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Globalization, globalisation: Trade, technology, and wages

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Abstract

I address a complex of globalization issues: the effect of globalization on the skill premium; on unemployment; on the ability of national governments to conduct independent social policies; the relative importance of globalization and exogenous technical change. A large empirical literature concludes that trade has played a relatively minor role, relative to skill-biased technical change, in the rise of the skill premium. This paper replaces the Stolper–Samuelson theorem's focus on inter-sectoral with attention to intra-sectoral relations between inputs. Specifically, I assume out-sourcing and unskilled labor are highly substitutable, equipment and skilled labor are complementary, production methods are flexible, and that the country undertaking out-sourcing has a significantly different structure from that providing it. Globalization then offers a simple and immediate possible explanation for prominent stylized facts regarding the skill premium *and* the presence of skill-biased technical change.

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GLOBALIZATION-TALK makes me puke. You just can't get away from it. So I've decided to stop trying and to investigate, in this paper, four basic issues central to globalization.

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1. Introduction

What is globalization? Presumably a reduction in the barriers – whether technological or legislative – to economic exchanges between nations. But the consequences of this have been the central focus of trade theory from its very beginning. So what's new here? I perceive three new foci of concern.

i The reduction in barriers has proceeded to the point where the increasingly widespread practice of international out-sourcing (also known as "slicing up the value-added chain," "fragmentation," or "production sharing") has become of fundamental practical significance, especially with respect to the wages of less skilled workers.
ii It has become possible quickly to adjust production methods globally in response to changes in the economic environment.
iii The historic GATT–WTO multilateral trade liberalization has, since World War II, focused mainly on the exchange of industrial goods between (relatively similar) advanced economies. But in the last 10–15 years less advanced and formerly communist nations have attempted fundamental economic reform and are struggling to become part of the multilateral system. This raises the prospect of a reallocation of global production more fundamental than that experienced thus far in the post World War II period.

I endorse all these concerns. But, from the standpoint of abstract trade theory (and I am an unabashedly abstract trade theorist), they are matters of degree rather than of kind. Therefore, in what follows, I also approach globalization from the viewpoint of the concerns[1] and issues associated with it. I will address in particular four of these.

1 *Globalization and the skill premium.* In recent decades wages of skilled workers have risen relative to those of the less skilled both substantially and globally.[2] The supposed link of this phenomenon to globalization has generated wide public comment, and investigation by academics of such a link constitutes probably the single largest part of the formal globalization literature.
2 *Unemployment.* Continental European countries have also experienced significant increases in rates of persistent unemployment of unskilled workers. This is widely thought to be a manifestation, in countries with distinct labor-market institutions and government social policies, of the phenomenon underlying the rise in the skill premium. Thus, its relation to globalization is a natural question to pursue.[3]
3 *Technology.* Much empirical work has investigated skill-biased technical change as a possible explanation for the rise in the skill premium and in unemployment. Usually such technical change and globalization have been treated as exogenous alternatives, but it is natural to want to investigate possible relations between the two.[4]

[1] See Rodrik (1997) for a good expression of globalization concerns.
[2] For the U.S., see Katz and Autor (1999).
[3] Davidson and Matusz (2001) address employment consequences of globalization. For the contrast between the U.S. and continental Europe, see Davis (1998) and Sapir (2000).
[4] For this see Falvey and Reed (2000), Feenstra and Hanson (1996), Jones (1997), and Neary (2001a).

4 *Independent national social policies.* One of the most prominent public concerns about globalization is its possible erosion or destruction of the ability of individual national governments to pursue distinct social objectives. Suppose that (unspecified) policies exist that allow a government to trade off increased unskilled unemployment for greater wage equality between the skilled and the unskilled. I address two questions. What effect does increased globalization have on the terms of this trade-off? How does globalization affect the ability of different countries to achieve distinct trade-offs?

The next section argues that an appropriate model to address these issues should emphasize certain features. I then present a model doing just that. Following sections analyze globalization, modeled to reflect the first two of the above foci, from the perspective of an economy able to transact on fixed terms with the rest of the world. The next two sections then provide a two-country international analysis, reflecting the last of the three above foci. The concluding section concludes.

2. Globalization building blocks

A simple trade-based hypothesis explaining the rise in the skill premium employs the standard two-factor, two-sector, Heckscher–Ohlin–Samuelson (HOS) model with the factors identified as skilled and unskilled labor. An increased export of unskilled-labor intensive goods from the unskilled-labor abundant country could then induce, via the familiar Stolper–Samuelson mechanism, an increase in the real wage of skilled workers and a decrease in that of unskilled workers in the skilled-labor abundant country. An alternative hypothesis posits, in the same 2×2 model, *exogenous* skill-biased technical change in both sectors, inducing firms to substitute skilled for unskilled labor.

A large empirical literature has addressed the trade vs. technology debate[5] and, for the most part, has found the trade explanation lacking.[6] This has largely been the result of three empirical regularities that have emerged from the literature. **i** There has not been a significant increase in the relative price of skilled-labor intensive goods. **ii** The ratio of the employment of skilled labor to that of unskilled labor has *risen* in all sectors rather than fallen, and there is little evidence of the inter-sectoral movements of both that are central to the Stolper–Samuelson explanation. **iii** The rise in the skill premium is not confined to countries that are net importers of unskilled-labor intensive goods, but appears to be a global phenomenon.

These regularities do not square with the Stolper–Samuelson story. Neary (2001a, 2001b) argues that they also do not sit well with exogenous skill-biased technical change in the 2×2 model, and he responds by introducing oligopolistic competition. Epifani and Gancia (2002) introduce inter-sectoral differences in economies of scale and high consumption substitution. An equally reasonable response is to hypothesize that inter-sectoral differences in technology – the very heart of the HOS model – have in practice little importance for the relation between trade and wages (or technology and wages). This paper follows the latter route.

[5] See Bound and Johnson (1992), Desjonqueres, Machin, and van Reenan (1999), Feenstra and Hanson (2001), Francois and Nelson (1998), Johnson and Stafford (1999), Lawrence and Slaughter (1993), and Slaughter (1998).

[6] But see Dasgupta and Osang (2002), Feenstra and Hanson (1996), Leamer (1998), and Wood (1994) for accounts giving trade more significance.

More precisely, I wish to minimize the role of *inter-sectoral* technology differences and concentrate instead on the *intra-sectoral* ease of substitution (or lack thereof) between inputs. To this end, I adopt a model in which all firms can use the same techniques. As I also assume constant returns to scale, this amounts to adopting an aggregate production function. The purpose of international trade in this model is to allow an international fragmentation of the production process. Thus, the model is consistent with the approach forcefully (and, in my view, convincingly) advocated by Feenstra and Hanson (1996, 2001). Although empirical work in trade has tended to take the HOS model as its point of departure, trade theory has for decades given much attention to the international, intra-sectoral, allocation of the production process.[7] Recent examples include Arndt and Kierzkowski (2001), Burda and Dluhosch (2001), Glass and Saggi (2001), and Jones (2000).

The suppression of inter-sectoral distinctions is one of the building blocks of this paper. Another is its treatment of the intra-sectoral relation between inputs. There are three aspects to this. First, focus **i** of concern about globalization (fragmentation) will be addressed by assuming a high degree of substitution in production between unskilled labor and out-sourcing. Second, the idea that skilled labor and equipment are complements, prominent since Griliches (1969), will be stressed here.[8] Third, to keep these first two aspects in clear relief, I also assume intermediate substitutability of equipment and skilled labor for unskilled labor and outsourcing.

Equipment must be provided for from output. As another building block of this paper, I incorporate the second focus of concern (quick global adjustment of production methods) by allowing firms to choose freely, in equilibrium, their degree of equipment utilization. I also allow the possibility of neutral, exogenous, technical change. However, assuming that equipment utilization is a choice variable, together with the assumption that equipment is complementary to skilled labor but substitutable for unskilled labor, allows the possibility of *endogenous* skill-biased technical change. A decision to utilize more equipment is a decision to switch to a more skill-biased technology.

The final building block accommodates the third focus of concern (the fuller entry into the multilateral system of countries with different economies) by considering trade between countries that differ significantly. In particular, I consider a two-country model in which one country, that can out-source part of the production process and can also supply equipment, trades with another country, that can provide out-sourcing but not equipment.

3. The home economy: small-country version

I use the following aggregate production function.

$$AF(U,V,E,S) = A\left[U^{\gamma} + V^{\gamma}\right]^{\frac{\alpha}{\gamma}}\left[E^{\sigma} + S^{\sigma}\right]^{\frac{1-\alpha}{\sigma}} \tag{1}$$

Here A indexes total factor productivity (TFP), U denotes the employment of unskilled labor, and V is a measure of the quantity of tasks out-sourced abroad. The economy possesses a stock U_0 of unskilled

[7] For a personal example, Ethier (1979, 1982, 1986, 1998) all assigned a central role to international production sharing. More generally, the theoretical literature on trade in intermediate goods, middle products, etc. is very large, and has been so for decades.

[8] See also Bergstrom and Panas (1992), Fallon and Layard (1975) and Krusell, Ohanian, Rios-Rull, and Violante (2000). The present paper draws especially on the latter reference.

labor: U_0-U equals unemployment. E denotes the stock of equipment and S that of skilled labor. This functional form has been chosen to focus directly on the degree of substitutability between inputs.

The central maintained hypothesis of this paper is the following.

$$1>\gamma>0>\sigma \tag{H1}$$

The assumption $\sigma<0$ is that E and S are complements;[9] $\gamma>0$ means that U and V are substitutes; $1>\gamma$ means that there are diminishing returns to out-sourcing: Some tasks can be more easily out-sourced than others. The Cobb–Douglas relation between the $U-V$ and $E-S$ sub-aggregates implies that U and V are more substitutable for each other than for E or S.

The services of V must be paid for with exports.

$$X = \frac{v^*}{g} V \tag{2}$$

The foreign price for effective units of V is v^*, and g is the "globalization index." It indexes the extra cost of foreign out-sourcing (because of legal restrictions, cultural differences, trade barriers, communication cost, etc.). I assume $1\geq g\geq 0$. A higher value of g reflects more globalization. Thus, nationally owned output (income) equals

$$y = AF - \frac{w^*}{g} V. \tag{3}$$

For simplicity, I assume that incomplete globalization, $(1-g)/g$, reflects only real costs such as those of transport, communication, administration, and so on, and therefore generates no tax revenue to be accounted for.

Equipment services E require that a portion of output be devoted to investment I:

$$I = \frac{E}{Q}, \tag{4}$$

where Q measures the technology for providing equipment services. Consumption c accordingly equals output minus investment minus exports.

$$c = AF(U, V, E, S) - \frac{E}{Q} - \frac{v^*}{g} V \tag{5}$$

Next, I define two critical endogenous variables. First the "fragmentation index" f:

$$f \equiv \frac{V^\gamma}{U^\gamma + V^\gamma}.$$

Here $1>f\geq 0$; f measures the relative importance of out-sourcing to the $U-V$ sub-aggregate. The second is the "equipment utilization index" e.

$$e \equiv \frac{S^\sigma}{E^\sigma + S^\sigma}$$

[9] Alternative definitions of complementarity are in the literature. In this paper I *define* complementarity between E and S to mean $\sigma<0$.

Here $1>e>0$; e measures the relative importance of equipment in the $E-S$ sub-aggregate. Differentiating these definitions yields the following.

$$\frac{V}{f}\frac{\mathrm{d}f}{\mathrm{d}V} = \gamma(1-f)$$

$$\frac{U}{f}\frac{\mathrm{d}f}{\mathrm{d}U} = -\gamma(1-f)$$

$$\frac{E}{e}\frac{\mathrm{d}e}{\mathrm{d}E} = -\sigma(1-e)$$

Thus, an increase in V or a decrease in U raises f if and only if $\gamma>0$. V measures out-sourcing and f indexes the extent that this *displaces* U, given that the two are substitutes. Were $\gamma<0$, the relevant fragmentation index would be $1-f$.

Similarly, e responds positively to an increase in E if and only if $\sigma<0$. Were $\sigma>0$, the relevant equipment utilization index would be $1-e$.

3.1. Input prices

Assuming competitive markets in which inputs receive the values of their marginal products, the following input pricing relations apply.

$$w = AF_U = \alpha\frac{AF}{U}(1-f) \tag{6}$$

$$\frac{v^*}{g} = AF_V = \alpha\frac{AF}{V}f \tag{7}$$

$$\frac{1}{Q} = AF_E = (1-\alpha)\frac{AF}{E}(1-e) \tag{8}$$

$$s = AF_S = (1-\alpha)\frac{AF}{S}e \tag{9}$$

Here w denotes the wage paid to unskilled labor U and s that of skilled labor. Thus, the *skill premium* $\pi=s/w$.

This model contains three pairs of exogenous variables.

Endowments: U_0 and S
Trade parameters: v^*, g
Technology parameters: A, Q.

The endogenous variables are y, V, E, s, π (or w), and U. Given the exogenous variables, the equilibrium conditions determine y, V, E, s, and a relation between π (or w), and U. The government pursues an active social policy which causes it to choose a particular $\pi-U$ combination from those available.

4. Globalization, out-sourcing, and fragmentation

Before getting into more detail, I first look at what can be said thus far about the skill premium π.

4.1. A preliminary look at the skill premium

From the input pricing relations,

$$\pi = \frac{1-\alpha}{\alpha}\frac{U}{S}\frac{e}{1-f}. \tag{10}$$

As expected, the skill premium responds positively to an increase in the employment U of unskilled labor and negatively to an increase in the stock S of skilled labor. It also responds positively to an increase in e or in f. Recall that e is an appropriate index of equipment utilization if and only if $\sigma<0$ and that f is an appropriate index of fragmentation if and only if $\gamma>0$.

Proposition 1. *An increase in equipment utilization will raise the skill premium if and only if skilled labor and equipment are complements ($\sigma<0$). An increase in fragmentation will raise the skill premium if and only if unskilled labor and out-sourcing are substitutes ($\gamma>0$).*

The following corollary is immediate.

Proposition 2. *An increase in the stock S of skilled labor can coincide with an increase in the skill premium if also accompanied by a sufficient increase in the index of equipment utilization or in the index of fragmentation, provided that $\sigma<0$ and/or $\gamma>0$.*

These results are preliminary in the sense that e and f are endogenous variables, and they are jointly determined in equilibrium. I turn to this next, but first note the elementary bottom-line implication of (10).

Proposition 3. *Given α, U, and S, changes in technology or in trade will influence the skill premium solely through their effect on equipment utilization and on fragmentation*.

4.2. Equilibrium out-sourcing

Differentiation of the equilibrium pricing condition for out-sourcing implies the following.

$$\varepsilon_{VV}\hat{V} - \varepsilon_{VU}\hat{U} - \varepsilon_{VE}\hat{E} = \hat{A} + \hat{g} - \hat{v}^* \tag{11}$$

Here $\varepsilon_{VV} \equiv -\frac{VF_{VV}}{F_V} = 1-[\alpha f + \gamma(1-f)]>0, \varepsilon_{VE} \equiv \frac{EF_{VE}}{F_V} = (1-\alpha)(1-e)>0$, and $\varepsilon_{VU} = \frac{UF_{VU}}{F_V} = (\alpha-\gamma)(1-f)$.

Thus, given the exogenous parameters (the right-hand side equals zero), an increase in equipment utilization ($\hat{E}>0$) implies more out-sourcing ($\hat{V}>0$), given the volume of employment ($\hat{U}=0$). More E increases the productivity of V, so the volume of the latter must also increase to hold constant the value of its marginal product.

But employment U plays a more complex role. An increase in U increases F, and, therefore, the share, αF, that goes to U and V together, but it also reduces the portion f of this that goes to V. The latter effect dominates if and only if $\gamma>\alpha$; in this case an increase in U must be accompanied by a reduction in V to maintain the value of the latter's marginal product.

Proposition 4. *Given the cost of out-sourcing and TFP, an increase in equipment utilization implies more out-sourcing; an increase in employment implies less or more out-sourcing according as γ exceeds or falls short of α.*

4.3. Equilibrium equipment utilization

Differentiation of the equilibrium pricing condition for equipment utilization implies the following.

$$\varepsilon_{EE}\hat{E} - \varepsilon_{EV}\hat{V} - \varepsilon_{EU}\hat{U} = \hat{A} + \hat{Q} \tag{12}$$

Here $\varepsilon_{EE} \equiv -\frac{EF_{EE}}{F_E} = \alpha(1-e) + e(1-\sigma) > 0$, $\varepsilon_{EV} \equiv \frac{VF_{EV}}{F_E} = \alpha f > 0$, and $\varepsilon_{EU} \equiv \frac{UF_{EU}}{F_E} = \alpha(1-f) > 0$. Thus, given the level of technology, an increase of either employment or out-sourcing requires an increased use of equipment to maintain the value of the latter's marginal product.

Proposition 5. *Given the price of equipment and the level of technology, an increase in either out-sourcing or employment implies an increase in equipment utilization.*

4.4. The elasticity of demand for unskilled labor

From (6) the elasticity of the demand for unskilled labor is

$$-\frac{w}{U}\frac{\partial U}{\partial w} = \frac{1}{(1-\gamma) + (\gamma - \alpha)(1-f)} \equiv \frac{1}{\varepsilon_{EE}}.$$

Thus, the following is immediate.

Proposition 6. *A higher level of fragmentation is associated with a more elastic demand for unskilled labor if and only if $\gamma > \alpha$.*

The possibility and consequences of globalization making the demand for unskilled labor more elastic is discussed in Rodrik (1997); Slaughter (2001) provides interesting empirical support.

4.5. The relation of the skill premium to globalization and to technical change

Eqs. (11) and (12) imply, after some algebra, the following.

$$\varepsilon\hat{V} = (\varepsilon_{VE} + \varepsilon_{EE})\hat{A} + \varepsilon_{VE}\hat{Q} + \varepsilon_{EE}(\hat{g} - \hat{v}^*) + \eta_V\hat{U}$$

$$\varepsilon\hat{E} = (\varepsilon_{EV} + \varepsilon_{VV})\hat{A} + \varepsilon_{VV}\hat{Q} + \varepsilon_{EV}(\hat{g} - \hat{v}^*) + \eta_E\hat{U} \tag{13}$$

Here,

$$\eta_V \equiv \varepsilon_{VE}\varepsilon_{EU} + \varepsilon_{EE}\varepsilon_{VU}$$

$$\eta_E \equiv \varepsilon_{VV}\varepsilon_{EU} + \varepsilon_{EV}\varepsilon_{VU}$$

$$\varepsilon \equiv \varepsilon_{EE}\varepsilon_{VV} - \varepsilon_{EV}\varepsilon_{VE} = \alpha(1-e)(1-\gamma)(1-f) + e(1-\sigma)[f(1-\alpha) + (1-\gamma)(1-f)]$$

Thus, $\varepsilon>0$. Any sort of technological progress or any reduction in the cost of out-sourcing will increase both equipment utilization and out-sourcing. Then, Propositions 1 and 3 imply the following.

Proposition 7. *Given the level of employment, either an increase in globalization or any sort of technology improvement will increase the skill premium, provided that skilled labor and equipment are complements and that unskilled labor and out-sourcing are substitutes.*

Globalization increases out-sourcing, which is substitutable for unskilled labor and therefore exerts downward pressure on the latter's wage. Since out-sourcing implies trade, trade will appear to be the cause. But globalization also increases equipment utilization; since equipment is complementary to skilled labor, this will put upward pressure on the latter's wage. This second effect will *appear* as skill-biased technical change: It shifts the production relation between U and S in such a way as to induce firms, at initial wages, to substitute skilled for unskilled labor. But this shift is itself the result of globalization. Hypothesis (H1) is obviously central to this result. Similar comments apply to the effects of an increase in TFP (unbiased technical change).

4.6. The relation of equipment utilization and out-sourcing to employment

The influence of employment is more complex. Looking first at the effect of employment on out-sourcing,

$$\eta_V = (1-f)\{e[(1-\sigma)(\alpha-\gamma)] + (1-e)\alpha(1-\gamma)\}. \tag{14}$$

The expression on the right is necessarily negative if γ is sufficiently close to 1 and necessarily positive if γ is sufficiently close to 0 (or negative).

Proposition 8. *Given the technology and the external variables, an increase in employment will reduce out-sourcing if U and V are highly substitutable but will increase out-sourcing if they are not.*

Look next at the effect on equipment utilization.

$$\eta_E = \alpha(1-f)(1-\gamma)>0 \tag{15}$$

Proposition 9. *Given the technology and the external variables, an increase in employment will increase equipment utilization.*

5. Social policy

Assume that social policy is driven by an egalitarian need to limit the skill premium π plus a need to maximize employment U. The government's preferences are convex: Successive increases in the skill premium must be accompanied by successively larger increases in employment to leave the government indifferent. I also assume that the government is aware of the relation between the two and possesses policy instruments that enable it to choose whatever $\pi-U$ combination it most prefers. Thus, the key question is the effect of globalization on the trade-off between these two goals.

5.1. The skill premium again

The expression (10) for the skill premium implies that accepting unemployment will *directly* lower the skill premium: $\hat{U}<0$ implies $\pi<0$ other things equal. But there will also be *indirect* effects, since a change in U will influence e and f. Differentiating (10),

$$\hat{\pi}(1-\gamma f)\hat{U}-\sigma(1-e)\hat{E}+(\gamma f)\hat{V}. \tag{16}$$

Thus, if equipment utilization (e) and fragmentation (f) are low, a change in employment will influence the skill premium both directly and through its effect on equipment utilization, but only slightly through its effect on out-sourcing. If equipment and skilled labor are complements ($\sigma<0$), the indirect effect through equipment utilization is positive but becomes less significant as equipment utilization increases; if unskilled labor and out-sourcing are substitutes ($\gamma>0$), an increase in fragmentation reduces the direct effect while increasing the indirect effect through out-sourcing. These conclusions reflect diminishing returns in production.

5.2. The policy trade-off

To see the net effect of changes in employment on the skill premium, substitute (13) into (16) and rearrange terms.

$$\hat{\pi}=\left[(1-\gamma f)+\gamma f\frac{\eta_V}{\varepsilon}-\sigma(1-e)\frac{\eta_E}{\varepsilon}\right]\hat{U}+\frac{1}{\varepsilon}[\gamma f(\varepsilon_{VE}+\varepsilon_{EE})-\sigma(1-e)(\varepsilon_{EV}+\varepsilon_{VV})]$$
$$\hat{A}+\frac{1}{\varepsilon}[\gamma f\varepsilon_{VE}-\sigma(1-e)\varepsilon_{VV}]\hat{Q}+\frac{1}{\varepsilon}[\gamma f\varepsilon_{EE}-\sigma(1-e)\varepsilon_{EV}](\hat{g}-\hat{v}^*) \tag{17}$$

To establish a benchmark frame of reference, consider the special case $\gamma=\sigma=0$. Here (17) reduces to just $\hat{\pi}=\hat{U}$. The skill premium can always be reduced by 1% by accepting a 1% fall in employment, and changes in the exogenous variables have no effect on the policy trade-off. The explanation is straightforward: $\gamma=\sigma=0$ implies that the production function is Cobb–Douglas in its four arguments, which in turn implies that income shares are constant and that $e+f=1$ (recall that e and f are meaningful indices of equipment utilization and of fragmentation only if $\gamma>0>\sigma$). Thus, from (10), π is strictly proportional to U.

Next, note that $\gamma>0>\sigma$ implies that the coefficients of $\hat{A}$, $\hat{Q}$, and $\hat{g}-\hat{v}$ in (17) are all positive. Thus, a favorable technology shock or a favorable trade shock will make the government's task harder: To keep employment unchanged it must accept a rise in the skill premium.

Proposition 10. *If unskilled labor and out-sourcing are substitutes and skilled labor and equipment are complements, an increase in TFP, the relative cost of providing equipment services, or the degree of globalization, or a fall in the foreign price for out-sourcing, will require the government to accept a rise in the skill premium to keep employment unchanged.*

The coefficient of $\hat{U}$ in (17) has no clear relation to the value of f, even as γ approaches unity. An increase in fragmentation might make the policy trade-off more favorable or less favorable, depending on circumstances.

To put the role of substitutability of U and V into sharp relief, look at the limiting case of perfect substitution: γ=1. Then (17) reduces to

$$\hat{\pi} = \frac{1}{e(1-\alpha)}\hat{A} + \frac{1-e}{e}\hat{Q} + \frac{e(1-\alpha)+\alpha}{e(1-\alpha)}(\hat{g} - \hat{v}^*). \tag{18}$$

The policy trade-off ceases to exist. If unskilled labor and out-sourcing are perfect substitutes and if the latter is available at a constant cost, variations in the employment of unskilled labor will be offset exactly by variations in out-sourcing and will therefore have no effect on the skill premium.

Proposition 11. *Given the degree of complementarity between skilled labor and equipment, if unskilled labor and out-sourcing are sufficiently substitutable the government will be unable to influence significantly the skill premium with policies involving variations in employment.*

Note also that each of the coefficients of exogenous shocks in (18) is decreasing in e and independent of f.

Proposition 12. *Given the degree of complementarity between skilled labor and equipment, if unskilled labor and out-sourcing are sufficiently substitutable, an increase in equipment utilization will worsen the policy trade-off and reduce the impact of changes in the exogenous variables on either the skill premium or the volume of employment; an increase in fragmentation will also worsen the policy trade-off, but will have a negligible effect on the impact of changes in exogenous variables.*

Finally, for a perspective on the role of complementarity between skilled labor and equipment, look at what happens when $-\sigma$ is allowed to become arbitrarily large. In this case (17) converges to the following.

$$\hat{\pi} = \frac{(1-\alpha)(1-\gamma)}{(1-\gamma)+(\gamma-\alpha)f}\hat{U} + \frac{1-e}{e}\frac{\left(\gamma\frac{f}{1-e}\right)f+(1-\gamma)}{(\gamma-\alpha)f+(1-\gamma)}\hat{A} + \frac{1-e}{e}\hat{Q} + \frac{(\gamma-\alpha)+\frac{\alpha}{e}}{(\gamma-\alpha)+\frac{1-\gamma}{f}}(\hat{g}-\hat{v}^*). \tag{19}$$

The coefficient of $\hat{U}$ in (19) is necessarily less than unity: The policy trade-off is less favorable than in the Cobb–Douglas case. Also, this coefficient decreases in f if $\gamma>\alpha$ and increases in f if $\gamma<\alpha$. Thus, more fragmentation implies a worsened policy trade-off if unskilled labor is sufficiently substitutable for out-sourcing *and* skilled labor is sufficiently complementary to equipment.

Proposition 13. *If the complementarity between skilled labor and equipment is sufficiently strong, an increase in fragmentation will worsen the policy trade-off if $\gamma>\alpha$ and improve it if $\gamma<\alpha$. An increase in equipment utilization will have a negligible effect on the trade-off.*

Finally, the coefficients of the changes in the exogenous variables in (19) immediately imply the following.

Proposition 14. *Given the degree of substitutability between unskilled labor and out-sourcing, if skilled labor and equipment are sufficiently complementary, an increase in equipment utilization will reduce the impact of changes in the exogenous variables on either the skill premium or the volume of employment; an increase in fragmentation will have a negligible effect on the impact of changes in the technology for providing equipment services, but will increase the impact of changes in the other exogenous variables.*

6. The Southern economy

Thus far, the Home economy has been supposed able to out-source at a constant price. I now explicitly introduce a trading partner, the South, with a distinct structure.

6.1. A model of the South

The South possesses following aggregate production function.

$$A^*F^*(U^*, E^*, S^*) = A^*[U^*]^{\alpha}[(E^*)^{\sigma} + (S^*)^{\sigma}]^{\frac{1-\alpha}{\sigma}} \tag{20}$$

Here A^* indexes South TFP, U^* Southern employment of unskilled labor, S^* skilled labor, and E^* the quantity of equipment in the South. This production function is analogous to that of Home, and I assume it has the same parameters α and σ, so that, in the South also, equipment and skilled labor are substitutes. The Southern index of equipment utilization is also defined analogously:

$$e^* = \frac{(S^*)^{\sigma}}{(E^*)^{\sigma} + (S^*)^{\sigma}}$$

Thus, the South differs from Home in not producing equipment, in not out-sourcing, and in providing out-sourcing for Home. As a final distinction, I suppose that South utilizes equipment at a low level, in particular, that

$$e^* < \frac{(1-\alpha)}{(1-\alpha)-\sigma}. \tag{H2}$$

Southern output may be used to provide either consumption or out-sourcing.

$$c^* + V = A^*F^*(U^*, E^*, S^*)$$

The South does not produce equipment and so must import it from Home, paying for it by performing out-sourcing:

$$E^* = v^*QV. \tag{21}$$

Thus, $v^*Q \equiv P$, the relative price of out-sourcing in terms of equipment, is also the terms of trade.

Assuming competitive markets in which inputs receive the values of their marginal products, the following input pricing relations apply.

$$\frac{w^*}{v^*} = A^*F_U^* = \alpha\frac{A^*F^*}{U^*} \tag{22}$$

$$\frac{1}{Q_v^*} = A^*F_E^* = (1-\alpha)\frac{A^*F^*}{E^*}(1-e^*) \tag{23}$$

$$s^* = A^*F_S^* = (1-\alpha)\frac{A^*F^*}{S^*}e^* \tag{24}$$

Here w^* denotes the wage paid to unskilled labor and s^* that of skilled labor. Thus, the South skill premium equals:

$$\pi^* = \frac{1-\alpha}{\alpha}\frac{U^*}{S^*}e^*. \tag{25}$$

Since e^* is an appropriate index of South equipment utilization if and only if $\sigma<0$, the following is immediate.

Proposition 15. *An increase in equipment utilization will raise the South skill premium if and only if skilled labor and equipment are complements ($\sigma<0$).*

6.2. Equilibrium equipment utilization

Differentiation of the equilibrium pricing condition for equipment utilization implies the following.

$$\varepsilon^*_{EE}\hat{E}^* - \alpha\hat{U}^* = \hat{A}^* + \hat{v}^* + \hat{Q} \tag{26}$$

Here $\varepsilon^*_{EE} \equiv -(E^*F^*_{EE}/F^*_E) = \alpha(1-e^*)+e^*(1-\sigma)>0$. Note that $\varepsilon^*_{EE}>\alpha$. Also, (H1) implies that ε^*_{EE} is decreasing in e^*.

Proposition 16. *Given the terms of trade and Southern TFP, an increase in employment implies a less than proportionate increase in equipment utilization.*

In light of the pattern of trade, (26) can also be interpreted as showing the response of the demand for imports to changes in the terms of trade, employment, and TFP. The elasticity of South import demand with response to the terms of trade is thus $1/\varepsilon^*_{EE}$ Thus, this elasticity decreases as South's index of equipment utilization rises. (H2) implies that $\varepsilon^*_{EE}<1$ and therefore amounts to assuming that equipment utilization in the South is sufficiently low to render South import demand elastic. Likewise, the first equation of (13) shows the response of Home import demand to changes in its determinants.

6.3. South social policy

South policy makers are also concerned about both wage inequality and unemployment. Differentiating (25) and substituting into (26) yields the following.

$$\hat{\pi}^* = \left[1 - \alpha\frac{\sigma(1-e^*)}{\varepsilon^*_{EE}}\right]\hat{U}^* - \frac{\sigma(1-e^*)}{\varepsilon^*_{EE}}\left\{\hat{v}^* + \hat{Q} + \hat{A}^*\right\} \tag{27}$$

The following is immediate.

Proposition 17. *If and only if South skilled labor and equipment are complements:* ***i*** *A decrease in employment will produce a more than proportional fall in the skill premium;* ***ii*** *An improvement in the terms of trade or in TFP will oblige the South government to accept an increase in the skill premium to keep employment unchanged, or a reduction in employment to leave the skill premium unchanged;* ***iii*** *An increase in complementarity implies an improvement in the policy trade-off and increased sensitivity to the terms of trade and to TFP;* ***iv*** *An increase in equipment utilization implies a deterioration in the policy trade-off and decreased sensitivity to the terms of trade and to TFP.*

7. The global economy

Turn now to the comparative statics of international equilibrium.

7.1. Trade

These comparative statics are described by the first equation of (13), by differentiation of (21), and by (26). After some algebra, these yield the following.

$$\hat{P} = \frac{1}{\varepsilon^*}\left\{\varepsilon\hat{A}^* - \varepsilon^*_{EE}(\varepsilon_{VE} + \varepsilon_{EE})\left(\hat{A} + \hat{Q}\right) - \varepsilon^*_{EE}\varepsilon_{EE}\hat{g} + \alpha\varepsilon\hat{U}^* - \varepsilon^*_{EE}\eta_V\hat{U}\right\} \tag{28}$$

$$\hat{E}^* = \frac{1}{\varepsilon^*}\left\{(\varepsilon - \varepsilon_{EE})\hat{A}^* - (\varepsilon_{VE} + \varepsilon_{EE})\left(\hat{A} + \hat{Q}\right) - \varepsilon_{EE}\hat{g} + \alpha(\varepsilon - \varepsilon_{EE})\hat{U}^* - \eta_V\hat{U}\right\} \tag{29}$$

$$\hat{V} = \frac{1}{\varepsilon\varepsilon^*}\left\{-\left[(\varepsilon_{VE} + \varepsilon_{EE})\varepsilon\left(1 - \varepsilon^*_{EE}\right)\right]\left(\hat{A} + \hat{Q}\right) - \varepsilon\varepsilon_{EE}\left(1 - \varepsilon^*_{EE}\right)\hat{g} - \varepsilon\varepsilon_{EE}\hat{A}^* - \alpha\varepsilon\varepsilon_{EE}\hat{U}^* + \varepsilon_{EE}\varepsilon^*_{EE}\eta_V\hat{U}\right\} \tag{30}$$

where $\varepsilon^* = \varepsilon^*_{EE}\varepsilon - \varepsilon - \varepsilon^*_{EE}\varepsilon_{EE} = -\varepsilon^*_{EE}\varepsilon_{EE}(1-\varepsilon_{VV}) - \varepsilon^*_{EE}\varepsilon_{EV}\varepsilon_{VE} - \varepsilon < 0$. Thus,

Proposition 18 (Globalization). *If (H1) holds, an increase in globalization turns the terms of trade in favor of South, increases South equipment utilization, and increases Home out-sourcing.*

Proposition 19 (Home Technological Progress). *If (H1) holds, an increase in either Home employment or Home TFP, or a decrease in the relative cost of equipment, turns the terms of trade in favor of South, increases South equipment utilization, and increases Home out-sourcing.*

Note also that

$$\varepsilon - \varepsilon_{EE} = -\alpha(1-e)[f + \gamma(1-f)] - e(1-\sigma)(1 - [(1-e)(1-\gamma)\alpha + f(1-\alpha)]) < 0.$$

Thus,

Proposition 20 (South Technological Progress). *If (H1) holds, an increase in either South employment or South TFP turns the terms of trade in favor of Home, increases Southern equipment utilization, and increases Home out-sourcing.*

7.2. Globalization and skill premia

Rewrite the second equation of (13) as follows.

$$\varepsilon\hat{E} = (\varepsilon_{EV} + \varepsilon_{VV})\left(\hat{A} + \hat{Q}\right) + \varepsilon_{EV}\left(\hat{g} - \hat{P}\right) + [\varepsilon_{VV}\varepsilon_{EU} + \varepsilon_{EV}\varepsilon_{VU}]\hat{U} \tag{31}$$

Thus, globalization will have a direct positive effect on Home equipment utilization, and Proposition 18 indicates that it will also increase Home out-sourcing. This is just as in the small-country case. But

Proposition 18 also indicates that it will turn the terms of trade against Home, and (31) then indicates that this will have a countervailing influence on equipment utilization. To see the net effect, note that (28) implies, if technology and employments do not change,

$$\hat{P} = -\frac{\varepsilon^*_{EE}\varepsilon_{EE}}{\varepsilon^*}\hat{g} < \hat{g}$$

since $-(\varepsilon^*_{EE}\varepsilon_{EE}/\varepsilon^*) = -(\varepsilon^*_{EE}\varepsilon_{EE}/(-\varepsilon^*_{EE}\varepsilon_{EE} - \varepsilon(1-\varepsilon^*_{EE}))) < 1$ because (H2) implies that $\varepsilon^*_{EE} < 1$.

Thus, in (31) the direct effect of globalization on Home equipment utilization dominates the countervailing influence through the terms of trade. So globalization increases the Home skill premium and it increases equipment utilization in both countries. Finally, (27) implies that an improvement in South's terms of trade $\hat{Q}+\hat{v}>0$, will also raise the skill premium in South, provided that equipment and skilled labor are complements. Thus, we have the following basic result.

Proposition 21 (Globalization and Skill Premia). *If (H1) and (H2) hold, an increase in globalization will increase the skill premium in both countries. It will also increase equipment utilization in both countries, implying common skill-biased technical change in the sense that, at unchanged wages, firms world-wide will wish to substitute skilled labor for unskilled labor.*

The story is as follows. An increase in globalization causes Home to increase out-sourcing. Since out-sourcing substitutes for Home unskilled labor, it depresses the wage of the latter. It also increases the marginal product of equipment, which will tend to induce Home to increase equipment utilization. But in addition it turns the terms of trade against Home, producing a countervailing effect. If equipment utilization in South is sufficiently small, South import demand will be elastic and the deterioration in the terms of trade will not be large enough to reverse the direct positive effect on Home equipment utilization. Since skilled labor is complementary to equipment, this increases the wage of the latter. Finally, the improvement in its terms of trade will induce South to utilize more equipment, and this will increase the wage of skilled labor there, again because of the complementarity of the latter with equipment.

7.3. Technology and skill premia

In Proposition 21, the skill-biased change in production technique is endogenous, a consequence of globalization. But this does not imply that such a change reflects the presence of globalization: It could be caused by something else. In particular, consider the effects of changes in Home TFP, South TFP, or the relative cost of equipment.

From (31), $\hat{A}+\hat{Q}>0$ implies a direct positive effect on Home equipment utilization, and Proposition 19 indicates that it will also increase Home out-sourcing, but that, in addition, it will turn the terms of trade against Home, and (31) then indicates that this will again have a countervailing influence on equipment utilization. To see the net effect, note that (28) and (31) imply, if foreign technology, globalization, and employments do not change,

$$\begin{aligned}\hat{E} &= \frac{1}{\varepsilon\varepsilon^*}\left(\varepsilon^*[\varepsilon_{EV}+\varepsilon_{VV}] + \varepsilon_{EV}\varepsilon^*_{EE}[\varepsilon_{VE}+\varepsilon_{EE}]\right)\left(\hat{A}+\hat{Q}\right)\\ &= \frac{1}{\varepsilon\varepsilon^*}\left(\varepsilon_{EV}\left[\varepsilon^* + \varepsilon_{EE}\varepsilon^*_{EE}\right] - \varepsilon\varepsilon_{VV} - \varepsilon\varepsilon^*_E[1-\varepsilon_{VV}]\right)\left(\hat{A}+\hat{Q}\right)\end{aligned}$$

(H2) implies that the coefficient of $\hat{A}+\hat{Q}$ in the bottom line is positive. Thus, the direct effect of $\hat{A}+\hat{Q}$ on Home equipment utilization dominates the countervailing influence through the terms of trade, and therefore it increases the Home skill premium and equipment utilization in both countries. Again, (27) implies that an improvement in South's terms of trade will also raise the skill premium in South, provided that equipment and skilled labor are complements. Thus, the following result.

Proposition 22 (Home Technology and Skill Premia). *If (H1) and (H2) hold, an improvement in Home TFP or in the technology for providing equipment will increase the skill premium in both countries. It will also increase equipment utilization in both countries generating common skill-biased technical change.*

Globalization and improvements in Home technology produce qualitatively identical effects on the skill premia in the two countries, and both induce a skill-biased change in production techniques in both countries. This paper therefore strongly endorses the argument of Feenstra and Hanson (2001, p 2) that "distinguishing whether the change in wages is due to international trade, or technological change, is fundamentally an empirical rather than a theoretical question." Furthermore, the presence of skill-biased changes in observed technology does *not* contribute to making this distinction.

Next, consider an improvement in South TFP. Eq. (31) reveals that an increase in A^* has no direct effect on Home equipment utilization, but will increase it indirectly if it causes an improvement in the Home terms of trade. This plus Proposition 20 therefore imply:

Proposition 23 (South Technology and Skill Premia). *If (H1) holds, an increase in South TFP will increase the skill premium in both countries. It will also increase equipment utilization in both countries, generating common skill-biased technical change.*

Thus, an improvement in South technology produces the same qualitative effects as an improvement in Home technology on fragmentation, equipment utilization, and the skill premia. The only difference is in the effect on the terms of trade.

7.4. Globalization and social policy

Next, examine the interrelation between Home social policy and South social policy, and how this interrelation is sensitive to the degrees of: substitution between inputs (as reflected in γ and σ), fragmentation (f), and equipment utilization (e). To this end, substitute (28) into (17) and (27), note that $P=Qv^*$, and rearrange terms to obtain, for given g, A, Q, and A^*,

$$\begin{aligned}\hat{\pi} &= \mu_U \hat{U} + \mu_{U^*} \hat{U}^* \\ \hat{\pi}^* &= \mu^*_U \hat{U} + \mu^*_{U^*} \hat{U}^*\end{aligned} \tag{32}$$

where

$$\begin{aligned}\mu_U &= \frac{1}{\varepsilon}\left\{\varepsilon(1-\gamma f) + \gamma f \eta_V - \sigma(1-e)\eta_E + [\gamma f \varepsilon_{EE} - \sigma(1-e)\varepsilon_{EV}]\frac{\varepsilon^*_{EE}}{\varepsilon^*}\eta_V\right\} \\ \mu_{U^*} &= -\frac{\alpha}{\varepsilon^*}[\gamma f \varepsilon_{EE} - \sigma(1-e)\varepsilon_{EV}] \\ \mu^*_U &= \frac{1}{\varepsilon^*}[\sigma(1-e^*)\eta_V] \\ \mu^*_{U^*} &= \frac{1}{\varepsilon^*}[\varepsilon^* - \alpha\sigma(1-e^*)(\varepsilon - \varepsilon_{EE})]\end{aligned} \tag{33}$$

Note, first, if $\gamma=\sigma=0$ (the Cobb–Douglas case), $\mu_U=\mu^*_{U^*}=1$, $\mu^*_U=\mu_{U^*}=0$. Thus, there is no policy interdependence between Home and South, and neither country's policy trade-off is influenced by fragmentation or by equipment utilization.

Further, (H1) implies that $\mu^*_{U^*},\mu_{U^*}>0$, so that a reduction in South employment will reduce the skill premium in both countries if Home employment is unchanged. Next, look at the consequences of the following additional assumption.

$$\mu_U>0, \qquad \mu_U\mu^*_{U^*}>\mu_{U^*}\mu^*_U \tag{H3}$$

This is not a strong assumption, as it is satisfied for many values of the underlying parameters, but it is not innocuous: Cases do exist where it is not met. (H3) implies that, given the skill premium in the partner country, policies that lower employment in a country will also reduce the skill premium there, both directly and after international repercussions are accounted for.

Note that, if γ is sufficiently large, $\mu^*_U>0$ Then both of the cross terms in (33) will be positive: Policies intended to reduce the skill premium in one country, by accepting a reduction in employment, will also reduce the skill premium in the other country. Thus, the actions of policymakers in one country will facilitate policymaking in the other if both are trying to move in the same direction, but will frustrate policy if they are not. That is, the international environment will reduce national policy autonomy.

Proposition 24 (Erosion of National Autonomy). *If (H3) holds and γ is sufficiently large, the actions of policymakers in each country will tend to frustrate the actions of policymakers in the other, whenever they attempt to pursue divergent objectives.*

Proposition 24 is consistent with the concerns of many globalization critics. But there is more to it than that. To put the concerns of this paper into sharp relief, let $-\sigma$ become indefinitely large. Then the terms in (33) converge to the following.

$$\mu_U = 1-\gamma f+\frac{1-e}{e}\frac{\alpha f}{G}(1-\gamma)-\left[\frac{\gamma f(1-f)}{G-1}+\frac{1-e}{e}\frac{\alpha f(1-f)}{G(G-1)}\right](\gamma-\alpha)$$

$$\mu_{U^*} = 0$$

$$\mu^*_U = \frac{1-e^*}{e^*}\frac{1-f}{1-\gamma+f(\gamma-\alpha)}(\gamma-\alpha)$$

$$\mu^*_{U^*} = 1+\alpha\frac{1-e^*}{e^*} \tag{34}$$

where $G\equiv 1-\gamma f(\gamma-\alpha)>0$. Note that, if γ is sufficiently large, $\mu_U>0$, which in turn implies $\mu_U\mu_{U^*}{}^*>\mu_U{}^*\mu_{U^*}$. This establishes the relevance of Proposition 24 when the maintained hypothesis of this paper is pronounced.

Proposition 25. *If γ and $-\sigma$ are sufficiently large, (H3) necessarily holds.*

Note next that, if complementarity between skilled labor and equipment is complete, fluctuations in employment in South will have no spillover effects on the Home skill premium. An increase in South unskilled employment will not increase South demand for equipment if the latter is strictly complementary to the unchanged stock of skilled labor. Thus, South demand for imports will not

change nor, at the initial terms of trade, will its supply of out-sourcing. An increase in South employment will therefore raise the skill premium in South with no effects on either the volume or the terms of trade and, therefore, on the Home skill premium.

But this no-spillover conclusion is not symmetric. When $\gamma>\alpha$ an increase in Home employment raises the skill premium in the South. This is because it raises Home demand for out-sourcing which turns the terms of trade in favor of the South, inducing the latter to increase equipment utilization, which in turn raises the skill premium.

Proposition 26 (Asymmetric Spillovers). *If skilled labor and equipment are highly complementary, employment fluctuations in South will have negligible effects on the Home skill premium, but Home employment fluctuations will significantly influence the South skill premium.*

Finally, note that the spillover effect of Home employment fluctuations on South's skill premium become negligible once the degree of fragmentation becomes large, and so do the effects on Home's skill premium if γ is also large. If V is large and substitutable for U, changes in the latter have little effect on the $U-V$ sub-aggregate.

Proposition 27. *If γ and $-\sigma$ are sufficiently large, fluctuations in Home employment will have little effect on Home and South skill premia when fragmentation is extensive.*

8. Concluding remarks

Popular concern about globalization embraces a large (and amorphous) number of concerns. This paper addresses a complex of issues that have been of concern to economists: the effect of globalization on the skill premium; the effect of globalization on unemployment; the relative importance of globalization and exogenous technical change; the effect of globalization on the ability of national governments to conduct independent social policies. Thinking about these topics has been dominated by a large empirical literature concluding, for the most part, that trade has played a relatively minor role in the rise of the skill premium, while exogenous skill-biased technical change has played a major role.

Most of this work has utilized, at least implicitly, the standard 2×2 HOS model as a theoretical framework. This paper investigates the consequences of replacing the focus on inter-sectoral substitution that is at the heart of the Stolper–Samuelson theorem with more attention to the intra-sectoral relations between inputs. Specifically, I assume that out-sourcing and unskilled labor are highly substitutable and that equipment and skilled labor are complementary, that production methods are flexible, and that the country undertaking out-sourcing (Home) has a significantly different structure from that providing it (South). The more important results include the following.

- An increase in fragmentation or in equipment utilization will raise the skill premium. Thus, an increase in the stock of skilled labor can coincide with an increase in the skill premium if also accompanied by a sufficient increase in equipment utilization or fragmentation.
- More fragmentation is associated with a more elastic demand for unskilled labor if and only if out-sourcing and unskilled labor are sufficiently substitutable.

- Given the complementarity between skilled labor and equipment, if unskilled labor and out-sourcing are sufficiently substitutable the government will be unable to influence significantly the skill premium with policies involving variations in employment.
- If the complementarity between skilled labor and equipment is sufficiently strong, an increase in fragmentation will worsen the policy trade-off if out-sourcing and unskilled labor are highly substitutable and improve it if they are less highly substitutable.
- An increase in globalization turns the terms of trade in favor of South, increases Southern equipment utilization, and increases Home out-sourcing.
- An increase in globalization will increase the skill premium in *both* countries. It will also increase equipment utilization in both countries, generating common skill-biased technical change.
- An increase in Home TFP or fall in the relative cost of providing equipment will increase the skill premium in *both* countries. It will also increase equipment utilization in both countries, generating common skill-biased technical change.
- If unskilled labor and out-sourcing are sufficiently substitutable, the actions of policymakers in each country will tend to frustrate the actions of policymakers in the other, whenever they attempt to pursue divergent objectives.
- If skilled labor and equipment are highly complementary, employment fluctuations in South will have negligible effects on the Home skill premium, but Home employment fluctuations will significantly influence the South skill premium.
- If skilled labor and equipment are highly complementary and unskilled labor and outsourcing highly substitutable, fluctuations in Home employment will have little effect on Home and South skill premia when fragmentation is extensive.

In summary, when detail about intra-sectoral relations between inputs replaces focus on inter-sectoral substitution, globalization offers a simple and immediate possible explanation for the prominent stylized facts regarding the emergence of the skill premium *and* for the presence of skill-biased technical change. Trade vs. technology remains as an empirical issue, though, because exogenous neutral technological change offers an alternative simple and immediate possible explanation. But globalization-talk still makes me puke.

Appendix A. Elasticities

For convenience, definitions of elasticities used in the text are collected here.

A.1. Home elasticities

$$\varepsilon_{VV} \equiv -\frac{VF_{VV}}{F_V} = 1 - [\alpha f + \gamma(1-f)] = (1-\gamma) - (\alpha-\gamma)f$$

$$\varepsilon_{VU} \equiv \frac{UF_{VU}}{F_V} = (\alpha-\gamma)(1-f)$$

$$\varepsilon_{VE} \equiv \frac{EF_{VE}}{F_V} = (1-\alpha)(1-e)$$

$$\varepsilon_{EE} \equiv -\frac{EF_{EE}}{F_E} = \alpha(1-e) + e(1-\sigma)$$

$$\varepsilon_{EV} \equiv \frac{VF_{EV}}{F_E} = \alpha f$$

$$\varepsilon_{EU} \equiv \frac{UF_{EU}}{F_E} = \alpha(1-f)$$

$$\varepsilon_{UU} \equiv -\frac{UF_{UU}}{F_U} = 1 - [\alpha(1-f) + \gamma f] = (1-\gamma) - (\alpha-\gamma)(1-f)$$

$$\varepsilon_{UV} \equiv \frac{VF_{UV}}{F_U} = (\alpha-\gamma)f$$

$$\varepsilon_{UE} \equiv \frac{EF_{UE}}{F_U} = (1-\alpha)(1-e) = \varepsilon_{VE}$$

$$\varepsilon \equiv \varepsilon_{EE}\varepsilon_{VV} - \varepsilon_{EV}\varepsilon_{VE} = \alpha(1-e)(1-\gamma)(1-f) + e(1-\sigma)[f(1-\alpha) + (1-\gamma)(1-f)])$$

$$\eta_V \equiv \varepsilon_{VE}\varepsilon_{EU} + \varepsilon_{EE}\varepsilon_{VU} = (1-f)\{e[(1-\sigma)(\alpha-\gamma)] + (1-e)[\alpha(1-\gamma)]\}$$

$$\eta_E \equiv \varepsilon_{EU}\varepsilon_{VV} + \varepsilon_{EV}\varepsilon_{VU} = \alpha(1-f)(1-\gamma)$$

A.2. South elasticities

$$\varepsilon^*_{EE} \equiv -\frac{E^*F^*_{EE}}{F^*_E} = \alpha(1-e^*) + e^*(1-\sigma) > 0.$$

$$\varepsilon^* \equiv \varepsilon^*_{EE}\varepsilon - \varepsilon - \varepsilon^*_{EE}\varepsilon_{EE}$$

A.3. International elasticities

$$\mu_U \equiv \frac{U}{\pi}\frac{\mathrm{d}\pi}{\mathrm{d}U} = \frac{1}{\varepsilon}\left\{\varepsilon(1-\gamma f) + \gamma f\eta_V - \sigma(1-e)\eta_E + [\gamma f\varepsilon_{EE} - \sigma(1-e)\varepsilon_{EV}]\frac{\varepsilon^*_{EE}}{\varepsilon^*}\eta_V\right\}$$

$$\mu_{U^*} \equiv \frac{U^*}{\pi}\frac{\mathrm{d}\pi}{\mathrm{d}U^*} = -\frac{\alpha}{\varepsilon^*}[\gamma f\varepsilon_{EE} - \sigma(1-e)\varepsilon_{EV}]$$

$$\mu^*_U \equiv \frac{U}{\pi^*}\frac{\mathrm{d}\pi^*}{\mathrm{d}U} = \frac{1}{\varepsilon^*}[\sigma(1-e^*)\eta_V]$$

$$\mu^*_{U^*} \equiv \frac{U^*}{\pi^*}\frac{\mathrm{d}\pi^*}{\mathrm{d}U^*} = \frac{1}{\varepsilon^*}[\varepsilon^* - \alpha\sigma(1-e^*)(\varepsilon - \varepsilon_{EE})]$$

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