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Paolo Manasse and Alessandro Turrini

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Paolo Manasse, Università Statale di Milano-Bicocca
and Università Bocconi (IGIER)
Alessandro Turrini, Università degli Studi di Bergamo and CEPR

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Centre for Economic Policy Research
90–98 Goswell Rd, London EC1V 7RR
Tel: (44 20) 7878 2900, Fax: (44 20) 7878 2999
Email: cepr@cepr.org, Website: http://www.cepr.org

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ABSTRACT

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We study the effect of 'globalization' on wage inequality. Our 'global' economy resembles Rosen's (1981) 'Superstars' economy, where a) innovations in production and communication technologies enable suppliers to reach a larger mass of consumers and to improve the (perceived) quality of their products and b) trade barriers fall. When transport costs fall, income is redistributed away from the non-exporting to the exporting sector of the economy. As the former turns out to employ workers of higher skill and pay, the effect is to raise wage inequality. Whether the least skilled stand to lose or gain from improved production or communication technologies, in contrast, depends on whether technology is skill-complementary, or a substitute. The model gives an intuitive explanation for the empirical regularities that skill intensity, market size and wages tend to be positively associated with exporting activity across sectors and plants.

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Paolo Manasse
Department of Economics
Universita' degli Studi di Milano
Viale Sarca, 202
20126 Milan
ITALY
Tel: (39 02) 64486594
Fax: (39 02) 6437845
Email: paulo.manasse@unimi.it

Alessandro Turrini
Department of Economics
Universita' degli Studi di Bergamo
P.zza Rosate 2
24100 Bergamo
ITALY
Tel: (39 035) 277506
Fax: (39 035) 249975
Email: turrini@unibg.it

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NON-TECHNICAL SUMMARY

The enthusiasm that accompanies many of the recent institutional and technological developments occurring at the international level (the so-called globalization process) has been cooled down by the widespread worries concerning their possible consequences on income distribution and labour market outcomes. Will a globalized society be more or less ‘equal’? Who will be the winners and the losers from this tendency? In spite of abundant empirical work concerning the distributive implications of globalization, these questions still seem to be poorly understood. Standard trade theory predicts that the winners from the globalization process in the North would be the workers endowed with higher skills (who are relatively abundant) and the losers would be the unskilled (who are relatively scarce). This view, though, is not easily supported by the data. The actual changes in product prices are hardly sufficient to explain the observed deterioration of the relative position of the unskilled. There is a further limitation, much less emphasized in the current debate, in using the standard trade theory to explain ongoing developments in income distribution. Trade integration based on factor proportions can indeed explain a single dimension of inequality, namely that arising between the earnings of skilled labour versus those of the unskilled, taken as different factors of production. However, according to recent evidence (Juhn at al. (1993)), inequality has risen dramatically even within narrowly defined segments of the labour market. In other words, income differentials have also increased for workers sharing the same occupation or type of education, i.e. belonging to the same skill categories as defined in current empirical work. Turning to the contributions offered by the new trade theory, things do not improve in this respect, either. Imperfect competition and increasing returns help in explaining the failure of international convergence in factor prices, but what happens to within-country inequality remains an unexplored issue in almost all existing models.

In this Paper we highlight a new channel through which developments in trade and technology affect the distribution of income. In our description of a ‘global economy’, three ingredients play a crucial role. The first is increasing returns in production. Market size matters. This is the basic tenet of ‘new’ trade theory and we exploit it in view of addressing questions concerning domestic inequality. The second is a link relating sellers’ abilities to the degree of consumers’ satisfaction. According to the current state of production and communication technologies, more talented suppliers are in the position to reach a larger mass of consumers.

The third ingredient is barriers to trade due to transport costs or market-access costs that segment the international market. Combining these ingredients into a simple trade model, we obtain a representation of the labour market that is reminiscent of Rosen's (1981) description of the 'Economics of Superstar'. In his seminal paper, Rosen discussed the role that non-convexities in production may exert on income distribution. Some products are like non-rival public goods: singing on a satellite-broadcast TV programme or in a small café requires approximately the same effort. For products where these non-convexities are particularly important and where 'talents' are particularly appreciated by consumers, even small differences in 'skills' are associated with disproportionate differences in incomes (think of show business, sport, science etc.).

These insights seem to apply to an increasing number of occupations. As popularized by Frank and Cook (1995) in a recent best seller, 'winner-take-all' markets are spreading to more and more activities, as a result of deeper market integration and information technologies. The basic idea is that globalization and new technologies jointly contribute to expanding the market for skills from a local to a global one, thus increasing the opportunities for the best managers, lawyers, doctors, to become even more appreciated and better paid. To the extent that the earnings of executives and staff workers are increasingly tied to firm performance, this tendency is likely to spread also in the salaries and wages of more and more employees. According to this view, as globalization advances, compensations for the best paid will become greater within all segments of the labour market, as the evidence suggests.

In this Paper, we take this view of the labour market at its extreme. Individual income comes from claims on the earnings of raw inputs traded on competitive markets and from the *rents* associated with individual specific talents. As in Rosen (1981), income distribution is thus shaped by the distribution of rents generated by individual abilities. What we add to the Rosen (1981) analysis is a full-fledged general equilibrium framework, where the interaction between income distribution and market openness can be meaningfully analysed. We do that in the simplest way. Our point of depart is a standard monopolistic competition trade model (Krugman (1980)).

In such a setting, we let workers differ in their abilities, assuming that more talented workers produce better goods. As it is standard under monopolistic competition, firms will thus supply different product varieties, but the firms employing better workers will also capture larger market shares and enjoy higher profits. Since trade costs may take the form of fixed costs, only firms employing a high-quality staff are in the position to export a share of their output, because this is the condition for achieving a sufficiently big market share. The implication for income distribution is straightforward. Competition for skills will ensure that more able workers will receive a premium above those endowed with less talent. Skill premia, in turn, will depend on factors affecting firms' market size, including trade barriers and communication technology. In such a setting, since the decision to export on the part of each firm is endogenous, income distribution and the degree of market openness are interrelated phenomena.

We model globalization both as reduction in trade costs and improvements in production or communication technologies. As for trade costs, they may take the form of iceberg transport costs or fixed market-access costs. Lower transport costs allow exporting firms to sell a higher amount of output abroad, thus expanding the size of their market. If it is market-access costs that are reduced, as a direct effect, a higher mass of firms will start finding it convenient to sell a share of their output abroad. Finally, as new technologies allow firms to manufacture better products or to better communicate the quality of their goods, consumers everywhere start discriminating more and more among these products, placing a lot of weight on the perceived quality of the product. So, as globalization proceeds, consumers will not only dispose of higher product variety, but will also concentrate their sales on best-selling products, thus buying a lot of Spice Girls CDs, but very little of local singers' records.

In this setting, contrary to the predictions of the new trade theory, in spite of the fact that globalization entails aggregate welfare gains, some workers may lose both in nominal and real terms from reduced trade barriers in a model where trade is only intra-industry. This is because trade (and technology) shocks have different effects upon workers with different abilities. Real gains to a seller are guaranteed only if does better than the average competitor. Moreover, the model allows for a characterization of the different implications brought about by trade and technology on income distribution, thus helping in disentangling trade and technology as possible sources of income inequality. If globalization takes place in terms of reduced trade barriers, we find that income is redistributed from non-exporting to exporting firms (and that more firms choose to export). Since the former generally employ workers of lower skills and pay, the effect is to raise the extent of wage inequality, although welfare, as measured by real GDP, rises. If globalization takes place in terms of improved production or communication technologies, then we find more ambiguous effects: the less skilled may either lose or gain, depending on whether technology is skill-complementary or substitute and the share of exporting firms may either rise or fall. These findings provide a criterion for empirically disentangling the distributive impact of trade and technology. Rising wage inequality across plants or firms should be systematically associated with the export status of firms (as found in Bernard and Jensen (1997)) only in the case of trade shocks.

The main policy implication of the analysis is that globalization, although welfare-improving, is likely to raise inequality and to foster demand for protection, particularly by the non-traded sector. Redistribution, rather than protection, should be the answer. The implications for redistribution, however, may be more complex than the traditional skilled/unskilled distinction would suggest. Globalization entails income transfers even among those workers that appear to be skilled. The export status of firms and plants may guide policy action to target the sectors who stand to lose more.

1. Introduction

"Globalization", "Internet economy", "Electronic trade" are the buzzwords of the day. However, the enthusiasm for the opportunities offered by new markets and technologies is often cooled down by worries concerning their possible consequences on income distribution. Will a globalized society be more or less "equal"? Who will be the winners and the losers? In spite of abundant empirical work aimed at assessing the causes of increasing wage inequality, the distributive implications of globalization are not yet fully understood.

"New" trade theory based on imperfect competition, while accounting for the failure of international convergence in factor prices, are in general silent about the implications of trade integration upon within-countries inequality.[1] A general prediction is that intra-industry trade has a small effect on income distribution, and is likely to lead to higher welfare for all agents.

Traditional trade theory predicts that trade integration between developed and less developed countries will benefit skilled workers in the former, and manual workers in the latter (assuming these are the relatively abundant factors in the two areas). This view is generally refuted by the data. The actual changes in product prices generated by trade integration are hardly sufficient to explain the observed deterioration of the relative position of the unskilled.[2] In addition, the Stolper-Samuelson theorem cannot account for the fact that inequality has risen dramatically within narrowly defined segments of the labor market (Juhn at al. (1993) [11]) i.e. between workers of similar occupations, education levels, and, in general, belonging to similar "skill" categories.

The conventional view is that the most part of the rise in wage inequality during the last two decades is not due to changes in relative product demand associated with trade. The culprit is more often identified in shifts in labor demand, away from the unskilled, induced by technological change within most industries (see, e,g., Lawrence and Slaughter (1993)[12]).

[1] See, for instance, Helpman and Krugman (1985)[8].

[2] See Freeman (1995)[5], Rodrik (1997)[14] and Slaughter and Swagel (1997)[16] among recent surveys on the empirical literature concerning the trade and wages debate.

The empirical work aimed at assessing the e¤ect of trade on wage inequality has only recently shifted from industry to …rm-level analysis. A number of studies, conducted at …rm or establishment level, have found robust empirical links between exporting activity, …rms' performance, and wages. Bernard and Wagner (1998)[3], in a study on export decision of German …rms in Saxony, …nd evidence that "successful plants, measured by size or productivity, are more likely to become exporters, as plants with greater shares of skilled labor".[3] Bernard and Jensen (1997)[1], in a plant-level study for the US, …nd that skilled/unskilled wage premia has been rising during the eighties especially due to between-plants changes, with the most part of these changes explained by plants' export growth. This new "micro" evidence seems to suggest that changes in the goods market, and those related to trade in particular, have indeed a role in explaining the rise of wage inequality.

This paper studies the e¤ects globalization on wage inequality in a model that accounts for the positive association between exporting, market size, and wage premia.

Our description of a "global economy" is based on three crucial ingredients. The …rst is increasing returns in production. Market size matters. This is the basic tenets of "new" trade theory. The second is the role of technology in production and communication. Technological improvements enable more talented suppliers to improve the quality of their products and allow …rms to reach a larger mass of consumers. The third ingredient is transport costs and market access costs that segment the international market. As globalization proceeds, barriers to trade tend to fall. Combining these ingredients into a simple trade model, we obtain a representation of the "global" economy that is reminiscent of Rosen's (1981)[15] "Economics of Superstar".[4]

In his seminal paper, Rosen discussed the role that non-convexities in production may exert on income distribution. Some products are like non rival public goods: singing on a satellite-broadcast TV program or in a small cafe requires approximately the same e¤ort.

[3] Bernard and Jensen (1998)[3] …nd consistent evidence: larger and faster growing …rms are more likely to start exporting.

[4] See also Grossman and Maggi (1998)[6] for a representation for an open "Superstars" economy based on the use of submodular production functions.

For products where these non-convexities are particular important and where "talents" are particularly appreciated by consumers, even small di¤erences in "skills" are associated with disproportionate di¤erences in incomes (think of the show-biz, sport, science etc.).

Frank and Cook (1995)[4] recent best seller has popularized the idea of "winner-take-all" markets. To the extent that the earnings of executives and sta¤ workers are increasingly tied to …rm performance, the tendency towards increasing di¤erentials in earnings is likely to spread from professionals and executives towards salaries and wages (as shown, for instance, in Hall and Liebman (1998)[7]).

In this paper we take an admittedly extreme view of the labor market. Individuals derive their income from the rents associated with their speci…c skills. As in Rosen, the income distribution is shaped by the distribution of rents generated by individual abilities. To that we add a fully-‡edged general equilibrium model, where the interaction between the distribution of wages, the size of …rms and exporting decisions can be analyzed.

We consider a monopolistic competition trade model (Krugman (1980)[9]), where workers di¤er in their abilities. Firms supply di¤erent product varieties, and this generates demand "niches" and market power for all sellers. However, the usual symmetry that characterizes monopolistic competition models does not hold in our formulation because those …rms that employ better workers also manage to produce goods of better quality, to capture larger market shares and to enjoy higher pro…ts. Due to the presence of a …xed cost to access foreign markets, only …rms employing a "high-level" sta¤ bene…t from exporting. In such a setting, the decision to export is explicitly modelled, so that the economy's degree of openness and the distribution of income are jointly determined.

As barriers to trade fall, more …rms will bene…t from exporting and will have access to a larger market. Competition for skills boost skill premia in exporting …rms. Hence, trade integration unambiguously leads to a redistribution of income from the workers employed in non-exporting …rms to those employed in the export sector. Since the latter employs workers of greater skills, trade integration raises wage inequality. Even if aggregate welfare unambiguously rises following a reduction in trade barriers, low-skilled workers may end up losing in nominal and even in real terms.

The introduction of new technologies allows …rms to improve the quality of their products, and enables them to better communicate the characteristics of these goods to consumers. Hence, consumers everywhere start discriminating more and more among products, placing increasing weight on their (perceived) quality. As in the case of reduced trade barriers, consumers will concentrate their purchases on best-sellers products. Once general equilibrium e¤ects are taken into account, however, it emerges that the redistributive e¤ects of technological progress crucially depends upon the degree of complementarity of technology with workers' skills. Moreover, contrary to trade integration, technical change may reduce the share of exporting …rms in the economy.

These …ndings may be useful in disentangling trade and technology when interpreting empirical evidence. Increasing wage inequality would be systematically associated with export growth only when globalization takes place via reduced trade barriers.

The remainder of the paper is organized as follows. In section 2 we present the model. Consumers' and …rms' problems are solved in Section 3, while Section 4 presents the general equilibrium solution. Some comparative statics exercises are performed in Section 5. Section 6 summarizes the main conclusions.

2. The Model

The world consists of two symmetric countries. We focus on the domestic country. Firms produce di¤erentiated goods under imperfect competition and free-entry. Consumers like variety, according with the Dixit-Stiglitz formulation. Production requires two factors of production: skill ("talent"), whose total endowment is denoted by S, and a composite primary input, M (unskilled labor, raw materials). The market for production factors is competitive. The economy is populated by a continuum of households-workers, indexed by h, $h \in [0; H]$. Worker h is endowed with the amount raw inputs M^h, $\int_0^H M^h dh = M$. Skills are measured by the index

s. More talented workers are characterized by higher s. Skills are distributed over the interval $[\underline{s}; \overline{s}]$, according to an everywhere continuous cumulative distribution whose associated density is denoted by $\phi(s)$. Necessarily, $\int_{\underline{s}}^{\overline{s}} \phi(s) s ds = S$. Production requires one skilled worker and an amount of composite input proportional to output. Raw inputs provide standardized services for production. Workers' skills improves the quality of the product. As a consequence, products are differentiated both along a horizontal dimension (variety) and a vertical one (quality).

Shipping entails a iceberg transport cost plus a fixed market access cost (setting up a network of distributors abroad, covering legal expenses, etc.). Because of the fixed export costs, some firms prefer not to export their output at all. On the other hand, because of iceberg transport costs, no firm is willing to sell their production on the foreign market alone. As a result, firms may either sell only on the domestic market, or in both domestic and foreign markets.

2.1. Production Technology

There is one consumption good, X, which is suitable to be differentiated along a continuum of varieties i, $i \in R$: Each variety i is produced out of raw inputs, M; and skill, S. Each worker can employ her skills in the production of at most one variety of good X. The size of firms is normalized in such a way that one firm employs the skill of one worker. Each firm thus supplies only one variety. Raw inputs requirements are proportional to output. Let $w(s)$ and v denote, respectively, the return to skills of a worker endowed with "talent" s and that of raw inputs M. The cost of producing X units of variety i; when a type-$s(i)$ worker is involved is:

$$C(s(i); i) = w(s(i)) + v\beta X(s(i); i) + \delta^i v\gamma: \quad (2.1)$$

The parameter β represents the inverse of marginal productivity of raw inputs (units of inputs required for producing one unit of the variety i). The third term on the right hand side has the following interpretation. If the firm also sells in the foreign market it has to incur a fixed costs γ, which represents the extra units of composite inputs that are required to export [5]. We

[5] Market access costs have been modelled as fixed costs in other papers. See, for instance, Smith and Venables (1991)[17]. Empirically, fixed (sunk) costs seem to play a crucial role in affecting export decisions (see, for

denote the set of all different varieties supplied by N, and the subset of traded goods by N^e: If the variety i belongs to N^e; then $\delta^i = 1$ and the firms sells at home and abroad. If the variety is not exported, $i \notin N^e$; $\delta^i = 0$; and no cost is incurred.

Firms are atomistic profit-maximizers. They produce goods which are imperfect substitutes and set their price, taking as given other firms' choices (the "large group" Chamberlinian hypothesis holds). Consumers' utility increases with the extent of variety in consumption. As it is standard in monopolistic competition models, love for variety plus increasing returns in production insure that no firm is willing to supply the same variant offered by a rival. However, contrary to standard monopolistic competition models, the number of products here is determined by the equilibrium condition of the skill market. Since each firm requires the skill of one worker, we have necessarily that $N = H$. In turn, the condition of free-entry ensures that skilled workers perceive all the operating profits realized by firms. Workers' income is thus constituted by the sum of earnings from their endowment of raw inputs (sold on a competitive market) and skill rents associated with firms' operating profits.[6] This is a first analogy of our model with Rosen (1981)[15].

2.2. Preferences

Households have identical tastes, but different incomes, depending on their endowments of production factors. The income of household h, endowed with skills s and raw inputs M^h, is thus

$$I^h(s; M^h) = vM^h + w(s) \tag{2.2}$$

Consumers like variety, in the sense that their utility is increasing with the number of varieties consumed, according with the Dixit-Stigliz formulation. A distinguishing feature of our formulation is that more talented entrepreneurs produce better quality of each variety, and better quality is appreciated by consumers. Households derive utility from a combination of

instance, Bernard and Wagner (1988) [3] and Roberts and Tybout (1997) [13])

[6] In the remainder of the paper we will use indifferently the words wages, skill premia, or skill earnings, in referring to the rents accruing to workers' skills.

the quantity, X; and the "quality", indexed by $T(.)$; of each good. In this sense, a commodity is assimilated to a bundle of a physical good, X; and of an intangible good, $T(.)$ (the griffe of a fashionable tailor, the sound of a particular pop group, etc.), that is incorporated in the tangible commodity. For simplicity, we adopt a Cobb-Douglas specification to nest $T(.)$ and X^h, while we use the standard CES specification for different varieties:

$$U^h = \left[\int_{i=0}^{N} (T(s(i);a))^{1-\rho} \left(X^h(s(i);i) \right)^{\rho} di \right]^{\frac{1}{\rho}}. \tag{2.3}$$

As usual, the parameter $\rho \in (0;1)$ is related to the elasticity of substitution between different varieties $\sigma = 1/(1-\rho) > 1$. This coincides with the price elasticity of the demand for each variety and therefore (inversely) measures the degree of market power of individual firms. $T(.)$ is a function that matches the particular skill of the entrepreneur, s, and the state-of-the-art technology, a, into the appreciated quality of the good. A product "quality" thus depends on two factors: the skill of the entrepreneur producing the good, s; and the existing stock of technical knowledge a. This element reflects the cumulated stock of know-how in production and in communication. A technological break-through enables firms to improve their product quality or to market their products more effectively, raising consumers' satisfaction. Here a plays the role of a shift parameter. We assume that $T(s;a)$ is a twice-differentiable continuous function satisfying some requirements: First, quality improves with technical progress, so that $T_a(s;a) > 0$ for all $s;a$. Second, more talented entrepreneurs produce "better" goods, so that $T_s(s;a)) > 0$; for all s and a. Finally, we add structure to this function assuming that the elasticity of $T(.)$ with respect to s, $\vartheta(s;a) \equiv T_s(s;a)s/T(s;a)$, is monotonic in a. According as $\vartheta_a(s;a)$ is equal to , higher or lower than zero, we say that technology is skill-neutral, skill-complement or skill-substitute.

Notice that our production and consumption technologies capture two important asymmetries between the role of primary inputs and skills in production. First, while costs related to primary inputs increase with output, the same expenditure for talent is required in serving a large or a small market. Second, even if both factors are required for production of a "standardized " variety, X (i.e., a good of quality $T(.) = 1$), only workers' ("entrepreneurial") talent can add "quality", according to the technology $T(s;a)$: These particular features of our model – namely, non-convexities in production and consumers valuing the characteristics associated with talented producers – give it its Rosen-type ‡avor.

3. Firms' and households' equilibrium

3.1. Demand, Exports and Imports

The results of our model depart in some aspects from the standard monopolistic competition trade models (Helpman and Krugman (1986) [8]). Like the standard model, due to love for variety, consumers will try to spread their purchases across all available goods, produced either domestically or in the foreign country. However, not all …rms will …nd it convenient to supply foreign consumers, because of the presence of …xed market access costs. In the standard model all …rms sell abroad and their number is determined by the zero pro…t condition. Here, the total number of …rms (entrepreneurs) is given, while the mass of exporting …rms is endogenously determined.

We denote by an asterisk variables referring to the foreign country. Recall that, from the assumption of symmetry, all …rms and workers abroad have access to the same technology as domestic workers and …rms, de…ned by equation (2.1) and by the function $T(s;a)$. Let N and $N^{¤}$ denote, respectively, the mass of distinct varieties of the consumption good produced under free-trade at home and abroad. Now, let the subset N^e ´ fi 2 $[N_{m^¤}; N]$; $N_{m^¤}$ ¸ 0g be associated with goods that are sold both at home and abroad (domestic exports, foreign imports). By symmetry, the varieties N^m ´ fi 2 $[N^{¤}_m; N^{¤}]$; $N^{¤}_m$ ¸ 0g denote home imports of foreign goods.

In addition to the …xed market access costs ° (see (2.1)), there is another impediment to trade, namely transport costs of the iceberg type. For one unit shipped abroad, 1 ¡ ¿ is lost in transit, and only a fraction 0 < ¿ < 1 arrives to foreign consumers. Hence ¿ inversely measures the extent of transport costs.

Consider the home country. Household h maximizes utility (2.3) subject to the budget constraint (2.2). Domestic demand for home goods is given by

$$X(s(i);a;i;M) = T(s(i);a)\frac{I(M)}{P}\left(\frac{p(s(i);i)}{P}\right)^{-\sigma} \tag{3.1}$$

where I is total domestic income

$$I(M) = \nu M + \int_{s=\underline{s}}^{\overline{s}} \phi(s)w(s)ds \tag{3.2}$$

and P is the CES cost-of-living index that must also take into account imported goods

$$P = \left[\int_{i=0}^{N} T(s(i);a)\, p(s(i);i)^{1-\sigma}di + \right.$$

$$\left. + \int_{i^* = N^*_m}^{N^*} T(s(i^*);a^*)\, (p(s(i^*);i^*)/\tau)^{1-\sigma}\, di^* \right]^{1/(1-\sigma)} : \tag{3.3}$$

Note from (3.1) that demand for variety i has unit elasticity with respect to quality and real households' income, and decreases with the relative price of good i with elasticity σ. Demand for imports, $X^*_m(s(i^*);i^*)$; is instead as follows

$$X^*_m(s(i^*);a^*;i^*;M) = T(s(i^*);a^*)\frac{I(M)}{P}\left(\frac{p(s(i^*);i^*)}{P}\right)^{-\sigma}\tau^{\sigma-1}: \tag{3.4}$$

The lower the transport cost, the lower the relative import price of foreign varieties, the higher imports. Moreover, as the domestic price index falls, real domestic income rises, so that domestic demand for imports rises both for a substitution and for an income effect.

We choose domestic raw inputs as a numeraire, so that $v = 1$: Given the perfect symmetry of the model, it must also be $v^* = 1$ at equilibrium.

Denote the firm's exports (foreign demand for its goods) by X_{m*}: Depending on whether firm i is only selling on the domestic market or is also exporting, her profits will differ:

$$\pi(s(i);i) = p(\cdot)X(\cdot) + \delta^i p^*(\cdot)X_{m*}(\cdot) -$$

$$-\left[w(\cdot) + \beta\left(X(\cdot) + \delta^{-}X_{m^*}(\cdot)\right) + \delta^{-\gamma} \right]. \quad (3.5)$$

Profit maximization leads to mark-up pricing. Since the elasticity of demand is the same for each "quality", all firms will set the same mark-up over marginal costs. Moreover, since all firms share the same technology, all varieties will sell for the same ("free-on-board") price, in both countries[7]

$$p(s(i); i) = p^*(s(i); i) = \frac{\sigma}{\sigma - 1}\beta \equiv p \quad \text{for all } i;\ s(i). \quad (3.6)$$

As a result , the product quality will only show up in the quantities consumed by households, who will buy more unit of better goods. Using this condition of symmetric pricing (3.6), the domestic and foreign demand for home goods can be rewritten as follows:[8]

$$X(s; a; M) = p^{-\sigma} Y(M)\, T(s; a) \quad (3.7)$$

$$X_{m^*}(s; a; M^*) = p^{-\sigma} Y^*(M^*) T(s; a)\, \tau^{\sigma - 1} \quad (3.8)$$

where

$$Y(M) \equiv I(M)\, P^{\sigma-1}; \quad Y^*(M^*) \equiv I^*(M^*) P^{*\sigma-1} \quad (3.9)$$

denote the domestic and foreign demands for a good of unitary price and "standard" quality ($T(\cdot) = 1$). Because this variables enter multiplicatively in domestic and foreign sales, they can be interpreted as a measure of the scale of a "standard" firm.

Two (endogenous) variables affect the magnitude of Y: aggregate income, I; and the price index, P. Given M, the distribution of skill earnings $w(s)$ univocally determines aggregate income I. Other things being equal, higher households' income raises the demand for a firm's product. Note also that the real income elasticity of demand is unity, while the relative price elasticity is $\sigma > 1$. Therefore a higher P – a higher average price of competitors – raises the demand for each individual producer.

[7] Consistently, we can omit henceforth the index i.

[8] Similarly the domestic demand for foreign goods (imports) is $X^*_m(s; a^*; M) = p^{-\sigma} Y(M)\, T(s; a^*)\, \tau^{\sigma-1}$.

3.2. Income Distribution, Trade, and Technology

We now study the interaction between the distribution of wages and firms' choice to export. Suppose that a firm employing a type-s worker decides not to export. Free entry entails that the earnings of the worker coincides with the firm's operating profits. From (3.5) and (3.6) we see that

$$w^i(s;a;M) = (p-\beta)X(s;a;M) = p^{1-\sigma}Y\frac{T(s;a)}{\sigma} \equiv w^n(s;a;M); \quad i \notin N^e \tag{3.10}$$

In the non-export sector, the earnings of a worker with skill s is positively related to the scale of the domestic market, Y, and to the firm's market power, measured by the mark-up $p-\beta$ (which is inversely related to the price elasticity of demand, σ). Notice that the wage rate increases linearly with quality, $T(s;a)$. The elasticity of the wage with respect to the level of skill, s; coincides with the elasticity of the quality index T; $\vartheta(s;a) \equiv T_s s/T$: Whenever the quality of the product rises more than proportionately with the skill of the producer, $\vartheta(s;a) > 1$, even small differences in skills may result in a large earnings premia and in a skewed income distribution, as in Rosen (1981)[15].

Assume now that a firm employing a type-s worker decides to export. Recalling that an exporting firm must incur a fixed cost γ to access the foreign market, and imposing $a = a^*$; and $M = M^*$; the wage of type-s worker is

$$\begin{aligned} w^i(s;a;M) &= (p-\beta)\left(X(s;a;M) + X_{m^*}(s;a;M^*)\right) - \gamma = \\ &= p^{1-\sigma}\frac{T(s;a)}{\sigma}Y\left(1+\frac{Y^*}{Y}\tau^{\sigma-1}\right) - \gamma \equiv w^e(s;a;M); \quad i \in N^e \end{aligned} \tag{3.11}$$

Comparing (3.10) and (3.11) we see that the wage premium increases even more with s if the firm is exporting, see figure 1.

Insert figure 1 here

The intuition is simple. Each additional unit of talent in exporting firms allows for larger sales in both home and foreign markets. This difference in market size, $\frac{Y^*}{Y}\tau^{\sigma-1}$; is translated in earnings differentials. As in Rosen (1981), are the more talented that gain more from market size.[9] Note that the elasticity of the wage premium with respect to skills is larger in the exporting sector, $(w^e(s)+\gamma)/w^e(s))\,\vartheta(s;a) > \vartheta(s;a)$; a feature which is consistent with empirical evidence concerning the wage premium paid by exporting firms (Bernard and Jensen (1997)[1]).

From (3.10) and (3.11) it is clear that, for given market size Y, trade integration due to lower transport cost (higher τ) or lower access cost γ, boosts the earnings of workers employed in the export sector, while leaving unaffected wages in non-exporting firms. Since, as we shall see, the export sector employs workers of higher skills than the non-export sector, this tends to raise income concentration.

It is now easy to see under what conditions a firm employing a worker with skills s is willing to venture on the export market. It will do so provided this raises its operating profits, i.e. $w^e(s) \geq w^n(s)$. Since the access cost to foreign markets γ is independent of sales, while sales increase with talent, only firms employing sufficiently skilled workers will sell on the foreign market, from (3.10) and (3.11)

$$T(s;a) \geq \frac{\gamma p^{\sigma-1}\sigma}{Y^* \tau^{\sigma-1}}, \tag{3.12}$$

or

$$s \geq Z\left(\frac{\gamma p^{\sigma-1}\sigma}{Y^* \tau^{\sigma-1}}; a\right) \equiv z, \tag{3.13}$$

where $Z(\cdot;a) \equiv T^{-1}(\cdot;a)$.[10]

Consistently with the evidence previously discussed, firms in the export sector tend to employ workers with higher skill and, consequently, to pay them higher wages.

The "degree of openness" of the economy is measured by the share of exporting firms,

[9] "...no wonder that the best economists tend to be theorists and methodologists rather than narrow field specialists, that the best artists sell their work in the great market of New York and Paris, not in Cincinnati, .." Rosen (1981).

[10] Hence, $Z_1 = 1/T_s > 0$; $Z_a = -1/T_a < 0$.

$\int_z^{\bar{s}} \phi(s)ds$. This is endogenously determined. Openness rises (z falls) with the scale of the foreign market, Y^*, since this raises the skill premium and induces more entrepreneurs to venture abroad. Holding constant Y^*, technological change, as measured by changes in a, reduces the cut-off skill level z, because workers with lower skills start producing the threshold quality (check from (3.13), recalling that $Z_a = -1/T_a < 0$.) Clearly, the model generates trade provided

$$\underline{s} < z \leq \bar{s}, \tag{3.14}$$

a condition that we assume to be satisfied in the following analysis.

Trade and technology shocks affect openness z and market size Y^* simultaneously, so that the implications for the wage distribution requires a joint solution for these variables.

4. Model Solution

Invoking symmetry, we can set $Y = Y^*$, and $z = z^*$, and concentrate on the case of balanced trade.[11] Next we exploit the fact that each worker/firm produces a single variety of the good. The space of goods can consistently be mapped into that of skills, and the CES price index (3.3) can be rewritten in terms of the s-distribution,

$$P = \left[p^{1-\sigma} \left(\int_{\underline{s}}^{\bar{s}} T(s;a)\, \phi(s)\, ds + \tau^{\sigma-1} \int_z^{\bar{s}} T(s;a)\, \phi(s) ds \right) \right]^{-1/(\sigma-1)} \tag{4.1}$$

Note that the price level P depends on openness, z. The price index falls whenever more firms decide to venture abroad (z falls). Due to "love for variety", a larger mass of varieties available through imports raises indirect utility, thus reducing the true price index (which is dual to it). In order to derive an expression for Y which only depends upon z, integrate across wages (3.10) and (3.11) and substitute the resulting expressions into aggregate income (3.2). This yields

[11] By symmetry, $N = N^*$, $N_{m^*} = N_m^*$ is required for trade to balance.

$$Y = P^{\sigma-1}\left[M + \frac{p^{1-\sigma}Y}{\sigma}\left(\int_{\underline{s}}^{\bar{s}} T(s;a)\phi(s)ds + \tau^{\sigma-1}\int_{z}^{\bar{s}} T(s;a)\phi(s)ds\right) - \gamma\int_{z}^{\bar{s}} \phi(s)ds\right] \quad (4.2)$$

Substituting the expression for P (4.1) into (4.2), gives

$$Y = \frac{M - \gamma\int_z^{\bar{s}}\phi(s)\,ds}{\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1-\sigma}\left[\int_{\underline{s}}^{\bar{s}} T(s;a)\phi(s)ds + \tau^{\sigma-1}\int_z^{\bar{s}} T(s;a)\phi(s)ds\right]} \quad (4.3)$$

The numerator of expression (4.3) represents the total income of primary inputs employed in manufacturing, M; net of the income earned in export services. Clearly, the more resources are used up in market-access services, the lower the amount of resources that are left for production, and the lower the market size facing a standard firm, Y. The denominator is inversely related to the price index. Since elasticity of demand to the firm relative price exceeds unity (see (3.1)), the substitution effect prevails on the income effect. Hence when the general price index rises (the denominator falls), the individual producer becomes more competitive and her sales rise. It is immediate to check that this expression depends positively on z, $Y_z > 0$. Two effects at work in the same direction. First, when the number of exporting firm falls (z rises), less resources are used for market access, so that the mass of production factors employable in production increases, together with firms' scale. Second, as imports fall, the CES price index rises (see (4.1)), and this makes domestic firms more competitive.

Equations (3.13) and (4.3) jointly determine the size of the export sector, z and the size of a standard firm in the domestic market, Y. The equilibrium can be represented on a simple diagram. Figure 2 depicts equation (4.3), the YY curve, and equation (3.13), the ZZ curve, in the $(z;Y)$ space.[12]

Insert Figure 2 here

The properties of the two curves imply that there exists an unique equilibrium, represented

[12] Note that since we consider an equilibrium with trade, $\underline{s} < z \le \bar{s}$ must hold. Consistently, the range of admissible values for market size must satisfy $\underline{Y} < Y \le \overline{Y}$, where $\underline{Y} \equiv \sigma\gamma\left(\frac{\sigma\beta}{(\sigma-1)\tau}\right)^{\sigma-1}/T(\bar{s};a)$ and $\overline{Y} \equiv \sigma\gamma\left(\frac{\sigma\beta}{(\sigma-1)\tau}\right)^{\sigma-1}/T(\underline{s};a)$.

by the intersection of the two loci. This diagram will help the analysis of next sections, where we perform comparative statics on the system.

5. Trade Integration

Our aim is in this section is to assess the implications of trade integration on the wage distribution. From our diagram and from (3.13) we see that a reduction in transport costs (a rise in ¿) shifts the ZZ curve down to the left (see …gure 3). As transport costs fall, the price set abroad by domestic …rms is reduced, foreign demand increases, and the mass of exporters rises (z falls). From (4.3) we see that the YY locus shifts up to the left. Lower transport costs increase competition from abroad, thus reducing demand for each …rm, at given z. In the new equilibrium, Y unambiguously falls. Even if total sales are boosted by increased exports, each …rm operates on a smaller scale. The degree of openness is subject to two con‡icting forces. One the one hand, lower transport costs boost the demand for exports through a direct price e¤ect. This raises the mass of …rms willing to export (see (3.13)), and z falls. On the other hand, lower transport costs have a negative e¤ect on foreign demand through a scale e¤ect (Y¤ falls), and this reduces the mass of export-oriented …rms (z rises). It can be shown (see the Appendix) that the price e¤ect always dominates, so that the economy becomes more open when transport costs falls, dz=d¿ < 0, con…rming partial equilibrium intuitions.

Insert …gure 3 here

From this result we can derive the e¤ects on the distribution of wages. Equation (3.10) shows that skill premia in the non-exporting sector, $w^n(s)$, must fall proportionately to the contraction the …rm's scale, Y: Conversely, from (3.11) we see that wages in the export sector, $w^e(s)$ may either fall, because market scale Y shrinks, or rise, because lower transport costs entail larger sales abroad.[13] Clearly, even if wages fall in the exporting sector, prevailing the …rst direct e¤ect, they will fall by less than they do in the non export sector. More precisely,

[13] This second e¤ect dominates provided demand is su¢ciently elastic (¾ high).

taken any one worker in the non export sector, indexed by skill $s' \geq z$ and any one in the export sector, $s'' < z$, it is possible to show that their relative wage differential , $w^e(s')/w^n(s'')$, widens with trade integration (see the Appendix). Given that lower transport costs tend to raise the share of the export sector ($dz/d\tau < 0$); a reduction in transport costs unambiguously implies a redistribution of income from the non-export to the export sector of the economy.

It is easy to work out the distributional effects between skilled workers, S on one hand, and owners of primary inputs, M. Denote aggregate skill rents by $\Delta \equiv \int_{\underline{s}}^{z} w^n(s)\phi(s)ds + \int_{z}^{\overline{s}} w^n(s)\phi(s)ds$. From (4.3) one can show that

$$\Delta = \frac{M}{\sigma - 1} - \frac{\gamma\sigma}{\sigma - 1}\int_{z}^{\overline{s}} \phi(s)\, ds. \tag{5.1}$$

Differentiating expression (5.1) yields

$$\frac{d\Delta}{d\tau} = \frac{\gamma\sigma}{\sigma - 1}\phi(s)\frac{dz}{d\tau} < 0; \tag{5.2}$$

since $dz/d\tau < 0$. A reduction in transport costs tilts the income distribution in favor of primary inputs. This result follows immediately by recalling that exporting requires a fixed access cost in term of these inputs. As more firms venture abroad, more primary commodities are demanded for export services. Hence the share of wage rents must fall.

Finally, the effect of trade integration on total welfare can be assessed by looking at changes in the utilitarian indicator $W \equiv I/P = \Delta/P + M/P$. First notice that a fall in transport costs reduces the price level. From (4.1), we see that this is due to two reasons. First, a direct positive effect via lower price of imported good. Second, an indirect effect through the reduction of the threshold z, which raises average quality. As a consequence, the "real" earnings of primary inputs, M/P, unambiguously rises. As for aggregate real skill earnings, Δ/P, the effects are ambiguous, since Δ is reduced by higher τ. In the Appendix we show that the overall effect of lower transport is to increase total welfare, as measured by I/P.

In summary:

Proposition 1. trade integration via lower transport costs (higher τ) has the following effects:

i) openness rises (z falls) and the scale of the standard firm on the domestic market Y shrinks; ii) wages in non-exporting firms are reduced, wages in exporting firms may rise or fall, and their ratio, $w^e(s')/w^n(s'')$, rises iii) there is a redistribution from skill to raw inputs: Δ falls; iv) total welfare W rises.

Two remarks are in order. First, whether trade integration occurs as a result of lower transport cost or because of a reduction in the fixed cost of exporting, γ, does somewhat affects the results. Again, it can be shown that trade integration via lower market access cost redistributes income towards the exporting sector, raises the share of traded goods in the economy, and is welfare improving. However the effects on aggregate skill rents and upon the firms' scale become ambiguous.[14] Second, the fact that aggregate welfare rises as transport costs fall, does not imply that lower trade barriers lead to a Pareto improvement. In other words, some agents may end up worse off when transport costs fall. The distribution of the gains and looses clearly depends on the skill distribution and on the initial distribution of raw inputs M^h. If a worker is employed in the non-export sector (has low skill) and has also a small endowment of raw inputs, it is likely to be hurt by trade integration. To see this more formally, consider a worker employed in the non-exporting sector, who has zero endowment of raw inputs, $M^h = 0$ Her wage, deflated by the CES price index is

$$\omega^n(s) = p^{1-\sigma}\frac{T(s;a)}{\sigma}\frac{Y}{P}. \qquad (5.3)$$

Applying the definition $Y \equiv IP^{(\sigma-1)}$ and totally differentiating $\omega^n(s)$ with respect to τ yields

$$\frac{\partial \omega^n(s)}{\partial \tau} = p^{1-\sigma}\frac{T(s;a)}{\sigma}\left[\frac{\partial I}{\partial \tau}P^{(\sigma-2)} + (\sigma-2)P^{(\sigma-3)}\frac{\partial P}{\partial \tau}\right]. \qquad (5.4)$$

Since $\partial P/\partial \tau < 0$ and $\partial I/\partial \tau = \partial \Delta/\partial \tau < 0$; $\sigma \geq 2$ is sufficient to imply $\partial \omega^n(s)/\partial \tau < 0$.

[14] These results can be obtained from the authors upon request.

6. Technological Progress

Now consider what happens when, as a result of a rise in technical knowledge, a, the quality of all products improves. Clearly, this means that a lower skill endowment is now required for achieving any given quality standard. Thus, from (3.13) the ZZ curve shifts down to the left in Figure 2 (recall that $Z_a = -1/T_a < 0$.) A higher fraction of firms can benefit from exporting, at given scale Y. In turn, from (4.3), the YY curve shifts up to the left, since the price index falls when average quality improves. Hence, each firm's output becomes relatively more expensive compared with that of competitors, and demand falls. In the new equilibrium, a technology shock reduces the firm's size, Y, but, differently from trade integration, has an ambiguous effect on openness, z.

The implications for wages can be assessed as follows. Denote the elasticity of product quality and of firm scale with respect to a, respectively, by $\eta(s;a) = T_a(s;a)a/T(s;a)$, and $\xi(a) = -(dY/da)a/Y > 0$. Differentiating the wage equations (3.10), (3.11) with respect to a we find

$$\frac{dw(s)}{da} \gtrless 0 \Leftrightarrow \frac{p^{1-\sigma}}{\sigma}\frac{T(s;a)Y}{a}\left[\eta(s;a) - \xi(a)\right] \gtrless 0 \qquad (6.1)$$

in both the export and non export sector.

A technology shock exerts two contrasting forces on wages: a positive, firm-specific effect, η, and a common negative effect, ξ. The first one reflects the fact that better quality directly raises firms' demand, thus boosting operating profits. The second effect works through rivals' competition. As the general price level falls due to better average quality, each firm's product become relatively more expensive, and this lowers firms' size Y. As a consequence, the effects on skill earnings and income distribution are in general ambiguous.

A useful benchmark is the case of a linear technology $T(s;a) = as$. It is easy to show that in this case $\eta(s;a) = \xi(a) = 1$, (see Appendix). The firm-specific effect is completely offset by the common effect, so that nominal wages are unaffected by the shock. In this linear example, aggregate skill earnings Δ are not affected by technology shocks (see from (5.1)). Nor is the income distribution between entrepreneurs and primary inputs. In summary, when technological improvements are skill-neutral, they simply result into a lower price index, thus raising welfare, W.

In order to generalize the analysis, remember that all firms experience lower sales via the common competition effect, $\xi(a)$; while the positive "quality" effect, $\eta(s;a)$; varies across firms. For some s; the square bracket in (6.1) may be positive: these firms will benefit from technical progress. For some other, the opposite may hold, $\eta(s;a) < \xi(a)$; implying a loss. Of course, results crucially depend on how $\eta(s;a)$ changes with s. Suppose, for instance, that technology is skill-complement, that is $T_{as}(s;a)$ is "sufficiently" large, so that entrepreneurs with high skill can exploit the technical innovation better than less talented entrepreneurs.[15] Then the "quality" effect will tend to dominate for more skilled workers, who will benefit from the innovation, while the "competition" effect may dominate for the less skilled, who will lose. In the Appendix we show that there always exists a skill level $\hat{s} \in [\underline{s};\bar{s}]$ such that the two effect cancel out: $\eta(\hat{s};a) = \xi(a)$: Provided technology and skill are complements, a technological shock boosts the earnings a workers with skill $s > \hat{s}$ and reduces those of workers of type $s < \hat{s}$. Also, for reason discussed in the Appendix, the effect on z has ambiguous sign.

Finally, skill-biased technology shocks also have ambiguous implications on the aggregate income distribution between raw inputs and skilled workers. This can be understood by differentiating Δ in (5.1) with respect to a:

$$\frac{d\Delta}{da} = \frac{\gamma\sigma}{\sigma - 1}\phi(z)\frac{dz}{da} \qquad (6.2)$$

and recalling that z may either fall or rise.

Similarly to trade shocks, technical progress can be show to raise welfare W (see the Appendix).

Summarizing,

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[15] A simple example of skill-complement technology is $T(s;a) = as + c; c > 0$: The product's quality depends on a common "state of the art" component, c; and on an idiosyncratic one, proportional to the level of skills.

Proposition 2. technological progress (an increase in a) has the following effects i) openness (z) may rise or fall, while firms' scale Y falls; ii) if technology is skill-complement (skill-substitute), workers endowed with talent $s < \hat{s}$ experience a fall (rise) in their wage rate; iii) the aggregate skill premium, Δ, may rise or fall; iv) total welfare, W, rises.

Two are the main differences with respect to trade integration. First, skill-biased technology shocks may redistribute earnings among firms belonging to the same sector, while trade shocks unambiguously redistributes income from the non-export to the export sector. Second, while reduced trade barriers increase the extent of trade integration, technological shocks have an ambiguous effect on the share of exporting firms.

7. Conclusions

We have studied the effects "globalization" on wage inequality. Many different things are often meant by "global economy". In the spirit of the "Economics of Superstar", we have discussed two: trade integration in the form of lower transport cost, and technology innovations that enable suppliers to improve the (perceived) quality of their products and raise consumers' satisfaction.

If globalization takes place in terms of reduced trade barriers, then we find that income is redistributed from non-exporting to exporting firms (and that more firms choose to export). Since the former generally employ workers of lower skill and pay, the effect is to raise the extent of wage inequality, although welfare, as measured by real GDP, rises. This result differs from the conclusions of much of the existing trade theory. Income redistribution in favor of the export sector is a well-known feature of "fixed-factor" models (Jones (1971)[10]). In our model, however, trade is intra-industry, and wage differentials widen even among exporting firms. Conversely, the new trade theories typically imply that (intra-industry) trade does not produce victims. In our setting, trade (and technology) shocks have different effects upon workers with different abilities. Real gains to a seller are guaranteed only if she does better than the average competitor.

If globalization takes place in terms of improved production or communication technologies, then we find more ambiguous effects: the less skilled may either lose or gain, depending on whether technology is skill-complement or substitute, and the share of exporting firms may either rise or fall.

Clearly, our results derive from an extreme view of the labor market, where wage earnings are associated with skill-specific rents. However, these findings provide a criterion for disentangling empirically the distributive impact of trade and technology. Rising wage inequality across plants or firms should be systematically associated with the export status of firms (as found in Bernard and Jensen (1997)[1]) only in the case of trade shocks.[16]

The main policy implication of the analysis is that globalization, although welfare improving, is likely to raise inequality, and to foster demand for protection, in particular by the non traded sector. Redistribution, rather than protection, should be the answer. The implications for redistribution, however, may be more complex than the traditional skilled/unskilled distinction would suggest. Globalization entails income transfers even among those workers that appear to be skilled. The export status of firms and plants may guide policy action to target the sectors who stand to loose more.

8. Appendix

8.1. Lower transport costs

8.1.1. Effects on openness (z) and firm size (Y)

We show that $\partial z / \partial \tau < 0; \partial Y / \partial \tau < 0$

Proof. Total differentiation of the system formed by (3.13) and (4.3) yields

[16] Bernard and Jensen (1997)[1] are cautious in attributing wage inequality changes to export demand alone, in that export status and technology status appear to be strongly correlated. It is to note that, in our framework, this correlation is compatible with trade-induced shifts in income distribution.

$$\frac{\partial z}{\partial \tau} = \frac{z_\tau + z_Y Y_\tau}{1 - z_Y Y_z} \tag{8.1}$$

$$\frac{\partial Y}{\partial \tau} = \frac{Y_\tau + Y_z z_\tau}{1 - z_Y Y_z}; \tag{8.2}$$

where subscripts denote partial derivatives. Recall that $z_Y < 0$ and $Y_z > 0$; so that the denominator of (8.1) and (8.2) is positive. In the second expression $Y_\tau < 0$ and $z_\tau < 0$, so that $\frac{\partial Y}{\partial \tau} < 0$.

As for z, the two terms in the numerator have conflicting sign, $z_\tau < 0$ and $z_Y Y_\tau > 0$. Therefore $\frac{\partial z}{\partial \tau} > 0$ if and only if $z_Y Y_\tau > -z_\tau$. Computing these expressions from (3.13) we have

$$z_Y = -\frac{1}{T_s(z;a)} Y^{-2} \frac{\gamma\sigma p^{\sigma-1}}{\tau^{\sigma-1}} = -T(z;a)/T_s(z;a)Y; \tag{8.3}$$

$$z_\tau = \frac{1}{T_s(z;a)} \frac{\gamma\sigma p^{\sigma-1}}{Y}(1-\sigma)\tau^{-\sigma} = -(\sigma-1)T(z;a)/T_s(z;a)Y\tau. \tag{8.4}$$

From (4.3) we derive

$$Y_\tau = -Y\Lambda^{-1}p^{1-\sigma}\frac{(\sigma-1)^2}{\sigma}\tau^{\sigma-2}\int_z^{\bar{s}} T(s;a)\phi(s)ds;$$

where $\Omega > 0$ and $\Lambda > 0$ represent, respectively, the numerator and denominator of (4.3). Therefore, we can write

$$z_Y Y_\tau = \frac{1}{T_s(z;a)} \gamma Y^{-1}\Lambda^{-1}(\sigma-1)^2\tau^{-1}\int_z^{\bar{s}} T(s;a)\phi(s)ds. \tag{8.5}$$

It appears that the condition $z_Y Y_\tau > -z_\tau$ which is necessary and sufficient for $\frac{\partial z}{\partial \tau} > 0$ can be satisfied if and only if

$$p^{1-\sigma}(\sigma-1)\Lambda^{-1}\int_z^{\bar{s}} T(s;a)\phi(s)ds > \sigma\tau^{1-\sigma}. \tag{8.6}$$

After developing the denominator Λ; we can rewrite

$$\frac{\sigma\int_z^{\bar{s}}\phi(s)T(s;a)ds}{\int_{\underline{s}}^{\bar{s}} T(s;a)\phi(s)ds + \tau^{\sigma-1}\int_z^{\bar{s}} T(s;a)\phi(s)ds} > \sigma\tau^{1-\sigma}; \tag{8.7}$$

which implies

$$\frac{\tau^{\sigma-1}\int_z^{\bar{s}}\phi(s)T(s;a)ds}{\int_{\underline{s}}^{\bar{s}}T(s;a)\phi(s)ds+\tau^{\sigma-1}\int_z^{\bar{s}}T(s;a)\phi(s)ds}>1. \tag{8.8}$$

This inequality is never satisfied. So we find that $\frac{\partial z}{\partial \tau}<0$. ■

8.1.2. Effects on relative wages,

We show that $\partial(w^e(s')/w^n(s''))/\partial\tau>0$ for $s'>z$, $s''\leq z$.

Proof. First, remark that given any pair of wages for skill levels $s'>z$, $s''\leq z$ the following holds

$$\frac{\partial(w^e(s'))/w^n(s''))}{\partial\tau}>0 \iff \frac{\partial w^e(s')/\partial\tau}{w^e(s')}>\frac{\partial w^n(s'')/\partial\tau}{w^n(s'')}. \tag{8.9}$$

Since $\partial w^n(s'')/\partial\tau<0$, it follows that $\partial(w^e(s')/w^n(s''))/\partial\tau>0$ is trivially satisfied whenever $\partial w^e(s')/\partial\tau>0$. We show in the following that it is satisfied also when $\partial w^e(s')/\partial\tau<0$.

Take any relative wage rate in the non-export sector $w^n(s')/w^n(s'')$, $s'\geq z$, $s''\geq z$. These are not affected by transport costs (check (3.10)). It follows from (8.9) that $\frac{\partial w^n(s')/\partial\tau}{w^n(s')}=\frac{\partial w^n(s'')/\partial\tau}{w^n(s'')}$. Remark also that by definition of z, (i.e., $s\in(\underline{s};\bar{s})$ satisfying $w^e(z)=w^n(z)$), and by $\partial z/\partial\tau<0$ we have

$$\frac{\partial(w^e(z))/w^n(z))}{\partial\tau}>0. \tag{8.10}$$

Following a reduction in trade barriers, relative wages between exporting and non exporting firms computed at the threshold value z must rise. Using (8.10) and (8.9) yields

$$\frac{\partial w^e(z)/\partial\tau}{w^e(z)}>\frac{\partial w^n(s)/\partial\tau}{w^n(s)}=\frac{\partial w^n(s')/\partial\tau}{w^n(s')},\quad \text{for any } s \text{ and } s'<z.$$

As for wage changes in the export sector, they are expressed as follows

$$\frac{\partial w^e(s)/\partial\tau}{w^e(s)}=\frac{p^{1-\sigma}T(s;a)\left[\frac{\partial Y}{\partial\tau}(1+\tau^{\sigma-1})+Y(\sigma-1)\tau^{\sigma-1}\right]}{p^{1-\sigma}YT(s;a)(1+\tau^{\sigma-1})-\sigma\gamma},\quad s\geq z.$$

Since when $\partial w^e(s')/\partial\tau<0$ the previous expression is increasing in s, we can write

$$\frac{\partial w^e(s')/\partial\tau}{w^e(s')}>\frac{\partial w^e(z)/\partial\tau}{w^e(z)}>\frac{\partial w^n(s'')/\partial\tau}{w^n(s'')},\quad \text{for any } s'>z,\ s''\leq z;$$

which trivially implies $\frac{\partial (w^e(s')/w^n(s''))}{\partial \tau} > 0.$ ■

8.1.3. Effects on welfare

We show that $\frac{\partial W}{\partial \tau} > 0$:

Proof. Our utilitarian welfare indicator, $W = \frac{I}{P}$ can be rewritten as $W = \left[\frac{\sigma}{\sigma - 1}\right]^{\frac{\sigma}{\sigma-1}} \Theta^{\frac{1}{\sigma-1}} \beta$. Therefore,

$$\frac{\partial W}{\partial \tau} = \left[\left(\frac{\sigma}{\sigma - 1}\right)^{\frac{\sigma}{\sigma-1}}\right] \left[\frac{\partial \beta}{\partial \tau} \Theta^{\frac{1}{\sigma-1}} + \frac{1}{\sigma - 1} \beta \Theta^{\frac{1}{\sigma-1} - 1} \frac{\partial \Theta}{\partial \tau}\right]. \tag{8.11}$$

After developing $\frac{\partial \beta}{\partial \tau}$ and simplifying, we note that $\frac{\partial W}{\partial \tau} > 0$ is satisfied if and only if

$$-\gamma \phi(z) \frac{\partial z}{\partial \tau} \Theta^{\frac{1}{\sigma-1}} < \beta \frac{1}{\sigma - 1} \Theta^{\frac{1}{\sigma-1} - 1} \frac{\partial \Theta}{\partial \tau}; \tag{8.12}$$

a condition that can be rewritten as

$$-\gamma \phi(z) \frac{\partial z}{\partial \tau} < Y \frac{1}{\sigma - 1} \frac{\partial \Theta}{\partial \tau}. \tag{8.13}$$

Using expression (3.13) the above inequality can be written as

$$-\phi(z) \frac{\partial z}{\partial \tau} T(z; a) \frac{p^{1-\sigma}}{\sigma} \tau^{\sigma - 1} < \frac{1}{\sigma - 1} \frac{\partial \Theta}{\partial \tau}. \tag{8.14}$$

Developing $\frac{\partial \Theta}{\partial \tau}$ and simplifying (8.14) can be reduced to

$$(\sigma - 1) \tau^{-1} \int_z^{\bar{s}} T(s; a) \phi(s) ds > 0; \tag{8.15}$$

an inequality which is always satisfied. ■

8.2. Technological progress

8.2.1. Linear Technology

We show that when $T(s; a) = as$, then $\frac{dw(s)}{da} = 0$ for all s, a:

Note first that when $T(s;a) = as$, trivially $\eta(s;a) = 1$ for all s, a: From equations (4.3) and (3.13) Y and z can be written as

$$Y = \frac{M - \gamma \int_z^{\bar{s}} \phi(s)\, ds}{a\left(\frac{\sigma-1}{\sigma}\right)^{\sigma-1-\sigma}\left[\int_{\underline{s}}^{\bar{s}} s\phi(s)ds + \tau^{\sigma-1}\int_z^{\bar{s}} s\phi(s)ds\right]};\ z = \frac{\gamma\sigma p^{\sigma-1}}{aY\tau^{\sigma-1}} \tag{8.16}$$

When $T(s;a) = as$, z is unaffected by technology shocks (the term a at the denominator of z cancels out with the term a appearing at the denominator of Y). As a result, $\eta(s;a) = \xi(a) = 1$, and, by (??), $\frac{dw(s)}{da} = 0$ for all s, a ■

8.2.2. Effects on wages

We prove that there always exists one and only one value $\tilde{s}$; $\tilde{s} \in [\underline{s};\bar{s}]$ such that $\eta(s;a) = \xi(a)$:

Proof. We first claim the following results.

Result 1. The term $\eta(s;a)$ is monotonically increasing (respectively., decreasing) in s whenever technology is skill-complement (respectively., skill substitute).

Proof. Consider the case of skill-complement technology, so that the elasticity $\vartheta(s;a) \equiv T_s(s;a)s/T(s;a)$; is increasing in a; $\vartheta_a(s;a) > 0$ for all $s;a$. Note that $\vartheta_a(s;a) > 0$ if and only if $T_{as}(s;a) > \frac{T_a(s;a)T_s(s;a)}{T(s;a)}$: From the definition of $\eta(s;a)$, $\eta(s;a) = T_a(s;a)a/T(s;a)$, it emerges that this condition is also necessary and sufficient for $\eta_s(s;a) > 0$. Symmetrically, in the case of skill-substitute technology, $\vartheta_a(s;a) < 0$ implies $\eta_s(s;a) < 0$. ■

Result 2. $\eta(z;a) - \xi(a) \geq 0$ is a necessary and sufficient condition for $\partial z/\partial a \leq 0$

Proof. >From the definition of z; $w^e(z) = w^n(z)$; so that $\partial z/\partial a \leq 0$ requires

$$\frac{\partial w^e(z)}{\partial a} \geq \frac{\partial w^n(z)}{\partial a} \tag{8.17}$$

Using (3.11), (3.10), and (6.1), the above condition amounts to

$$[\eta(z;a) - \xi(a)]\tau^{\sigma-1} \geq 0. \qquad (8.18)$$

■

Consider the case of skill-complement technology. Assume that a value for s satisfying $\eta(s;a) = \xi(a)$ does not exist. Then, by Result 1, either

$$\text{i)} \quad \eta(\underline{s};a) > \xi(a); \qquad (8.19)$$

or

$$\text{ii)} \quad \eta(\overline{s};a) < \xi(a). \qquad (8.20)$$

Assume that i) holds. Then, by Result 1 and (6.1), following a rise in the stock of knowledge a, all wages must rise. Moreover, by Result 2, it must be $\partial z/\partial a < 0$. From (6.2), $\partial z/\partial a < 0$ implies $\partial \Delta/\partial a < 0$. But this contradicts Result 1, according to which $\partial \Delta/\partial a > 0$, because all wages must rise after the shock. Assume, conversely, that ii) holds. Then, by Result 1 and (6.1), a rise in the stock of knowledge a, must reduce all wages. Furthermore, by Result 2, it must be $\partial z/\partial a > 0$. Again, $\partial z/\partial a > 0$ is in contradiction with Result 1, according to which $\partial \Delta/\partial a < 0$ because all wages must fall. A symmetric argument applies to the case of skill-substitute technology.

So, Result 1, Result 2, and (6.1) imply that a value $\hat{s}$, $\hat{s} \in [\underline{s}, \overline{s}]$ such that $\eta(s;a) = \xi(a)$ must exist. Uniqueness is insured by the fact that $\eta(s;a)$ is monotonic in s. ■

8.2.3. Effects on welfare

We show that $\partial W/\partial a > 0$

Proof. Note first that $\partial W/\partial a > 0$ if and only if

$$\frac{\partial I/\partial a}{I} > \frac{\partial P/\partial a}{P}. \qquad (8.21)$$

Since $I = \frac{\sigma}{\sigma - 1}\left(M - \gamma\int_z^{\bar{s}}\phi(s)ds\right) = \frac{\sigma}{\sigma-1}\Omega$, and $P = \left(\frac{\sigma}{\sigma-1}\Lambda\right)^{-1/(\sigma-1)}$, condition (8.21) rewrites as follows

$$\phi(z)\frac{\partial z}{\partial a}\left[\frac{\gamma}{\Omega} - \frac{T(z;a)\tau^{\sigma-1}}{\sigma\Lambda}\right] > -\frac{\partial\int_{\underline{s}}^{\bar{s}}T(s;a)\phi(s)ds/\partial a + \tau^{\sigma-1}\partial\int_z^{\bar{s}}T(s;a)\phi(s)ds/\partial a}{\sigma\Lambda} \qquad (8.22)$$

Using the definition of $T(z;a)$ from (3.13) it is straightforward that the left hand side of (8.22) is identically equal to zero, so that the inequality holds. ■

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