a relevant cause of the observed wage dispersion. However, the average values of $\varepsilon_{U,D}$ and $\varepsilon_{S,D}$ over the period 1980-1991 are relatively small, assuming values 0.022 and –0.012, respectively. This implies that a 20% decrease in the relevant price, similar to that observed over the period examined, would decrease unskilled labor wages by roughly 0.44% and increase skilled labor wages by about

0.24%[31]. Hence, in accordance with the popular view, decreases in the price of imports from LDCs are found to facilitate augmentation of the wage dispersion. However, given the small size of the relevant elasticities, the role of LDC imports in the prevailing wage differential is of virtually no consequence[32].

Finally, we examine the elasticities $\varepsilon_{ji} = \partial \ln w_j / \partial \ln p_Y$. Given the "partial" dimension of such elasticities, the change in the price of output Y cannot account for simultaneous changes in the price of the importable, which is implicitly held constant. Hence, these elasticities represent the impact of a change in the terms of trade on wages. As can be seen, the average values of nearly all relevant elasticities given by $\varepsilon_{U,Y}$, $\varepsilon_{S,Y}$ and $\varepsilon_{K,Y}$ are statistically significant at the 1% level with average values that range from 0.961 to 1.097. While all relevant elasticities assume for the most part roughly similar values, there does not appear to be much consistency in terms of their relative magnitudes beyond the fact that by 1991 $\varepsilon_{U,Y} > \varepsilon_{S,Y}$ in the case of model 1a whereas $\varepsilon_{U,Y} < \varepsilon_{S,Y}$ in the case of model 1b. Hence, relative terms-of-trade distributional effects are rather sensitive to the definition of skill adopted but do not exhibit a level of consistency across time, or substantial size differences that could be meaningfully employed to explain the trend in the prevailing wage differential.

Bhagwati and Dehejia (1994) have recently argued that, rather than trade, the observed trend in wage dispersion 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). In this vein Bhagwati and Dehejia (1994) point out

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[31] Given the partial nature of the estimated elasticities such comparative statics should be interpreted with care.

[32] As can be seen in table VI, the pattern of the relative impact of imports of different origin on skilled and unskilled labor demand also prevails in the medium to long run. The method used to derive the relevant indirect elasticities is outlined in Appendix 3.

the lack of empirical investigations (see p. 55) of the *economy-wide* impact of such factors on the wage differential using an "aggregate production function approach" (p. 53). While the role of capital accumulation in wage dispersion has been largely ignored by recent empirical studies in this area[33], technical change has been extensively examined in the relevant context by a number of authors, including Berman *et al.* (1994) and Bound and Johnson (1992). However, the models employed by these studies are defined strictly within *industry level* confines and, as such, they are not useful in evaluating the aggregate dimension of this process. Contrary to the mainstream approach in the empirical study of wage dispersion, the model that we employ in this paper relies on an aggregate-production-function framework of analysis. We are therefore able to shed light on the *economy-wide* role of capital accumulation and technical change in wage dispersion discussed by Bhagwati and Dehejia (1994).

The impact of technical change on wages, made possible by the passage of time, is captured in our model by the semi-elasticities $\varepsilon_{U,t}$ and $\varepsilon_{S,t}$. As can be seen, in half of the estimated models $\varepsilon_{U,t}$ exhibits sign reversals, implying that technical change may occasionally be correlated with a decrease in the wage of the unskilled, whereas $\varepsilon_{S,t}$ is invariably positive and without exception statistically significant at the 1-2% level. The results of all six implementations suggest that by 1991 $\varepsilon_{S,t} > \varepsilon_{U,t}$, with all but implementation AN3SLS-1a converging to this relationship as early as 1980. This finding, which is quantitatively more pronounced in the case of the semi-elasticities affiliated with the labor skill index of model 1b, suggests that technological advancements are more (less) likely to substitute (complement) demand for unskilled rather than skilled labor. Given that $\varepsilon_{S,t}$ is, on average, about three times as large as

[33] For a review of pre-1980s relevant literature see Hamermesh and Grant (1979).

$\varepsilon_{U,t}$, and given that the two elasticities assume reasonably large values, with the former ranging, in the relevant implementations, from 0.133 to 0.324, and the latter from −0.128 to 0.190, respectively, technical change is likely to be an important contributor to the prevailing trend in wage dispersion. This result is consistent with the findings of studies that examine this issue at the micro level such as Berman *et al.* (1994) and Bound and Johnson (1992). According to the majority of these studies the lion's share of the expanding wage differential is attributed to skill complementing "innovative computer-aided technologies" that have been increasingly employed over the last two decades[34].

Examination of the capital-labor elasticities in the two models reveals an interesting pattern. In model 1a capital accumulation is found to increase the wage rate of the skilled relative to that of the unskilled. This observation holds in the case of all annual observations and across all estimation methods with remarkable consistency, and with five out of the six relevant elasticities reported exhibiting statistical significance at the 1-2% levels. The average values assumed by $\varepsilon_{U,K}$ and $\varepsilon_{S,K}$ are large, ranging from −0.123 to 0.282, and from 0.256 to 0.603, respectively. An examination of the corresponding average values assumed by these elasticities in the case of model 1b is not useful as in the majority of econometric implementations $\varepsilon_{S,K}$ exhibits sign reversals. However, it is worth noting that, contrary to our findings in the case of model 1a, in the case of model 1b $\varepsilon_{U,K} > \varepsilon_{S,K}$ across all annual observations and estimation methods. An intuitive interpretation of the orthogonal

[34] Care should be exercised when comparing our results with those of previous studies as the latter have focused primarily on the "within-industries" effects, whereas, given the construction of our data, our estimates are likely to reflect the "between-industries" effects. See Berman *et al.* (1994) for a relevant discussion.

pattern assumed by the two pairs of elasticities across the two models is not readily evident. It is, however, useful to note that the results of model 1a, which as compared to the corresponding estimates of model 1b, are substantially more statistically robust, are not subject to curvature violation corrections, and do not exhibit sign reversals, are consistent with the findings of Schwartzman (1996, p. 84), and the conclusions of Hamermesh and Grant (1979) who review the relevant econometric literature.

Out of the four sets of elasticities, pertaining to the impact of technology and capital accumulation on the wage differential that prevailed in the later part of the time period examined, only the partially statistically robust capital-labor related estimates of model 1b contradict the notion that such aggregate-production-function specific processes may facilitate wage dispersion. The remaining three sets of results suggest that such processes are likely to play an important role in the declining relative wages of the unskilled. Hence, our results may be viewed as providing support to the notion that, instead of imports, it is "the aggregate production function *that represents unskilled labor's* ultimate threat"[35], to borrow a phrase from Bhagwati and Dehejia (1994, p. 69).

V. Concluding Remarks

Studies of the impact of imports on wages have consistently ignored their function in inducing positive effects if subject to sufficiently labor intensive downstream processes. In addition, they have invariably limited their investigations to samples of manufacturing industries, rather than the economy as a whole, and ignored the relevance of *economy-wide* dynamic processes such as technical change and capital accumulation. The production theory approach that is employed in this paper corrects for these shortcomings. The sensitivity of our results is tested in various ways

[35] Italics added for clarity.

by investigating matters of time-specificity of the estimated elasticities, in conjunction with issues of serial correlation and endogeneity of right-hand-side variables in the context of alternative skill definitions. Remarkably, some of our most important results are invariant across time, definition of skill and estimation method.

The most novel contribution of our findings is that decreases in import prices are often found to improve wages. In the case of imports that originate in LDCs this effect surfaces disproportionately in relation to skilled labor, and provides a secondary, previously unchartered, channel through which such imports may drive wage dispersion. Yet, given the size of the relevant elasticities, the impact of such imports on the relevant wage differential is too small to be taken seriously, let alone viewed as policy pertinent. Economy-wide specific processes of capital accumulation and technical change appear to play a far more important role in wage dispersion. These results may inform the relevant ongoing debate directly, but we feel that they are most useful in introducing a new framework of analysis of the imports – wage inequality nexus with policy relevant implications.

APPENDIX 1 - Tornqvist Chain Price Index

The Tornqvist chain price index, normalised for 1987, is given by

$p'_T = e^{\sum_{t=1}^{T}\sum_{n=1}^{N}\frac{1}{2}(s_{n,t}+s_{n,t-1})\cdot\ln(p_{n,t}/p_{n,t-1})} \Big/ p_{1987}$ where $s_{n,t} = p_{n,t}\cdot q_{n,t} \Big/ \left(\sum_{n=1}^{N} p_{n,t}\cdot q_{n,t}\right)$ and N identifies the components to be aggregated at time t with associated quantities $q_{n,t}$ and prices $p_{n,t}$. The related implicit normalised quantity index, denoted by q'_T, is obtained by $q'_T = \left(\sum_{n=1}^{N} p_{n,t}\cdot q_{n,t}\right) \Big/ p'_T$.

APPENDIX 2 – Proof of Proposition 1

In section III we argued that a modified Wiley *et al.* (1973) technique which preserves linear homogeneity requires that a sufficient condition for an arbitrary square matrix of order M to be negative semidefinite is that its leading principal minor of order $M-1$ is also negative semidefinite. To prove this proposition let **F** be any

$n \times n$ symmetric matrix, and **G** be the $(n+1)\times(n+1)$ symmetric matrix whose leading principal minor of order n is **F**, and whose rows and columns each sum to zero. In addition, let **u** be the $n \times 1$ vector of 1's.

Hence:

(A1) $$\mathbf{G} = \begin{bmatrix} \mathbf{F} & -\mathbf{F}\cdot\mathbf{u} \\ -\mathbf{u}'\cdot\mathbf{F} & \mathbf{u}'\cdot\mathbf{F}\cdot\mathbf{u} \end{bmatrix}$$

Let $\mathbf{f} \equiv [r_1, r_2, \ldots, r_n, \nu]'$, $\mathbf{g} \equiv [r_1, r_2, \ldots, r_n]'$ and $\mathbf{h} \equiv [r_1, r_2, \ldots, r_n, 0]'$. Then,

(A2) $$\mathbf{f}'\cdot\mathbf{G}\cdot\mathbf{f} = (\mathbf{g}' - \nu\cdot\mathbf{u}')\cdot\mathbf{F}\cdot(\mathbf{g} - \nu\cdot\mathbf{u}) \text{ and}$$

(A3) $$\mathbf{g}'\cdot\mathbf{F}\cdot\mathbf{g} = \mathbf{h}'\cdot\mathbf{G}\cdot\mathbf{h}$$

Thus, **F** is negative (positive) semidefinite if and only if **G** is negative (positive) semidefinite. Alternatively, this result implies that a sufficient condition for **G** to be negative (positive) semidefinite is that **F** is negative (positive) semidefinite.

APPENDIX 3 – Derivation of Indirect Medium-run Elasticities

In the medium to long run it may be reasonable to expect labor input to be variable. As shown by Appelbaum and Kohli (1997, p. 622-3), in the case of an expected utility maximisation framework, the medium-run elasticities can be derived from their corresponding short-run values in a fairly straightforward manner.

In the case of our model, the comparative statics are outlined below

(A4) $$\begin{bmatrix} \hat{y}_Y \\ \hat{y}_D \\ \hat{y}_I \\ \hat{w}_K \\ \hat{w}_U \\ \hat{w}_S \end{bmatrix} = \begin{bmatrix} \varepsilon_{Y,Y} & \varepsilon_{Y,D} & \varepsilon_{Y,I} & \varepsilon_{Y,K} & \varepsilon_{Y,U} & \varepsilon_{Y,S} \\ \varepsilon_{D,Y} & \varepsilon_{D,D} & \varepsilon_{D,I} & \varepsilon_{D,K} & \varepsilon_{D,U} & \varepsilon_{D,S} \\ \varepsilon_{I,Y} & \varepsilon_{I,D} & \varepsilon_{I,I} & \varepsilon_{I,K} & \varepsilon_{I,U} & \varepsilon_{I,S} \\ \varepsilon_{K,Y} & \varepsilon_{K,D} & \varepsilon_{K,I} & \varepsilon_{K,K} & \varepsilon_{K,U} & \varepsilon_{K,S} \\ \varepsilon_{U,Y} & \varepsilon_{U,D} & \varepsilon_{U,I} & \varepsilon_{U,K} & \varepsilon_{U,U} & \varepsilon_{U,S} \\ \varepsilon_{S,Y} & \varepsilon_{S,D} & \varepsilon_{S,I} & \varepsilon_{S,K} & \varepsilon_{S,U} & \varepsilon_{S,S} \end{bmatrix} \cdot \begin{bmatrix} \hat{p}_Y \\ \hat{p}_D \\ \hat{p}_I \\ \hat{x}_K \\ \hat{x}_U \\ \hat{x}_S \end{bmatrix}$$

As a first step, in deriving indirect medium-run elasticities, we isolate labor by the following partition of equation (A4):

(A5) $$\begin{bmatrix} \hat{\vartheta}_1 \\ \hat{\vartheta}_2 \end{bmatrix} = \begin{bmatrix} \mathbf{E}_{1,1} & \mathbf{E}_{1,2} \\ \mathbf{E}_{2,1} & \mathbf{E}_{2,2} \end{bmatrix} \cdot \begin{bmatrix} \hat{\mathbf{v}}_1 \\ \hat{\mathbf{v}}_2 \end{bmatrix}$$

where $\hat{\vartheta}_1 \equiv [\hat{y}_Y, \hat{y}_D, \hat{y}_I, \hat{y}_K]'$, $\hat{\vartheta}_2 \equiv [\hat{w}_U, \hat{w}_S]'$, $\hat{\mathbf{v}}_1 \equiv [\hat{p}_Y, \hat{p}_D, \hat{p}_I, \hat{x}_K]'$, $\hat{\mathbf{v}}_2 \equiv [\hat{x}_U, \hat{x}_S]'$,

$$\mathbf{E}_{1,1} \equiv \begin{bmatrix} \varepsilon_{Y,Y} & \varepsilon_{Y,D} & \varepsilon_{Y,I} & \varepsilon_{Y,K} \\ \varepsilon_{D,Y} & \varepsilon_{D,D} & \varepsilon_{D,I} & \varepsilon_{D,K} \\ \varepsilon_{I,Y} & \varepsilon_{I,D} & \varepsilon_{I,I} & \varepsilon_{I,K} \\ \varepsilon_{K,Y} & \varepsilon_{K,D} & \varepsilon_{K,I} & \varepsilon_{K,K} \end{bmatrix}, \mathbf{E}_{1,2} \equiv \begin{bmatrix} \varepsilon_{Y,U} & \varepsilon_{Y,S} \\ \varepsilon_{D,U} & \varepsilon_{D,S} \\ \varepsilon_{I,U} & \varepsilon_{I,S} \\ \varepsilon_{K,U} & \varepsilon_{K,S} \end{bmatrix}, \mathbf{E}_{2,2} \equiv \begin{bmatrix} \varepsilon_{U,U} & \varepsilon_{U,S} \\ \varepsilon_{S,U} & \varepsilon_{S,S} \end{bmatrix} \text{ and}$$

$$\mathbf{E}_{2,1} \equiv \begin{bmatrix} \varepsilon_{U,Y} & \varepsilon_{U,D} & \varepsilon_{U,I} & \varepsilon_{U,K} \\ \varepsilon_{S,Y} & \varepsilon_{S,D} & \varepsilon_{S,I} & \varepsilon_{S,K} \end{bmatrix}.$$

Solving (A5) for $\hat{\vartheta}_1$ and $\hat{\mathbf{v}}_2$ gives:

(A6)
$$\begin{bmatrix} \hat{\vartheta}_1 \\ \hat{\mathbf{v}}_2 \end{bmatrix} = \left[\begin{array}{c:c} \mathbf{E}_{1,1} - \mathbf{E}_{1,2} \cdot \mathbf{E}_{2,2}^{-1} \cdot \mathbf{E}_{2,1} & \mathbf{E}_{1,2} \cdot \mathbf{E}_{2,2}^{-1} \\ \hdashline -\mathbf{E}_{2,2}^{-1} \cdot \mathbf{E}_{2,1} & \mathbf{E}_{2,2}^{-1} \end{array}\right] \cdot \begin{bmatrix} \hat{\mathbf{v}}_1 \\ \hat{\vartheta}_2 \end{bmatrix}$$

Hence, the medium run elasticities are given by $\Psi \equiv [\psi_{i,j}]$ where

(A7)
$$\left[\begin{array}{cccc:cc} \psi_{Y,Y} & \psi_{Y,D} & \psi_{Y,I} & \psi_{Y,K} & \psi_{Y,U} & \psi_{Y,S} \\ \psi_{D,Y} & \psi_{D,D} & \psi_{D,I} & \psi_{D,K} & \psi_{D,U} & \psi_{D,S} \\ \psi_{I,Y} & \psi_{I,D} & \psi_{I,I} & \psi_{I,K} & \psi_{I,U} & \psi_{I,S} \\ \psi_{K,Y} & \psi_{K,D} & \psi_{K,I} & \psi_{K,K} & \psi_{K,U} & \psi_{K,S} \\ \hdashline \psi_{U,Y} & \psi_{U,D} & \psi_{U,I} & \psi_{U,K} & \psi_{U,U} & \psi_{U,S} \\ \psi_{S,Y} & \psi_{S,D} & \psi_{S,I} & \psi_{S,K} & \psi_{S,U} & \psi_{S,S} \end{array}\right] = \left[\begin{array}{c:c} \mathbf{E}_{1,1} - \mathbf{E}_{1,2} \cdot \mathbf{E}_{2,2}^{-1} \cdot \mathbf{E}_{2,1} & \mathbf{E}_{1,2} \cdot \mathbf{E}_{2,2}^{-1} \\ \hdashline -\mathbf{E}_{2,2}^{-1} \cdot \mathbf{E}_{2,1} & \mathbf{E}_{2,2}^{-1} \end{array}\right]$$

Given that the method employed to derive medium run elasticities entails a conceptual "switch" between endogenous and exogenous variables, its accuracy depends critically on a comprehensive correction of right-hand-side endogeneity and the absence of curvature violations. In view of that we employ the results of the elasticities derived from model N3SLS-1a (which is not subject to curvature corrections and which provides the most explicit correction for endogeneity) for the year 1985 (when the increase in the wage differential appears to have accelerated). Similar results are derived in the case of elasticities associated with other years and methods of estimation.

Bibliography

Adams, James D. "The Structure of Firm R&D, the Factor Intensity of Production, and Skill Bias." *The Review of Economics and Statistics*, August 1999, 499-510.

Appelbaum, Elie, and Ulrich Kohli. "Import Price Uncertainty and the Distribution of Income." *Review of Economics and Statistics*, November 1997, 620-30.

Aw, Bee Yan, and Mark J. Roberts. "The Role of Imports from the Newly-industrializing Countries in U.S. Production." *Review of Economics and Statistics*, February 1985, 108-17.

Berman, Eli, John Bound, and Zvi Griliches. "Changes in the Demand for Skilled Labor within U.S. Manufacturing: Evidence from the Annual Survey of Manufactures." *Quarterly Journal of Economics,* May 1994, 367-97.

Berndt, E. R. *The Practice of Econometrics: Classic and Contemporary.* Reading, MA: Addison-Wesley, 1991.

Bhagwati, Jagdish, and Vivek Dehejia. "Freer Trade and Wages of the Unskilled - Is Marx Striking Again?" In *Trade and Wages: Leveling Wages Down?*, edited by Jagdish Bhagwati and Marvin H. Kosters, 36-71. Washington DC: American Enterprise Institute, 1994.

Borjas, George J., and Valerie A. Ramey. "Time-Series Evidence on the Sources of Trends in Wage Inequality." *American Economic Review,* May 1994, 10-16.

Bound, John, and George Johnson. "Changes in the Structure of Wages in the 1980's: An Evaluation of Alternative Explanations." *American Economic Review,* June 1992, 371-92.

Burgess, David F. "Production Theory and the Derived Demand for Imports." *Journal of International Economics* 1974, 103-18.

__________. "Tariffs and Income Distribution: Some Empirical Evidence for the United States." *Journal of Political Economy* 1976, 17-43.

Burtless, Gary. "International Trade and the Rise in Earnings Inequality." *Journal of Economic Literature,* June 1995, 800-816.

Diewert, Walter Erwin. "Applications of Duality Theory." In *Frontiers of Quantitative Economics,* edited by Michael D. Intriligator and David A. Kendrick, 106-206. Amsterdam: North-Holland, 1974.

Diewert, Walter Erwin, and Terence J. Wales. "Flexible Functional Forms and Global Curvature Conditions." *Econometrica,* January 1987, 43-68.

__________. "Quadratic Spline Models for Producer's Supply and Demand Functions." *International Economic Review,* August 1992, 705-22.

Gorman, W. M. "Measuring the Quantities of Fixed Factors." In *Value, Capital and Growth: Papers in Honour of Sir John Hicks,* edited by J. N. Wolfe. Chicago: Aldine, 1968.

Goss, Barry A. "The Forecasting Approach to Efficiency in the Wool Market." *Applied Economics,* July 1990, 973-93.

Hamermesh, Daniel S., and James Grant. "Econometric Studies of Labor-Labor Substitution and their Implications for Policy." *Journal of Human Resources,* Fall 1979, 518-42.

Hotelling, H. "Edgeworth's Taxation Paradox and the Nature of Demand and Supply Functions." *Journal of Political Economy* 1932, 577-616.

International-Monetary-Fund. *Direction of Trade: A Supplement to International Financial Statistics (Yearbook)*, various annual issues.

__________. *International Financial Statistics: A Supplement to Trade Statistics*, various annual issues.

__________. *International Financial Statistics: Yearbook*, various annual issues.

__________. *International Financial Statistics*, various monthly issues.

Kohli, Ulrich. *Technology, duality, and foreign trade: The GNP function approach to modeling imports and exports, Studies in International Trade Policy*. Ann Arbor: University of Michigan Press, 1991.

__________. "A Symmetric Normalized Quadratic GNP Function and the U.S. Demand for Imports and Supply of Exports." *International Economic Review*, February 1993, 243-55.

__________. "Canadian Imports and Exports by Origin and Destination: A Semi-flexible Approach." *Canadian Journal of Economics*, August 1994, 580-603.

__________. "Stolper-Samuelson-Like and Rybczynski-Like Results in 2 x 2 Production Models." *Journal of International Trade and Economic Development*, March 1995, 63-79.

Krugman, Paul R. "Growing World Trade: Causes and Consequences." *Brookings Papers on Economic Activity* 1995, 327-62.

__________. "Trade and Wages." In *Advances in economics and econometrics: Theory and applications*, edited by David M. Kreps and Kenneth F. Wallis, 1-18. Cambridge; New York and Melbourne: Cambridge University Press, 1997.

Lawrence, Robert Z., and Matthew J. Slaughter. "International Trade and American Wages in the 1980s: Giant Sucking Sound or Small Hiccup?" *Brookings Papers on Economic Activity, Microeconomics* 1993, 161-210.

Ray, Edward John. "The Determinants of Tariff and Non-Tariff Trade Restrictions in the United States." *Journal of Political Economy* 1981, 105-21.

Richardson, J. David. "Income Inequality and Trade: How to Think, What to Conclude." *Journal of Economic Perspectives*, Summer 1995, 33-55.

Sachs, Jeffrey D., and Howard J. Shatz. "Trade and Jobs in U.S. Manufacturing." *Brookings Papers on Economic Activity* 1994, 1-69.

__________. "U.S. Trade with Developing Countries and Wage Inequality." *American Economic Review*, May 1996, 234-39.

Samuelson, Paul A. "Prices of Factors and Goods in General Equilibrium." *Review of Economic Studies* 1953-54, 1-20.

Schwartzman, David. "Unemployment, Capital and Unskilled Labor." In *Global Unemployment: Loss of Jobs in the '90s*, edited by John Eatwell, 79-85. Armonk and London: M. E. Sharpe, 1996.

Stolper, W. F., and P. A. Samuelson. "Protection and Real Wages." *Review of Economic Studies* 1941, 58-73.

Tombazos, Christis G. "US Production Technology and the Effects of Imports on the Demand for Primary Factors." *Review of Economics and Statistics*, August 1998, 480-483.

__________. "The Role of Imports in Expanding the Demand Gap Between Skilled and Unskilled Labour in the U.S." *Applied Economics*, April 1999a, 509-517.

__________. "The Impact of Imports on the Demand for Labour in Australia." *Economics Letters*, March 1999b, 351-356.

Trefler, Daniel. "International Factor Price Differences: Leontief was Right!" *Journal of Political Economy* 1993, 961-87.

United States Department of Commerce, Bureau of Economic Analysis. *The National Income and Product Accounts of the United States - Statistical Tables*. Washington D.C.: US Government Printing Office, various annual issues.

__________. *Survey of Current Business*. Washington D.C.: US Government Printing Office, various monthly issues.

United States Department of Commerce, Bureau of the Census. *Census of Population 1970, Subject Reports: Occupations by Industry*. Washington D.C.: US Government Printing Office, 1973.

White, Kenneth J. "The Durbin-Watson Test for Autocorrelation in Nonlinear Models." *Review of Economics and Statistics* 1992, 370-73.

Wiley, D. E., W. H. Schmidt and W. J. Bramble. "Studies of a Class of Covariance Structure Models." *Journal of the American Statistical Association* 1973, 317-23.

Wood, Adrian. "How Trade Hurt Unskilled Workers." *Journal of Economic Perspectives*, Summer 1995, 57-80.

Wood, Adrian. "Globalisation and the Rise in Labour Market Inequalities." *Economic Journal*, September 1998, 1463-82.

FIGURE 1
Wage Dispersion Between Skilled and Unskilled Labor

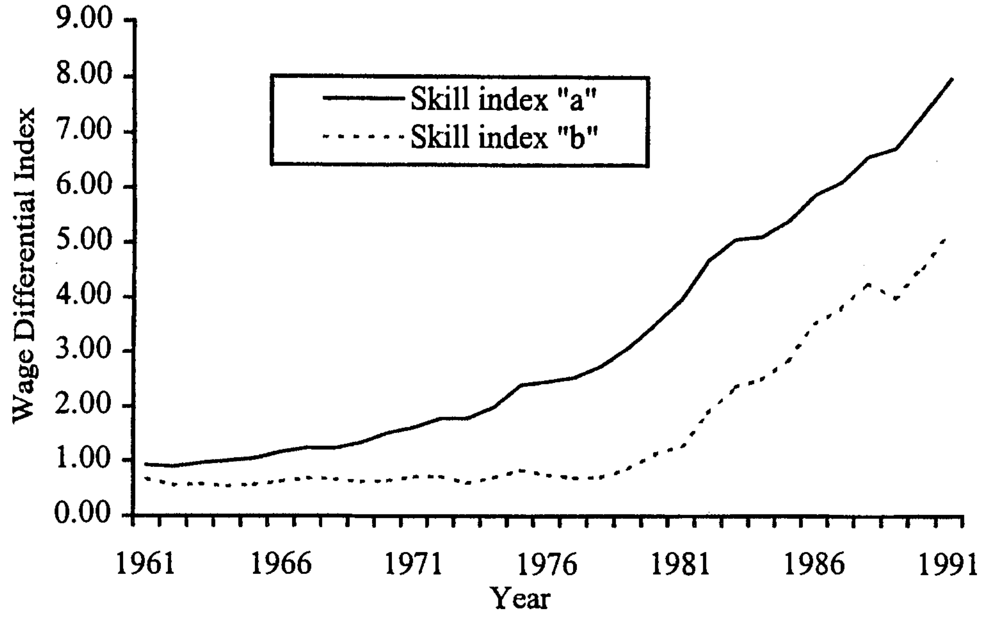

TABLE I
Eigenvalues of Matrices **A** and **B** of Estimated Symmetric Normalised Quadratic Variable Profit Function

Model	Eigenvalues (Cholesky Values) **Matrix A**	**Matrix B**
ANSUR-1a	0.404, 0.007, 0.000	-0.496, -0.028, 0.000
N3SLS-1a	0.380, 0.000, 4.000	-0.770, 0.000, -5.551
AN3SLS-1a	0.386, 0.033, 0.000	-0.335, -0.002, 0.000
ANSUR-1b‡	0.352, 0.005, 5.204 (0.350, 0.005, 0.000)	-0.150, 0.018, 0.000 (-0.159, 0.000, 0.000)
N3SLS-1b	0.365, 0.028, 0.000	-0.635, -0.096, 0.000
AN3SLS-1b‡	0.270, -0.083, 0.000 (0.365, 0.065, 0.000)	-0.516, 0.044, 0.000 (-0.358, 0.000, 0.000)

Notes: ‡ Model violating one or both curvature conditions. 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 II

Estimated Parameters of the Symmetric Normalised Quadratic Variable Profit Function of Model 1a

Parameter	ANSUR		N3SLS		AN3SLS	
	Econometric Implementation					
$a_{Y,D}$	0.0065936*	(2.920)	-0.069285*	(-3.477)	-0.028366	(-1.514)
$a_{Y,I}$	-0.20025*	(-7.085)	-0.16974*	(-4.611)	-0.18579*	(-3.887)
$a_{D,I}$	-0.11546*	(-4.082)	0.43481****	(1.856)	0.0049339	(0.218)
$b_{U,S}$	0.14185*	(5.785)	0.10980	(0.953)	0.050277	(1.039)
$b_{U,K}$	-0.066527*	(-2.952)	0.18085*	(2.644)	-0.037034	(-0.801)
$b_{S,K}$	0.18682*	(5.038)	0.30614*	(4.772)	0.15509*	(2.679)
$c_{Y,U}$	0.41548*	(5.719)	0.54840*	(7.156)	0.54165*	(4.510)
$c_{Y,S}$	0.85721*	(9.801)	0.81505*	(8.687)	0.84982*	(6.441)
$c_{Y,K}$	1.1460*	(14.835)	1.0887*	(16.172)	1.0532*	(9.717)
$c_{D,U}$	0.014354	(0.581)	0.019567	(0.210)	-0.039567	(-0.554)
$c_{D,S}$	-0.024230	(-1.095)	-0.027374	(-0.232)	0.11703	(1.292)
$c_{D,K}$	0.0068098	(0.627)	0.047538	(0.568)	-0.070731	(-0.955)
$c_{I,U}$	0.38164*	(6.062)	0.055588	(0.403)	0.32565**	(2.428)
$c_{I,S}$	-0.033999	(-0.390)	-0.045514	(-0.229)	-0.19316	(-1.082)
$c_{I,K}$	-0.12392****	(-1.693)	0.034431	(0.286)	0.013812	(0.101)
$\delta_{Y,U}$	0.82111*	(8.849)	0.43329*	(3.892)	0.62378*	(3.704)
$\delta_{Y,S}$	0.29700*	(2.782)	0.16667	(1.389)	0.25406	(1.511)
$\delta_{Y,K}$	-0.20795***	(-2.309)	0.025509	(0.281)	-0.081145	(-0.615)
$\delta_{D,U}$	-0.017411	(-0.579)	-0.12866	(-1.088)	0.040805	(0.457)
$\delta_{D,S}$	0.035553	(1.282)	-0.036068	(-0.239)	-0.18613****	(-1.661)
$\delta_{D,K}$	-0.012011	(-0.668)	0.0049617	(0.051)	0.097097	(0.985)
$\delta_{I,U}$	-0.64535*	(-8.502)	-0.38041*	(-2.918)	-0.51921*	(-3.458)
$\delta_{I,S}$	-0.10479	(-1.014)	-0.068389	(-0.358)	0.10242	(0.523)
$\delta_{I,K}$	0.18890***	(2.165)	0.0038924	(0.032)	-0.022868	(-0.147)
ξ_{tt}	-0.083275	(-1.116)	0.43106*	(3.080)	0.11316	(0.471)
DOF	150		150		150	
$\tilde{R}^2$	0.9999925		0.9999811		0.9997600	
MV	Id-I obs: 1962-63		Id-D obs: 1962-65		Id-I, Id-D obs: 1962	
W	0.980		-		-	

Notes: t statistics in parentheses. One, two, three and four asterisks denote significance at the 1%, 2%, 5% and 10% levels with a two-tailed test, respectively. Id-D and Id-I represent the inverse demand functions for imports from LDCs and ICs, respectively.

TABLE III

Estimated Parameters of the Symmetric Normalised Quadratic Variable Profit Function of Model 1b

Parameter	ANSUR		N3SLS		AN3SLS	
	Econometric Implementation					
$a_{Y,Y}$	0.16843*	(6.373)			0.20539*	(4.632)
$a_{Y,D}$	0.0053367***	(1.764)	-0.072709*	(-3.987)	-0.034667	(-1.576)
$a_{Y,I}$			-0.15913*	(-4.538)		
$a_{D,D}$	0.0035980***	(2.013)			0.044241***	(2.101)
$a_{D,I}$			0.034955	(1.585)		
$z_{1,1}$	0.30012*	(3.129)			0.44451*	(8.783)
$z_{2,1}$	-0.040755	(-0.776)			-0.047443	(-0.809)
$z_{2,2}$	-0.71859×10^{-7}	(-0.000)			0.30965×10^{-6}	(0.000)
$b_{U,S}$			-0.052901	(-0.633)		
$b_{U,K}$			0.24562*	(3.783)		
$b_{S,K}$			0.17277***	(1.964)		
$c_{Y,U}$	0.80996*	(11.353)	0.69585*	(12.599)	0.88249*	(8.903)
$c_{Y,S}$	0.77358*	(6.608)	0.70867*	(7.795)	0.62161*	(5.120)
$c_{Y,K}$	1.0165*	(12.075)	1.1257*	(20.148)	1.0560*	(11.445)
$c_{D,U}$	-0.044113**	(-2.522)	0.049132	(0.810)	0.023353	(0.336)
$c_{D,S}$	0.093667***	(2.157)	0.0019396	(0.015)	0.0055393	(0.052)
$c_{D,K}$	-0.0048688	(-0.332)	-0.0051134	(-0.071)	0.011347	(0.143)
$c_{I,U}$	0.098727	(1.558)	0.023968	(0.314)	0.010633	(0.093)
$c_{I,S}$	-0.15888	(-1.144)	-0.076751	(-0.446)	0.14865	(0.748)
$c_{I,K}$	-0.016623	(-0.204)	0.032010	(0.360)	-0.063779	(-0.512)
$\delta_{Y,U}$	0.22875**	(2.501)	0.25277*	(2.844)	0.11179	(0.818)
$\delta_{Y,S}$	0.36175**	(2.429)	0.33180*	(2.933)	0.50729*	(3.340)
$\delta_{Y,K}$	-0.017374	(-0.181)	-0.044655	(-0.577)	-0.063549	(-0.556)
$\delta_{D,U}$	0.048536***	(2.315)	-0.12936***	(-1.995)	-0.11440	(-1.308)
$\delta_{D,S}$	-0.14976**	(-2.555)	-0.15275	(-1.170)	-0.11127	(-0.893)
$\delta_{D,K}$	0.0045873	(0.174)	0.065813	(0.878)	0.019009	(0.191)
$\delta_{I,U}$	-0.23955*	(-3.114)	-0.23690*	(-3.129)	-0.15311	(-1.242)
$\delta_{I,S}$	0.053175	(0.322)	-0.10173	(-0.568)	-0.25844	(-1.220)
$\delta_{I,K}$	0.017433	(0.175)	0.011507	(0.125)	0.032476	(0.242)
ξ_{tt}	0.14757	(1.576)	0.56363*	(4.347)	0.51912*	(2.114)
DOF	150		150		150	
$\tilde{R}^2$	0.9999974		0.9999952		0.9999509	
MV	-		Id-D obs: 1962-66		Id-D obs: 1962-67	
W	0.774		-		-	

Notes: t statistics in parentheses. One, two, three and four asterisks denote significance at the 1%, 2%, 5% and 10% levels with a two-tailed test, respectively. Id-D represents the inverse demand function for imports from LDCs.

TABLE IV

Selected and Average Elasticities of the Symmetric Normalised Quadratic Variable Profit Function of Model 1a

	ANSUR					N3SLS					AN3SLS				
	1970	1980	1991	Average		1970	1980	1991	Average		1970	1980	1991	Average	
Price elasticities of inverse factor demands (Stolper-Samuelson Elasticities) $\varepsilon_{ji} = \partial \ln w_j / \partial \ln p_i$															
$\varepsilon_{U,Y}$	0.856	1.105	1.353	0.972[a]	(26.524)	0.934	0.989	1.199	0.971[a]	(24.317)	0.911	1.071	1.255	0.974[a]	(20.875)
$\varepsilon_{U,D}$	0.015	0.015	-0.002	0.014†	(1.083)	0.057	0.072	0.030	0.068[d]	(1.758)	-0.029	-0.007	-0.013	†	
$\varepsilon_{U,I}$	0.142	-0.107	-0.350	†		-0.010	-0.096	-0.218	†		0.127	-0.063	-0.260	†	
$\varepsilon_{S,Y}$	1.091	1.176	1.147	1.097[a]	(27.481)	1.026	1.066	1.048	1.014[a]	(21.063)	1.079	1.148	1.124	1.079[a]	(19.902)
$\varepsilon_{S,D}$	0.005	-0.012	-0.016	†		-0.001	-0.045	-0.049	†		-0.016	0.018	0.026	†	
$\varepsilon_{S,I}$	-0.084	-0.148	-0.159	-0.110[a]	(-2.631)	-0.047	-0.046	-0.047	-0.045	(-0.505)	-0.151	-0.126	-0.053	-0.128[d]	(-1.652)
$\varepsilon_{K,Y}$	1.153	1.079	0.904	1.051[a]	(29.307)	1.111	1.110	1.052	1.053[a]	(33.754)	1.100	1.072	0.963	1.028[a]	(23.016)
Quantity elasticities of inverse factor demands $\varepsilon_{jk} = \partial \ln w_j / \partial \ln x_k$															
$\varepsilon_{U,K}$	-0.108	-0.162	-0.117	-0.123[a]	(-3.313)	0.268	0.358	0.238	0.282[b]	(2.243)	-0.044	-0.060	-0.040	-0.047	(-0.574)
$\varepsilon_{S,K}$	0.280	0.430	0.291	0.322[a]	(5.108)	0.519	0.805	0.547	0.603[a]	(5.283)	0.224	0.340	0.228	0.256[b]	(2.536)
Time semi-elasticities of inverse factor demands $\varepsilon_{jt} = \partial \ln w_j / \partial t$															
$\varepsilon_{U,t}$	0.267	-0.016	0.133	0.143[a]†	(5.241)	0.033	-0.128	0.094	†		0.257	0.122	0.190	0.187[a]	(4.443)
$\varepsilon_{S,t}$	0.257	0.232	0.189	0.232[a]	(7.997)	0.138	0.179	0.219	0.155[b]	(2.473)	0.203	0.079	0.212	0.166[a]	(3.645)
$\varepsilon_{K,t}$	-0.068	-0.034	-0.064	-0.052	(-1.017)	0.090	0.202	0.197	0.131[a]	(3.304)	0.004	0.119	0.032	†	

Notes: t-statistics for average elasticities in parentheses. Superscripts "a", "b", "c" and "d" denote significance at the 1%, 2%, 5% and 10% level with a two-tailed test, respectively. "†" Indicates sign reversals.

TABLE V

Selected and Average Elasticities of the Symmetric Normalised Quadratic Variable Profit Function of Model 1b

	ANSUR					N3SLS					AN3SLS				
	1970	1980	1991	Average		1970	1980	1991	Average		1970	1980	1991	Average	
Price elasticities of inverse factor demands (Stolper-Samuelson Elasticities) $\varepsilon_{ji} = \partial \ln w_j / \partial \ln p_i$															
$\varepsilon_{U,Y}$	1.006	1.058	1.095	1.013[a]	(28.131)	0.936	1.005	1.104	0.961[a]	(36.788)	1.054	1.067	1.091	1.041[a]	(25.367)
$\varepsilon_{U,D}$	-0.018	0.024	0.043	†		0.051	0.089	0.027	0.060[b]	(2.555)	0.003	-0.003	-0.016	†	
$\varepsilon_{U,I}$	0.011	-0.066	-0.140	†		-0.020	-0.072	-0.118	†		-0.030	-0.057	-0.073	-0.040[†]	(-0.728)
$\varepsilon_{S,Y}$	1.082	1.194	1.142	1.079[a]	(24.284)	1.053	1.156	1.144	1.053[a]	(24.291)	0.970	1.146	1.184	1.012[a]	(18.349)
$\varepsilon_{S,D}$	-0.029	-0.009	-0.020	†		0.056	0.078	0.010	0.054	(0.793)	-0.019	-0.082	-0.064	†	
$\varepsilon_{S,I}$	-0.152	-0.150	-0.083	-0.138[b]	(-2.519)	-0.072	-0.090	-0.079	-0.075	(-0.956)	0.050	-0.030	-0.104	†	
$\varepsilon_{K,Y}$	1.086	1.089	0.995	1.030[a]	(26.748)	1.128	1.099	1.017	1.053[a]	(42.405)	1.104	1.080	0.988	1.032[a]	(26.087)
Quantity elasticities of inverse factor demands $\varepsilon_{jk} = \partial \ln w_j / \partial \ln x_k$															
$\varepsilon_{U,K}$	0.110	0.158	0.108	0.123	(1.467)	0.390	0.574	0.404	0.444[a]	(4.832)	0.250	0.359	0.247	0.280[a]	(3.668)
$\varepsilon_{S,K}$	-0.006	0.004	0.008	†		0.303	0.470	0.307	0.345[a]	(2.753)	-0.004	0.021	0.026	†	
Time semi-elasticities of inverse factor demands $\varepsilon_{jt} = \partial \ln w_j / \partial t$															
$\varepsilon_{U,t}$	0.090	0.085	0.093	0.082[d]	(1.772)	-0.013	-0.089	0.105	†		-0.078	-0.118	0.045	†	
$\varepsilon_{S,t}$	0.336	0.228	0.310	0.289[a]	(11.499)	0.193	0.133	0.282	0.179[a]	(3.038)	0.279	0.189	0.324	0.243[a]	(6.377)
$\varepsilon_{K,t}$	0.021	0.067	0.060	0.038	(0.742)	0.100	0.307	0.243	0.171[a]	(5.027)	0.046	0.202	0.183	0.105[c†]	(2.038)

Notes: t-statistics for average elasticities in parentheses. Superscripts "a", "b", "c" and "d" denote significance at the 1%, 2%, 5% and 10% level with a two-tailed test, respectively. "†" Indicates sign reversals.

TABLE VI

Indirect Estimates of Medium-run Price Elasticities of Factor Quantities for 1985 derived for Implementation N3SLS-1a

$\psi_{U,D}$	0.3525	$\psi_{S,D}$	-0.1027
$\psi_{U,I}$	-0.6362	$\psi_{S,I}$	-0.0643

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