

## THE SKILL BIAS OF WORLD TRADE\*

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This article suggests that international trade, even between identical countries, can raise the relative demand for skilled labour. It shows that a simple generalisation of Krugman's (1979) model of trade in differentiated products has implications for the skill premium, through economies of scale rather than Heckscher–Ohlin effects, that are consistent with a number of stylised facts. It provides new evidence in support of these results by showing that increases in market size lead to higher returns to education, skill premia and income inequality.

The wage gap between high-skill and low-skill workers has widened over the recent past. To have a sense of the magnitude of this phenomenon, during the 1980s the skill premium rose on average by 8% in a sample of 35 developed and developing countries.<sup>1</sup> At the same time, an unprecedented wave of trade liberalisations took place: the share of countries classified as open according to the Sachs–Warner criteria rose from 35% in 1980 to 95% in the late 1990s and the trade share of the average country rose from 59% of GDP to 74%. The simple correlation between the change in the skill premium and the change in the trade share equals 50% in the above mentioned sample, suggesting that the two facts might indeed be related.

These observations have stimulated a growing body of research, aimed at investigating the effect of international trade on wage inequality. The traditional Heckscher–Ohlin model attributes the rising skill premium in OECD countries to the growing competition with imports from low-wage producers due to globalisation.<sup>2</sup> Yet, there are several reasons why this explanation fails to convince. First, although the last two decades have witnessed a substantial increase in the volume of North–South trade, advanced countries still trade too little with developing countries for the effect of low-price imports to be quantitatively relevant.<sup>3</sup> Second, the rise in the skill premium has also occurred in many developing countries, which runs counter

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<sup>1</sup> The skill premium is computed as the ratio of nonproduction to production wages in total manufacturing from the U.N. General Industrial Statistics database. See also Berman *et al.* (1998) and Berman and Machin (2000) for cross-country evidence.

<sup>2</sup> In particular, Wood (1994, 1998) proposes an augmented Heckscher–Ohlin theory based on specialised trading equilibria.

<sup>3</sup> Wood (1998) reports that imports of manufactures from developing countries constitute a small fraction of OECD GDP (about 3%), although this share has almost tripled between 1980 and 1995. The point that these volumes of trade are too small to have an important effect on wage inequality has been forcefully made by Krugman (2000). Leamer (2000) has criticised this argument, as the connection between trade volumes, their factor content and factor prices is model-specific. Deardorff (2000) studies specific cases where the factor content of trade can be used to infer how a move to autarky would have affected factor shares.

to the conventional trade story.<sup>4</sup> Third, most studies suggest that the relative price of skill-intensive goods did not increase during the period of rising skill premia,<sup>5</sup> whereas trade models usually imply a positive relationship between prices of factors and goods. Fourth, the change in relative wages is associated with a substantial increase in the demand for skill within all industries (skill upgrading), whereas the Hecksher-Ohlin model suggests that a trade-induced expansion of skill-intensive industries should be accommodated by skill downgrading.<sup>6</sup>

In this article, we propose a new role of international trade in explaining wage inequality consistent with the empirical evidence. We do so by revisiting the *new trade theory's* account of the distributional effects of intra-industry trade. By definition, intra-industry trade is trade in goods with similar factor intensities; therefore, according to conventional wisdom, it has no impact on relative factor demand and cannot explain the evolution of the skill premium. We argue that this seemingly plausible conclusion hinges either on Cobb-Douglas preferences or perfect symmetry between sectors. We show that an elasticity of substitution in consumption greater than one and stronger returns to scale in the skill-intensive sectors in an otherwise standard model of monopolistic competition imply that any increase in the volume of trade, even between identical countries, tends to be skill-biased. The intuition behind this result is simple. Trade expands the market size of the economy, which is beneficial because of increasing returns. In relative terms, however, output increases by more in the skill-intensive sectors, since they are characterised by stronger economies of scale, and their relative price therefore falls. With an elasticity of substitution in consumption greater than one, the demand for skill-intensive goods increases more than proportionally, raising their share of total expenditure and therefore also the relative wage of skilled workers.

This result has important implications. First, it suggests that the entire volume of world trade matters for factor prices and not only the small volumes of North-South trade. In particular, under plausible calibrations, our model suggests that a 50% fall of trade costs between identical countries can induce a 10% increase in the skill premium, whereas full integration can raise skill premia by up to 30%. Second, if the skill-biased scale effect is strong enough to overcome the standard relative scarcity effect, international trade will spur wage differentials even in the skill-poor developing economies, making the model consistent with the evidence of rising skill premia in developing countries after trade liberalisation. In this respect, an interesting case study is the recent episode of drastic trade liberalisation in Mexico followed by an upsurge in the skill premium. We perform a simple numeric exercise to show that full trade integration between the skill-poor Mexico and its main trade partner, the skill-rich US, can account for a 15% rise in Mexico's skill premium, broadly matching actual data. Third,

<sup>4</sup> Although systematic evidence on developing countries is still mixed, increases in wage differentials after trade liberalisation have been documented for Argentina, Chile, China, Colombia, Costa Rica, Uruguay and Mexico. On the contrary, trade seems associated with less inequality in East Asian countries during the 1960s and 1970s. See Robbins (1996), Hanson and Harrison (1999), Berman and Machin (2000) and the evidence reported in Section 4. Davis (1996) warns that these findings do not contradict the Hecksher-Ohlin model as countries that are labour abundant in a global sense might be skill abundant relative to trading partners. Wood (1997) proposes alternative ways to accommodate the evidence by adding more factors and nontraded goods. See also Ripoll (2005).

<sup>5</sup> In particular, Lawrence and Slaughter (1993) document a decline in the relative price of US skill-intensive goods in the 1980s. See also Slaughter (2000) on this point.

<sup>6</sup> See, in particular, Berman *et al.* (1994) and Berman *et al.* (1998).

our model can explain the decline in the relative price of skill-intensive goods during the period of rising skill premia and growing volumes of world trade. In the framework we propose, the so-called price puzzle (the empirical finding that relative factor and good prices moved in opposite directions) simply disappears. Fourth, we show that, so long as our mechanism applies to intermediate goods (or activities) within industries, it can also explain skill-upgrading.

Next, we extend our analysis by introducing physical capital. As the capital stock is an important component of economic size, we find that its accumulation tends to increase the skill premium. More interestingly, we show that the intersectoral mobility of capital is likely to magnify the effects of trade integration on wage differentials. Our findings are consistent with both the evidence on capital relocation towards the skill-intensive sectors (Caselli, 1999) and the literature on capital–skill complementarity.

We also confront the model's results with the data. After having discussed the available evidence on the main assumptions, we test for the empirical relevance of skill-biased scale effects. In particular, we propose various strategies to identify scale effects in three different datasets: a panel of economy-wide Mincerian returns to education, a panel of manufacturing skill premia and a panel of Gini coefficients of income inequality. Our results are strikingly consistent across datasets, samples and proxies for scale and wage inequality. Overall, they indicate that increases in market size tend to raise wage inequality and that the scale elasticity of the skill premium is roughly equal to 30%.

We are not alone in reconsidering the role of trade in explaining skill premia. Neary (2002) and Thoenig and Verdier (2003) develop models where trade liberalisation between similar countries can lead to skill-biased technical change. The idea underling their models is that of 'defensive innovation': increased competition makes skill-intensive technologies more profitable because they deter the entry of new firms. In contrast, we show that even abstracting from technical change and strategic considerations, the trade-induced expansion in market size is sufficient to raise the skill premium. Our result is also related to Acemoglu (2003). In his view, North–South trade induces skill-biased technical change by making skill-complement innovations more profitable.<sup>7</sup> However, trade between identical countries plays no role and trade opening in a developing country is unlikely to have an effect on the direction of technical change, since no single developing country has the economic size to affect world incentives to innovate. Another related work is Dinopoulos *et al.* (2001). In their model, intra-industry trade expands firm size, which is assumed to be skill-biased, and hence raises the skill premium. In this respect, a key contribution of our approach is to show how an increase in scale leads to skill-biased demand shifts without relying on non-homotheticities. Further, they consider a one-sector economy only, thereby missing important general equilibrium implications of trade models (e.g., the evolution of relative prices). Manasse and Turrini (2001) and Yeaple (2005), show instead that, in the presence of heterogeneity among skilled workers, trade can spur within-group wage inequality, while we focus on between-group inequality. Finally, Matsuyama (2007) and

<sup>7</sup> See also Jones (2000a) and Xu (2001) on the effects of the factor and sector bias of technical progress in open economies. Another channel through which trade can affect skill premia in models of endogenous technical change is by affecting the reward to innovation, an activity that is likely to be skill-intensive. This mechanism is studied by Dinopoulos and Segerstrom (1999).

Maurin *et al.* (2002) argue that the act of exporting requires more skilled labour, while the market size effect *per se* plays no role in their models.<sup>8</sup>

In models of outsourcing by Feenstra and Hanson (1996, 1997) or product cycles by Zhu and Trefler (2005), the relocation of production from OECD countries to developing countries increases the demand for skilled labour. This happens because the relocated activities are unskilled-labour intensive relative to those performed in the developed world but skilled-labour intensive relative to those performed in the developing countries. However, outsourcing and product cycle trade typically take place between dissimilar countries, whereas the kind of trade we emphasise is pervasive and most relevant for industrial countries. Moreover, in our view the skill bias of world trade is a pure consequence of trade liberalisation, whereas in these models other aspects of globalisation are also crucial, such as international capital flows or technological catching up. In summary, our contribution to this growing literature is to consider a more general mechanism based on asymmetries across activities in returns to scale that is both empirically relevant and able to reconcile several puzzling facts.<sup>9</sup>

Finally, while the literature has studied extensively the distributional implications of trade between countries with different factor proportions (the Stolper-Samuelson theorem being the cornerstone of this effort), these issues have been largely neglected in models of intra-industry trade. This is because trade in goods with similar factor intensity is often believed to be neutral on income distribution. An important contribution of this article is to show how this presumption is unwarranted and derive clear-cut predictions on the link between trade, market size and factor prices.

The plan of the article is as follows. Section 1 illustrates the basic model, analyses the effects of international trade on the skill premium and shows the role played by the intersectoral mobility of physical capital. Section 2 provides evidence on the key assumptions and shows how the model can reconcile the role of trade in explaining skill premia with the main stylised facts. Section 3 tests for the empirical relevance of skill-biased scale effects using three different datasets. Section 4 concludes.

## 1. A Simple Model

### 1.1. Preferences

Consider a country endowed with  $H$  units of skilled workers and  $L$  units of unskilled workers, where two final goods are produced. Consumers have identical homothetic preferences, represented by the following CES utility function:

$$U = \left[ (Y_l)^{\frac{\epsilon-1}{\epsilon}} + (Y_h)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}, \quad (1)$$

where  $Y_h$  and  $Y_l$  stand for the consumption of final goods  $h$  and  $l$ , respectively, and  $\epsilon > 1$

<sup>8</sup> Bernard and Jensen (1997) show evidence that exporting firms in US manufacturing sectors demand more skilled labour.

<sup>9</sup> An alternative approach, taken by Ethier (2005), is to disregard sectoral asymmetries to focus instead on the intra-sectoral substitution between inputs. Ethier shows that trade and technical progress can increase wage inequality provided that skilled labour and equipment are complement and that unskilled labour and outsourcing are substitutes.

is the elasticity of substitution between the two goods. The relative demand for the two goods implied by (1) is:

$$\left(\frac{P_h}{P_l}\right)^{-\epsilon} = \frac{Y_h}{Y_l}, \tag{2}$$

where  $P_h$  and  $P_l$  are the final prices of goods  $l$  and  $h$ , respectively. Note that  $\epsilon > 1$  implies that a fall in the relative price induces a more than proportional increase in relative demand. This is a crucial assumption for our results.

1.2. *Production and Market Structure*

Goods  $h$  and  $l$  are produced by perfectly competitive firms by assembling  $n_i$  ( $i = l, h$ ) own-industry differentiated intermediate goods. In particular, we assume that the production functions for final goods take the following CES form:<sup>10</sup>

$$Y_i = \left[ \int_0^{n_i} y_i(v)^{\frac{\sigma_i-1}{\sigma_i}} dv \right]^{\frac{\sigma_i}{\sigma_i-1}}, \tag{3}$$

where  $y_i(v)$  is the amount of the intermediate good type  $v$  used in the production of good  $i$ , and  $\sigma_i$  is the elasticity of substitution among any two varieties of intermediates used in sector  $i$ . In the following, we assume that  $\sigma_l > \sigma_h > \epsilon$ . In words, the elasticity of substitution among intermediates is greater in sector  $l$  than in sector  $h$ . Further, the elasticity of substitution in production among intermediates used in each sector is greater than the elasticity of substitution in consumption between the final goods.

The price for final good  $i$  (equal to the average cost) implied by (3) is:

$$P_i = \left[ \int_0^{n_i} p_i(v)^{1-\sigma_i} dv \right]^{1/(1-\sigma_i)}, \tag{4}$$

where  $p_i(v)$  is the price of the intermediate good type  $v$  used in the production of good  $i$ .

The two sectors producing intermediates are monopolistically competitive *à la* Dixit and Stiglitz (1977) with symmetric firms. The production of each intermediate in sector  $i$  involves a fixed requirement,  $F_i$ , and a constant marginal requirement,  $c_i$ , of labour. In order to keep the algebra as simple as possible, we assume that the two sectors are extreme in terms of skill-intensity, so that sector  $h$  uses only skilled workers  $H$ , whereas sector  $l$  uses only unskilled workers  $L$ . In the Appendix, we generalise our results to a setting where both sectors use both types of labour. Hence, the total cost function of a single variety produced in sector  $i$  is:

$$TC_i = (F_i + c_i y_i) w_i, \tag{5}$$

where  $w_h$  and  $w_l$  are the wage rates of skilled and unskilled workers, respectively.

Profit maximisation by producers of intermediates in the two sectors implies a markup pricing rule:

<sup>10</sup> As discussed later on, these production functions exhibit increasing returns to scale and were introduced into trade theory by Ethier (1982).

$$p_i(v) = p_i = \left(1 - \frac{1}{\sigma_i}\right)^{-1} c_i w_i = w_i, \tag{6}$$

where the latter equality follows from a choice of units such that  $c_i = (1 - \frac{1}{\sigma_i})$ . Hence, we have:

$$\frac{p_h}{p_l} = \omega, \tag{7}$$

where  $\omega = w_h/w_l$  is the skill premium. Intuitively, the relative price of any variety of sector  $h$  intermediates is an increasing function of the skill premium, since  $h$  is skill-intensive relative to  $l$ .

A free-entry condition guarantees zero profits in equilibrium:

$$\pi_i(v) = \pi_i = \left(\frac{y_i}{\sigma_i} - F_i\right) w_i = 0$$

and hence

$$y_i = F_i \sigma_i = 1, \tag{8}$$

where the latter equality follows from setting  $F_i = 1/\sigma_i$ .<sup>11</sup>

Equations (6) and (8) allow us to simplify the expressions for  $P_i$  and  $Y_i$ :

$$Y_i = n_i^{\frac{\sigma_i}{\sigma_i-1}} \tag{9}$$

$$P_i = n_i^{\frac{1}{1-\sigma_i}} p_i. \tag{10}$$

As (9) shows, the elasticity of  $Y_i$  with respect to  $n_i$  is greater the lower is  $\sigma_i$ . Hence,  $\sigma_i$  can be interpreted as an inverse measure of external scale economies at the industry level.<sup>12</sup> Our assumption  $\sigma_l > \sigma_h$  is thus equivalent to assuming stronger increasing returns to scale in sector  $h$  than in sector  $l$ .<sup>13</sup>

### 1.3. General Equilibrium

Conditions for full employment of skilled and unskilled workers determine the number of varieties produced in each sector:

<sup>11</sup> This assumption is meant to simplify the algebra only and is innocuous for the purpose of the article. As argued later on, our normalisations do not affect the elasticity of the skill premium to a change of any parameters (they only affect its level).

<sup>12</sup> These external scale economies, sometimes called ‘returns to specialisation’, come from the benefit of having more varieties in the production function for final goods (see (3)), and not directly from the presence of fixed costs at the firm level (as firm size is constant). Returns from specialisation depend on  $\sigma_i$  only, and disappear when varieties are perfect substitutes, as in this case only the overall quantity of inputs (and not also their variety) matters for final output.

<sup>13</sup> A production function  $Y = f(v)$  exhibits increasing returns to scale if  $f(\lambda v) > \lambda f(v)$  for  $\lambda > 1$ . An index of scale economies is the elasticity of  $f(\lambda v)$  with respect to  $\lambda$ :  $\frac{\partial f(\lambda v)}{\partial \lambda} \frac{\lambda}{f(\lambda v)} = \frac{\sigma_i}{\sigma_i - 1}$ . This index is clearly decreasing in  $\sigma_i$ . Note, also, that returns to scale do not depend on marginal and fixed costs, as firm size is constant.

$$n_l = L \text{ and } n_h = H. \tag{11}$$

Let  $\theta = H/\bar{L}$  be the country share of skilled workers in the total workforce,  $\bar{L} = H + L$ . Equations (11) can then be rewritten as:

$$n_l = (1 - \theta)\bar{L} \text{ and } n_h = \theta\bar{L}. \tag{12}$$

Substituting (9), (10), (7) and (12) into (2), and rearranging gives an equilibrium expression for the skill premium

$$(\theta\bar{L})^{\frac{\sigma_h - \epsilon}{\epsilon(\sigma_h - 1)}} \omega = [(1 - \theta)\bar{L}]^{\frac{\sigma_l - \epsilon}{\epsilon(\sigma_l - 1)}}, \tag{13}$$

which is interpreted below.

1.4. Trade and the Skill Premium

We can now analyse the effects of trade integration on the skill premium. Since we focus on equilibria with factor price equalisation (FPE), we can obtain the free trade prices by applying the above results to a hypothetical integrated economy whose endowments are the sum of those of each trading country. In particular, totally differentiating (13) and using the implicit function theorem, we can decompose the change in the skill premium into the following components:

$$\frac{d\omega}{\omega} = \left[ \frac{(\epsilon - 1)(\sigma_l - \sigma_h)}{\epsilon(\sigma_h - 1)(\sigma_l - 1)} \right] \frac{d\bar{L}}{\bar{L}} - \left[ \frac{\sigma_h - \epsilon}{\epsilon(\sigma_h - 1)} + \frac{\sigma_l - \epsilon}{\epsilon(\sigma_l - 1)} \frac{\theta}{1 - \theta} \right] \frac{d\theta}{\theta}. \tag{14}$$

Equation (14) shows how the skill premium is affected by a variation in the size of the economy ( $d\bar{L}/\bar{L}$ ) and the relative scarcity of skilled workers ( $d\theta/\theta$ ). We use (14) first to study the effect of intra-industry trade on wage inequality. As shown by Krugman (1979), in a Dixit-Stiglitz framework trade integration among two identical countries is formally equivalent to a doubling of country size,  $\bar{L}$ . Given that  $\sigma_l > \sigma_h > \epsilon > 1$ , (14) implies that the coefficient of  $d\bar{L}/\bar{L}$  is positive, and that its magnitude depends positively on the elasticity of substitution  $\epsilon$  and the sectoral asymmetries  $(\sigma_l - \sigma_h)$  in the degree of returns to scale. Thus, pure intra-industry trade among identical countries, often presumed to have no distributional effects, turns out to be skill-biased.<sup>14</sup>

<sup>14</sup> The general expression for the skill premium, without any normalisation, is:

$$\omega = \frac{1 - \theta}{\theta} \left[ \frac{\left( \frac{\theta}{\sigma_h F_h} \right)^{\frac{\sigma_h}{\sigma_h - 1}} F_h (\sigma_h - 1)}{\left( \frac{1 - \theta}{\sigma_l F_l} \right)^{\frac{\sigma_l}{\sigma_l - 1}} F_l (\sigma_l - 1)} \right]^{1 - 1/\epsilon} (\bar{L})^{\frac{(\epsilon - 1)(\sigma_l - \sigma_h)}{\epsilon(\sigma_h - 1)(\sigma_l - 1)}}$$

From this expression it can be seen that the elasticity to scale only depends on  $\{\epsilon, \sigma_h, \sigma_l\}$  and that, under our assumptions, larger countries tend to have, *ceteris paribus*, higher skill premia.

Equation (14) also shows the effect of inter-industry trade on the skill premium. Integration between dissimilar countries still implies an increase in the overall size of the economy but also changes the perceived relative scarcity of factors. Since the coefficient of  $d\theta/\theta$  is negative, an increase (fall) in the relative supply of skilled labour has the effect of reducing (increasing) the skill premium.<sup>15</sup> This effect works through the well-known mechanics of the Heckscher-Ohlin-Samuelson theorem, and can dampen or magnify the upward pressure on the skill premium due to the market size effect. Moreover, it can lead to a decline in the absolute wage of the factor perceived as more abundant after trade integration, whereas the first effect ( $d\bar{L}/\bar{L}$ ) tends to increase the real wage of all factors.

What drives the skill bias of trade? Growth in the size of the market increases relative productivity in the skill-intensive sector, since it enjoys stronger returns to scale. At the same time, an elasticity of substitution in consumption greater than one ensures that the relative price of skill-intensive goods does not fall too much, so that the market size expansion increases the share of skill-intensive goods in total income and hence the skill premium.

### 1.5. *Introducing Physical Capital*

We now show how the introduction of physical capital, assumed to be mobile across sectors, magnifies the skill-biased scale effect of trade. With physical capital ( $K$ ), the total cost function of a single variety produced in sector  $i$  becomes:

$$TC_i = (F_i + c_i y_i) r^\gamma w_i^{1-\gamma}, \quad (15)$$

where  $r$  is the rental rate and  $\gamma$  is the share of capital in sector  $i$ 's total cost. For simplicity, (15) considers the case where capital intensity is the same in both sectors ( $\gamma = \gamma_h = \gamma_l$ ).<sup>16</sup> The relative price of skill-intensive varieties implied by (15) and profit maximisation becomes:

$$\frac{p_h}{p_l} = \frac{r^\gamma w_h^{1-\gamma}}{r^\gamma w_l^{1-\gamma}} = \omega^{1-\gamma}. \quad (16)$$

Equations (2), (9) and (10) are unchanged; together with (16) they imply:

$$n_h^{\frac{\sigma_h - \epsilon}{\epsilon(\sigma_h - 1)}} \omega^{1-\gamma} = n_l^{\frac{\sigma_l - \epsilon}{\epsilon(\sigma_l - 1)}}. \quad (17)$$

Using Shephard's lemma, the demand for each factor can be found from the total cost function (15). Noting that  $(\partial/\partial w_i) r^\gamma w_i^{1-\gamma} = (1-\gamma) r^\gamma w_i^{-\gamma}$  and  $(\partial/\partial r) r^\gamma w_i^{1-\gamma} = \gamma r^{\gamma-1} w_i^{1-\gamma}$ , we have that the conditions for full employment of physical capital, skilled and unskilled workers are given by:

<sup>15</sup> Note that the coefficient of  $d\theta/\theta$  is negatively affected by the elasticity of substitution  $\epsilon$ , as a high substitutability implies a weak price effect of an increase in the relative supply.

<sup>16</sup> The assumption of equal capital shares in the two sectors simplifies the algebra significantly and seems natural, given that there is no strong evidence of any robust correlation between capital intensity and skill-intensity. In fact, equal capital intensity is also the benchmark case studied by Feenstra and Hanson (1996) in their related work on outsourcing and wage inequality. In any event, we have also analysed the more general case when the two sectors differ in capital intensity. We report in a following note how relaxing this assumption affects the main results.



$$\begin{aligned}
 K &= \gamma r^{\gamma-1} w_h^{1-\gamma} n_h (F_h + c_h y_h) + \gamma r^{\gamma-1} w_l^{1-\gamma} n_l (F_l + c_l y_l) \\
 H &= (1 - \gamma) r^\gamma w_h^{-\gamma} n_h (F_h + c_h y_h) \\
 L &= (1 - \gamma) r^\gamma w_l^{-\gamma} n_l (F_l + c_l y_l).
 \end{aligned}
 \tag{18}$$

After setting  $w_l = 1$ , we can use (18) to express  $n_h$  and  $n_l$  as functions of the skill premium and the exogenous variables:

$$n_h = \frac{H\omega^\gamma}{(1 - \gamma)^{1-\gamma}} \left( \gamma \frac{L + H\omega}{K} \right)^{-\gamma} \quad \text{and} \quad n_l = \frac{L}{(1 - \gamma)^{1-\gamma}} \left( \gamma \frac{L + H\omega}{K} \right)^{-\gamma}.
 \tag{19}$$

Substituting (19) into (17) and solving for  $\omega$  gives the equilibrium skill premium. Differentiating with respect to  $\omega, K$  and  $\bar{L} = H + L$ , and using the implicit function theorem, we find the elasticity of the skill premium to changes in the scale of the economy to be:

$$\frac{d\omega}{\omega} = \frac{\left[ \gamma \frac{dK}{K} + (1 - \gamma) \frac{d\bar{L}}{\bar{L}} \right] \frac{(\epsilon - 1)(\sigma_l - \sigma_h)}{\epsilon(\sigma_h - 1)(\sigma_l - 1)}}{1 - \gamma \left\{ \frac{\epsilon - 1}{\epsilon} \frac{1}{1 - \theta + \theta\omega} \left[ \frac{\sigma_h(1 - \theta)}{\sigma_h - 1} + \frac{\sigma_l\theta\omega}{\sigma_l - 1} \right] \right\}},
 \tag{20}$$

where again  $\theta = H/\bar{L}$  is the share of skilled workers in the total labour force.<sup>17</sup> Note that the coefficient multiplying the scale variables in the square bracket of the numerator is equal to the scale elasticity in (14). But now the denominator in (20) is less than one and decreasing in  $\gamma$ .<sup>18</sup> Therefore, the effect on the skill premium of trade integration among two identical countries, i.e., a doubling of both  $K$  and  $\bar{L}$ , is now greater the larger is the share  $\gamma$  of capital in total cost.<sup>19</sup> Further, (20) shows that capital accumulation and capital inflows tend to increase the skill premium, as they contribute to expand the scale of the economy. This result is consistent with the literature documenting capital-skill complementarities; see Krusell *et al.* (2000) among others. To see why capital magnifies the effects of trade integration on the skill premium, it is instructive to study the change in the allocation of capital between the two sectors:<sup>20</sup>

$$\frac{K_h/n_h}{K_l/n_l} = \omega^{1-\gamma}.
 \tag{21}$$

Equation (21) shows that the trade-induced rise in the skill premium is associated with a relative increase in capital intensity of firms operating in sector  $h$ . The reason is that, by expanding market size, trade integration increases the relative productivity of the resources used in the sector enjoying stronger returns to scale. Hence, trade implies an increase in the relative marginal productivity of capital in sector  $h$ . Since in equilibrium

<sup>17</sup> The elasticity to a change in the relative skill-endowment  $\theta$  is here omitted, though straightforward to calculate, because we are interested in showing how capital reallocation affects the scale effect.

<sup>18</sup> Note that, assuming decreasing marginal returns to capital in both sectors, we have  $\gamma(\sigma_i/(\sigma_i - 1)) < 1$  for  $i = h, l$ . This ensures that the denominator of (20) is positive.

<sup>19</sup> In the general case where the capital-intensity is allowed to differ across sectors, we find that an equi-proportional increase in the overall scale of the economy ( $H, L$  and  $K$ ) is more skill-biased when the skill-intensive sector is also capital intensive. Further, an increase in capital only is more beneficial for the factor used in the capital-intensive sector, while an equi-proportional increase in  $H$  and  $L$ , by raising the price of capital, hurts more the factor used in the capital-intensive sector.

<sup>20</sup> To obtain (21), note that  $K_r = \gamma P_i Y_i$ ; then use (9), (10) and (16).

the rental rate must be equalised across sectors, the only way of restoring the equality after trade integration is by shifting capital out of the less skill-intensive sector and into the skill-intensive sector. As a consequence, the endowment of capital per worker rises for the skilled and falls for the unskilled, which further increases wage inequality. Capital reallocations toward skill-intensive sectors introduce the possibility that the real wage of unskilled workers may actually fall with trade integration between identical countries. This is an interesting possibility, since empirical studies suggest that the real wage of less skilled workers may have declined in the US. Note, however, that also the standard Stolper-Samuelson effect (due to trade integration with less developed countries) may have contributed to this fact.

A similar mechanism is at work in Caselli (1999), where a skill-biased technological revolution induces a reallocation of capital toward the skill-intensive sectors. He also documents capital flows to skill-intensive industries in the US during the period of rising skill premium. Our contribution is to show that such a reallocation of capital can also be due to trade integration.

## 2. Trade and Wages: Reconsidering the Facts

In this Section, we show how the model can reconcile an important role of trade in explaining the rising skill premia with the main stylised facts. We start by considering the evidence on the main assumptions of the model. This will provide us with indicative estimates of the key parameters needed to quantify the skill bias of trade. After having shown that the scale effect can be large in magnitude, we will argue that it can also explain the decline in the relative price of skill-intensive goods and skill-upgrading within industries.

### 2.1. Evidence on the Key Assumptions

Our results rest on returns to scale being stronger in the skill-intensive sectors and the elasticity of substitution between goods of different skill-intensity being greater than one. How realistic are these assumptions? Morrison and Siegel (1999) estimate returns to scale in US manufacturing industries at the two-digit industry level for the period 1979–89. Figure 1 plots their estimates against a measure of sectoral skill-intensity. For each industry, the vertical axis reports the output elasticity of the long-run total cost function (an inverse measure of overall scale economies) and the horizontal axis the share of production workers in total employment in 1990 (an inverse measure of skill-intensity). The diagram clearly shows a positive correlation between skill-intensity and scale economies. We also report a weighted regression line, whose slope coefficient and standard error are 0.59 and 0.21, respectively.<sup>21</sup>

<sup>21</sup> The measure of scale economies illustrated in Figure 1 includes both internal and external economies of scale and is therefore a good proxy for total scale economies. Morrison and Siegel (1999) also compute a measure of scale economies that isolates external effects (the most relevant in our model) and whose linear correlation with the former equals 0.95. Not surprisingly, when we run the same regression as in Figure 1 using this alternative measure of scale economies, we find very similar results (the regression coefficient equals 0.52 with a standard error of 0.15). Diewert and Fox (2004) also provide estimates of sectoral returns to scale in 18 US two-digit SIC industries using different data and methodology. Remarkably, when we run the regression plotted in Figure 1 using their estimates, we find much the same result: the coefficient on the share of non-production workers equals 0.53, with a standard error of 0.30.

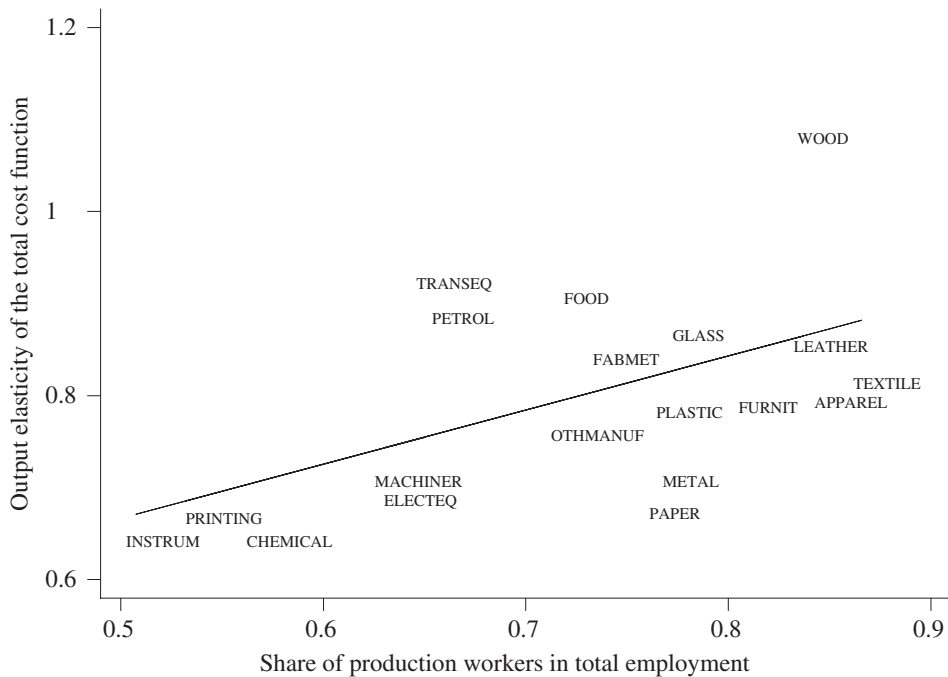


Fig. 1. *Skill-intensity and Increasing Returns*

Similar results are reported by Antweiler and Trefler (2002); using international trade data for 71 countries and a very different methodology, they find that skill-intensive sectors, such as Petroleum Refineries and Coal Products, Pharmaceuticals, Electric and Electronic machinery and Non-Electrical Machinery, have an average scale elasticity around 1.2, whereas low skill-intensive sectors, such as Apparel, Leather, Footwear and Food, are characterised by constant returns.<sup>22</sup> More generally, given that skill-intensive activities often have the nature of fixed costs (R&D and Marketing are two examples), it is reasonable to expect that they may generate scale economies.<sup>23</sup> We provide a possible micro-foundation for these asymmetries in increasing returns in another paper (Epifani and Gancia, 2006).

<sup>22</sup> Simple calculations on their results show that manufacturing sectors with strong evidence of increasing returns have an average index of skill-intensity (the normalised ratio of workers who completed high school to those who did not) equal to 0.4 (0.32 when including natural resources), while those with constant returns have an average value of 0.12. The remaining sectors, with non-robust estimates of returns to scale, lie in the intermediate range, with an average skill-intensity of 0.23.

<sup>23</sup> Some influential papers, e.g., Burnside (1996) and Basu and Fernald (1997), find little evidence of increasing returns in the average manufacturing industry. This is not so surprising, given that estimating returns to scale poses serious methodological difficulties. Yet, independent of the methodology used, the empirical literature always finds strong sectoral asymmetries in returns to scale. For instance, Burnside (1996) shows that the cross-industry equality restrictions on the parameters capturing returns to scale are always and overwhelmingly rejected. Unfortunately, his estimates of industry-level returns to scale suffer from loss of precision once the cross-industry equality restrictions are removed. Yet, after discarding implausible estimates, the remaining ones show a positive and significant association with skill-intensity.

Moving to our second crucial assumption, both direct and indirect evidence suggests that the elasticity of substitution between goods with different skill-intensity ( $\epsilon$ ) is greater than one. A unit elasticity would imply that expenditure shares are unresponsive to relative price changes but this is contradicted by US data. To show this, we have first computed the relative expenditure ( $E_h/E_l$ ) on two aggregates of high and low skill-intensive goods.<sup>24</sup> In the years from 1980 to 2000, we find that the relative expenditure on skill-intensive goods increased by more than 25%, from 1.04 to 1.3. Then, following a standard practice, we have computed the price index for each aggregate as the average of the price deflators of industries belonging to each group weighted by the employment shares at the beginning of the period. Using 1990 as the base year, we find that the relative price of unskill-intensive goods ( $P_l/P_h$ ) increased by more than 25%, from 0.93 in 1980 to 1.20 in 2000, a result broadly consistent with most of the studies on product prices surveyed in Slaughter (2000).

In Figure 2, we plot the relationship between expenditure shares and the relative price. The log of the relative expenditure on skill-intensive goods is on the vertical axis,  $\log(E_h/E_l)$ , and the log of the relative price of unskill-intensive goods is on the horizontal axis,  $\log(P_l/P_h)$ . Also reported in Figure 2 is a regression line, whose slope coefficient and standard error are 0.44 and 0.08, respectively, with an R-squared of 0.62. Given that the slope coefficient is equal to  $\epsilon - 1$ , the estimated coefficient implies an elasticity of substitution close to 1.5, consistent with our assumption. When controlling for the log of *per capita* GDP, the coefficient of the relative price is slightly reduced (0.36) but is still significant at the 7%-level (with a standard error of 0.19). In contrast, the coefficient of *per capita* GDP is positive (0.02), as expected but small and imprecisely estimated (its standard error equals 0.05).

Compelling indirect evidence also indicates that  $\epsilon$  is significantly greater than one. In particular, in our model  $\epsilon$  coincides with the aggregate elasticity of substitution in production between skilled and unskilled workers.<sup>25</sup> We can then refer to studies that provide estimates of this alternative parameter. Freeman (1986) concludes his review of the empirical evidence suggesting a value for the elasticity of substitution between more and less educated labour in the range between 1 and 2. Hamermesh and Grant (1979) review 20 estimates of the elasticity of substitution between production and non-production workers and find a mean estimate of 2.3. Using a different macroeconomic approach, Krusell *et al.* (2000) report an estimate of 1.67 for the US economy, while Katz and Murphy (1992) find a value of 1.41.

## 2.2. Quantitative Relevance

The first critique of traditional trade-based explanations concerns their quantitative relevance: North–South trade flows simply do not seem to be large enough to affect the

<sup>24</sup> Data is from the OECD STAN Database, whose principal source for the US is the Bureau of Economic Analysis. The aggregate of skill-intensive goods includes: Chemicals and chemical products, Coke, refined petroleum products and nuclear fuel, Machinery and equipment, Transport equipment, and Printing and publishing. The aggregate of unskill-intensive goods includes all the other manufacturing industries. Expenditure on each aggregate is calculated as production plus net imports.

<sup>25</sup> This is a special feature of the specific-factor model we use. In a more general formulation studied in the Appendix, we show that an aggregate elasticity of substitution in production greater than one also implies an aggregate elasticity in consumption greater than one.

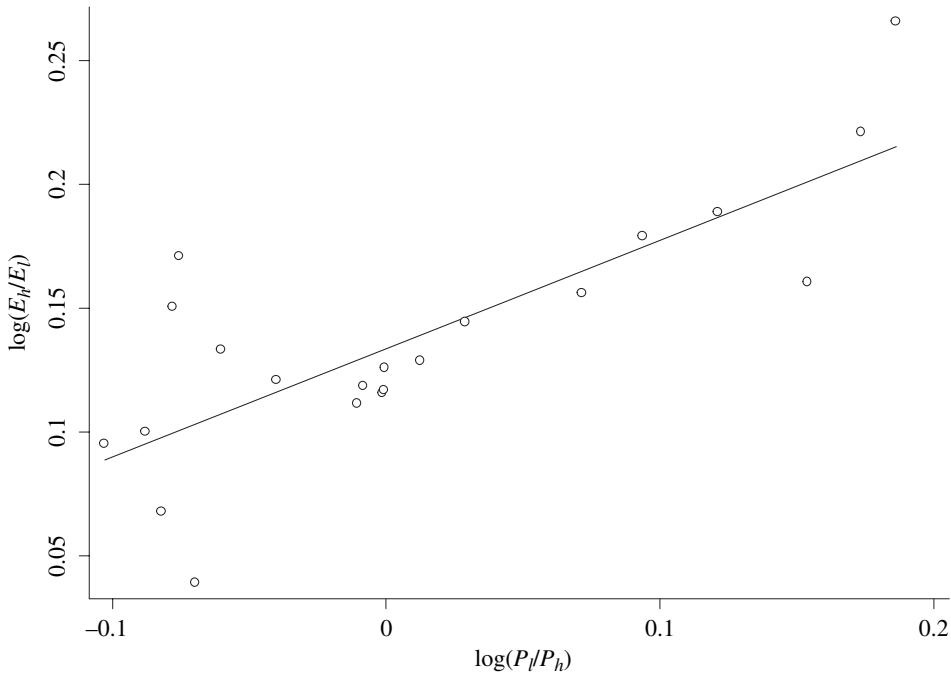


Fig. 2. *Relative Expenditure as a Function of the Relative Price*

skill premium significantly.<sup>26</sup> Compared to the standard Heckscher-Ohlin approach, our model is less exposed to this criticism as it shows that the entire volume of world trade matters for relative wages and not only its net factor content. It remains to argue that the trade-induced skill-biased scale effect can be of significant magnitude. To do so, we compute the scale elasticity of the skill premium given by (20). A conventional value for the capital share,  $\gamma$ , is  $1/3$ . As argued above, estimates of the elasticity of substitution  $\epsilon$  are mostly in the range (1–2), and therefore we take  $\epsilon = 1.5$  as a reasonable benchmark. Moving to industry-level returns to scale, recall that in our model they equal  $\sigma_i/(\sigma_i - 1)$ . Given that most studies find no significant departure from constant returns to scale in the unskill-intensive sectors, we set  $\sigma_l/(\sigma_l - 1) = 1$  and let  $\sigma_h/(\sigma_h - 1)$ , on which there is more disagreement, vary. Figure 3 shows the scale elasticity of the skill premium (on the vertical axis) as a function of  $\sigma_h/(\sigma_h - 1)$  (on the horizontal axis) for some critical values of  $\epsilon$ . It can be used to perform some interesting experiments.<sup>27</sup> For instance, with average returns to scale equal to 1.2 ( $\sigma_h = 6$ ) in the skill-intensive sectors – consistent with Antweiler and Trefler (2002) – the graph shows

<sup>26</sup> Leamer (2000) warns that low volumes of trade are compatible with external product markets that dictate lower wages for unskilled workers, because the relationship between the factor content of trade and factor prices is model specific. In fact, our model is an example of a situation in which trade can affect factor prices even when the net factor content of trade is zero (e.g., in case of trade integration between identical countries).

<sup>27</sup> Note from (20) that  $d\omega/\omega$  also depends on  $\theta$  and  $\omega$ . Numerical simulations show their effect to be negligible. To draw Figure 3, we have used values of 0.35 and 1.4, respectively.

that the scale elasticity of the skill premium ranges from zero (for  $\epsilon = 1$ ) to 13% (for  $\epsilon = 2$ ), with a value around 8% for  $\epsilon = 1.5$ . Hence, for plausible parameterisations, the model suggests that trade integration between two identical countries would increase the skill premium by roughly 10%. With less conservative estimates, the scale elasticity of the skill premium would grow very large. For instance, with average returns to scale equal to 1.4 ( $\sigma_h = 3.5$ ) in the skill-intensive sectors – consistent with Morrison and Siegel (1999) – the scale elasticity of the skill premium would rise over 20% even with an elasticity of substitution less than two.<sup>28</sup> In contrast, with returns to scale equal to 1.1 ( $\sigma_h = 11$ ) the scale elasticity of the skill premium would be below 6%, unless we believe in more extreme estimates for  $\epsilon$ .<sup>29</sup>

It is also worth stressing that these quantifications do not require unreasonable volumes of trade. This can be seen by computing the import to GDP ratio in the benchmark case of two identical countries with  $\sigma_l \rightarrow \infty$ . Given that unskill-intensive products are homogeneous, they will not be traded in the presence of any arbitrarily small transportation cost. On the contrary, one half of production of the skill-intensive sector is shipped abroad. The import share is thus  $(1/2)\omega\theta/(\omega\theta + 1 - \theta)$ . Using

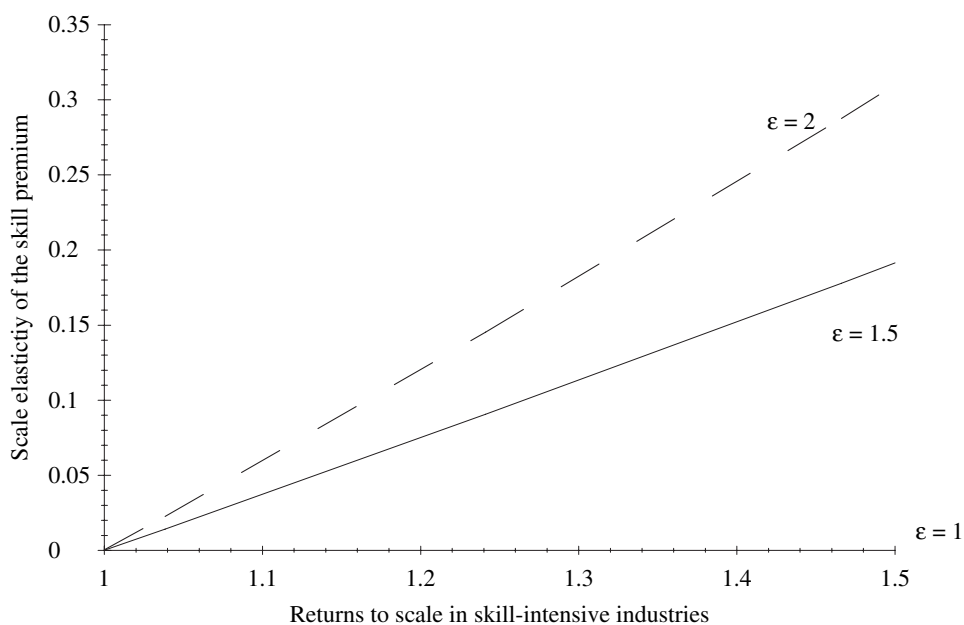


Fig. 3. *Scale Elasticity of the Skill Premium*

<sup>28</sup> Note, however, that Morrison and Siegel (1999) estimate positive, but much smaller, increasing returns even in less skill-intensive sectors. Taking this into account would lower the scale elasticity of the skill premium computed in Figure 3.

<sup>29</sup> In the Appendix, we discuss a more general model where both sectors employ both types of workers and show that, even in that case, the scale effect can be quantitatively large. An alternative model with labour mobility across sectors is suggested in Section 2.4.

plausible values, like  $\omega = 1.5$  and  $\theta = 1/3$ , this expression yields an import share around 0.2, a little high for the US economy, but lower than the import share of most other countries.

More generally, it is possible to show how the skill bias of trade varies with the volume of trade by introducing iceberg trade costs. Assume that  $t \geq 1$  units of an imported variety must be shipped for one unit to arrive at destination. For simplicity, we restrict our analysis to the model without capital and we study a symmetric case in which a country trades with  $M$  identical countries. The latter assumption isolates the scale component of trade, which is our focus, and implies that prices and wages are identical in all countries. Since iceberg trade costs do not affect monopoly pricing, (6) and (11) still apply. Using these and the fact that the price of an imported variety is  $t$  times the domestic price, the price index of the skill-intensive good (4) in a given country can be expressed as:

$$P_h = w_h H^{1/(1-\sigma_h)} (1 + Mt^{1-\sigma_h})^{1/(1-\sigma_h)}, \tag{22}$$

where  $H$  is the skill-endowment of the typical country. A similar formula holds for  $P_l$ . From demand, we can find the wage bill share of skilled workers as a function of prices only,  $\omega H/L = (P_h/P_l)^{1-\epsilon}$ . Substituting (22) yields:

$$\omega^\epsilon = \frac{L^{(\sigma_l-\epsilon)/(\sigma_l-1)} (1 + Mt^{1-\sigma_l})^{(1-\epsilon)/(\sigma_l-1)}}{H^{(\sigma_h-\epsilon)/(\sigma_h-1)} (1 + Mt^{1-\sigma_h})^{(1-\epsilon)/(\sigma_h-1)}}. \tag{23}$$

This equation relates the skill premium to factor supplies and trade openness. The only difference introduced by trade frictions is that foreign endowments are discounted by the factor  $t^{1-\sigma_h}$ : the higher the trade costs and the elasticity of substitution between varieties, the lower the trade volume and thus the contribution of foreign endowments to the relevant market size. Given our assumption  $1 < \epsilon < \sigma_h < \sigma_b$  the skill premium increases if domestic and foreign country size grow, if new countries join the world trading system and, of course, if trade costs fall. Setting  $\sigma_l \rightarrow \infty$  as the usual benchmark, we can derive the elasticity of the skill premium to a change in  $M$ ,  $t$  and  $\bar{L} = H + L$ :

$$\frac{d\omega}{\omega} = \left(\frac{\epsilon - 1}{\epsilon}\right) \left[ \left(\frac{Mt^{1-\sigma_h}}{1 + Mt^{1-\sigma_h}}\right) \left(\frac{1}{\sigma_h - 1} \frac{dM}{M} - \frac{dt}{t}\right) + \frac{1}{\sigma_h - 1} \frac{d\bar{L}}{\bar{L}} \right],$$

where the term  $Mt^{1-\sigma_h}/(1 + Mt^{1-\sigma_h})$  is the share of imports in the skill-intensive sector.

We can use this formula to do a simple back-of-the-envelope calculation of the impact of scale effects in the US economy over the years 1950–2000. For  $M = 5$  and  $\sigma_h = 6$ , a drop in trade costs from 2 to 1.5 (roughly matching the change in the import share from 0.04 to 0.14, if the skill-intensive sector accounts for one third of output) together with a doubling of domestic and world labour force increases the skill premium by 8–10% if  $\epsilon = 1.5$  and by 12–15% if  $\epsilon = 2$ , where the range of values depends on whether we use the import share at the beginning or at the end of the period. These numbers suggest that trade and scale effects alone can explain a substantial fraction of the 20–30% increase (according to various measures) in the US skill premium. In smaller and more open countries, these effects will be stronger. As a further

Table 1  
*Trade Integration and  $d\omega/\omega$*

	$dt/t = -100\%$		$dt/t = -50\%$	
	$\varepsilon = 2$	$\varepsilon = 1.5$	$\varepsilon = 2$	$\varepsilon = 1.5$
$\sigma_h = 3.5$	31.8%	20%	10.8%	7.1%
$\sigma_h = 6$	23.7%	15.2%	5.8%	3.9%
$\sigma_h = 11$	12.7%	8.3%	0.7%	0.5%

Note.  $t = 2$ ,  $\sigma_l = \infty$ ,  $M = 10$ .

illustration, we use (23) to compute the percentage increase in the skill premium after a reduction of trade barriers from  $t = 2$  to  $t = 1.5$  (partial integration) or to  $t = 1$  (full integration) for a country that is trading with  $M = 10$  identical economies. The results, for different parameter values, are reported in Table 1, showing that full integration can raise the skill premium by up to 32% and partial integration by 11%. Of course, these numbers are much reduced when scale economies are very weak (bottom line).

A second observation, seemingly at odds with trade models, is that commercial liberalisations seem to be followed by increases in the skill premium in some developing countries. Our model can rationalise this fact if the skill-biased scale effect is strong enough to overcome the factor proportions effect in skill-scarce countries. To see whether this is more than just a theoretical possibility, we use our model to study the recent episode of trade liberalisation in Mexico. This case is of particular interest because, prior to 1985, Mexico could be considered a closed economy due to heavy policies of trade protection. In 1985, Mexico announced its decision to join the GATT and undertook major reforms leading to a reduction of tariffs by 45% and of import licenses by more than 75% within three years. During the same period, the skill premium, starting from a value of 1.84, rose by more than 17%.

The Mexico experience is also interesting because its major trade partner is the skill-abundant US. We can then perform the following thought experiment. Assuming that Mexico was in autarky in 1985, we ask what our model says about the effect of a complete and instantaneous trade integration with the US. To answer this question, we first need measures of the economic size of the two countries and their relative skill endowment, so that we can compute the overall market enlargement and the change in factor scarcity after integration. We limit to the manufacturing sector, as it produces most of the traded goods. ILO statistics report that employment in manufacturing was about 5.5 million in Mexico and 21 million in the US. Capital per worker was instead 113% higher in the latter country. As for the skill endowment, Hanson and Harrison (1999) report that the share of white-collar workers in manufacturing employment was 0.26 in Mexico. Berman *et al.* (1994) report that the same figure was 0.35 in the US. Making use of the employment data, we can compute a share of white-collar workers equal to 0.33 for the sum of the two economies. Then, a move from autarky to the integrated equilibrium implies the following changes in Mexico:  $d\bar{L}/\bar{L} = 3.8$ ,  $dK/K = 8.1$  and  $d\theta/\theta = 0.27$ . Using these numbers together with conservative parameter values ( $\gamma = 1/3$ ,  $\varepsilon = 1.5$ ,  $\sigma_h = 6$ ,  $\sigma_l = \infty$ ), our model predicts the following change in the Mexican skill premium:



$$\frac{d\omega}{\omega} = +0.40 - 0.25 = +0.15,$$

where the first number represents the positive scale effect and the second number the negative factor proportions effect. Overall, trade opening in the skill-scarce Mexico may lead to a considerable 15% increase in the skill premium. These simple calculations suggest that the market size effect can play a significant role in developing countries that experience drastic trade liberalisations.

### 2.3. Reconciling Wages and Prices

The third puzzling fact that a satisfactory model should explain is the evolution of relative prices. Though the empirical findings are sometimes mixed, they tend to suggest a *decline* in the relative price of skill-intensive goods during the period of rising skill premia. Our model can help one to understand this evidence, as it breaks the simple positive relation between the price of goods and factors implied by the standard trade theory. On the one hand, a trade-induced expansion in market size lowers the relative final price of the skill-intensive good:

$$\frac{P_h}{P_l} = \left( \frac{n_l^{\frac{\sigma_l}{\sigma_l-1}}}{n_h^{\frac{\sigma_h}{\sigma_h-1}}} \right)^{1/\epsilon}.$$

Our assumption  $\sigma_l > \sigma_h$  implies that a larger market is associated with a lower relative price of the skill-intensive final good: as the skill-intensive sector is characterised by stronger returns to scale, its output grows more after an increase in market size and this depresses its relative price.

On the other hand, trade increases the relative price of each variety of intermediates in the skill-intensive sector, together with the skill premium, because of the stronger productivity gain:

$$\frac{p_h}{p_l} = \omega^{1-\gamma}.$$

These contrasting implications concerning the effects of international trade on price indexes and prices of individual goods may shed light on the mixed results emerging from empirical studies using different methodologies and different levels of sectoral aggregation. In particular, it is suggestive that Lawrence and Slaughter (1993) show a decline in the relative price of skill-intensive goods using a high level of aggregation, whereas Krueger (1997) finds the opposite result using highly disaggregated data.

### 2.4. Market Size and Skill-upgrading

A final argument often used to discredit the role of trade is that the demand for skill increased within all industries. We close this Section by showing how our theory

can also account for this stylised fact. All we need is to interpret the model of Section 1 as describing a single industry (or even a single plant) and to add an upward sloping supply curve of skilled labour. More precisely, assume that in the economy there are two industries producing final consumption goods,  $X$  and  $Y$ , using industry-specific intermediates of different skill intensity according to the following CES functions:<sup>30</sup>

$$X = \left[ (1 - \alpha_x)(X_l)^{\frac{\epsilon-1}{\epsilon}} + \alpha_x(X_h)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}$$

$$Y = \left[ (1 - \alpha_y)(Y_l)^{\frac{\epsilon-1}{\epsilon}} + \alpha_y(Y_h)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}},$$

The production functions for  $X_l$  and  $X_h$  are identical to those for  $Y_l$  and  $Y_h$ , still given by (3). Thus, returns to scale are higher for intermediates  $X_h$  and  $Y_h$  (employing skilled workers only) than for intermediates  $X_l$  and  $Y_l$  (employing unskilled workers only). The only difference between the two industries  $X$  and  $Y$  lies in the parameters  $\alpha_y$  and  $\alpha_x$ , capturing the relative importance of skill-intensive intermediates. Note that this formulation preserves entirely our basic insight: that skill-intensive activities (even within industries or plants) are characterised by stronger returns to scale. Under these assumptions, the wage bill share of skilled workers in industry  $X$  is given by:

$$\omega \frac{H_x}{L_x} = \frac{\alpha_x}{1 - \alpha_x} \left( \frac{X_h}{X_l} \right)^{(\epsilon-1)/\epsilon} \tag{24}$$

where  $H_x$  and  $L_x$  represent employment in industry  $X$  of skilled and unskilled workers, respectively. An analogous expression holds for industry  $Y$ . Imposing wage equalisation across industries, full employment, and using the reduced forms for  $X_h$  and  $X_l$ , we can derive an expression that links the labour endowment of the economy to employment in industry  $X$ :

$$\left( \frac{L_x}{L - L_x} \right)^{\frac{\sigma_l - \epsilon}{\epsilon(\sigma_l - 1)}} = \frac{\alpha_y(1 - \alpha_x)}{(1 - \alpha_y)\alpha_x} \left( \frac{H_x}{H - H_x} \right)^{\frac{\sigma_h - \epsilon}{\epsilon(\sigma_h - 1)}}. \tag{25}$$

Note that any increase in  $H$  and  $L$  must be matched by a proportional increase in  $H_x$  and  $L_x$ . The same happens in industry  $Y$ . Then, if the supply of skill is upward sloping, any increase in the skill premium (due to, say, a market size expansion) will raise  $H$  relative to  $L$  and, as a consequence of (25), every industry will employ a higher share of skilled workers. The intuition for this result, see (24), is again that, as long as the activities performed by skilled workers enjoy stronger returns to scale than those performed by the unskilled and the elasticity of substitution among them is sufficiently high, any increase in market size raises the relative demand for skill, even within industries or plants.<sup>31</sup>

<sup>30</sup> Note that  $\epsilon$  is now to be interpreted as the elasticity of substitution in production between inputs with different skill-intensity.

<sup>31</sup> Our result is also in line with a general principle that trade in intermediate inputs can have an important impact on the structure of production and demand for labour within industries. See Feenstra and Hanson (1996) and Jones (2000*b*).

### 3. Empirical Evidence

The main prediction of our theory is a positive effect of market size expansion on the skill premium. In this Section, we confront this prediction with the data. As recognised by a recent literature,<sup>32</sup> a country's overall market size can be identified empirically by two major components: the size of the internal market (proxied by measures of country size) and the degree of integration with foreign markets (proxied by the openness ratio). Thus, a natural way to test our model is to estimate the impact on the skill premium of an increase in both the openness ratio and country size.

A first potential problem raised by this empirical strategy is that data on wage differentials are often of low quality and are not fully comparable across countries. To address this issue, we appeal to three different measures of wage inequality coming from completely different sources. If we can show that our main results are consistent across datasets, we may then conclude that this is not merely by chance. In particular, we exploit the following widely used data (see the Data Appendix for more details on the datasets and the construction of the variables):

- (a) A panel of economy-wide Mincerian returns to education, drawn from Banerjee and Duflo (2005) and Psacharopoulos and Patrinos (2004), who provide the latest compilations of returns to education.<sup>33</sup> Our sample comprises 40 countries observed for at least two years between the early 1960s and the late 1990s (110 observations overall).
- (b) A panel of manufacturing skill premia, drawn from the UN – General Industrial Statistics database. Following other studies, we compute the skill premium as the ratio of non-production to production (operatives) wages in total manufacturing. Our sample comprises 35 countries (70 observations) observed roughly between 1980 and 1990.
- (c) A panel of Gini coefficients of the net income distribution, drawn from Dollar and Kray (2002). Our panel comprises 68 countries observed at least twice between the early 1960s and the late 1990s (277 observations overall). Although Gini coefficients represent a broader measure of inequality than Mincerian returns to education or manufacturing skill premia, which are more closely related to our theory, they may nonetheless shed light on the evolution of wage inequality overtime, since labour income is an overwhelming share of total income in most countries.

<sup>32</sup> The main references are Frankel and Romer (1999), Alesina *et al.* (2000) and Alcalá and Ciccone (2004), who are concerned with the effects of the extent of the market on *per capita* income. We focus instead on skill-biased scale effects.

<sup>33</sup> Mincerian returns to education are obtained as the coefficient of years of schooling in a regression of log wages on years of schooling. Notwithstanding the efforts of the compilers, estimates of returns to education are not fully comparable across studies, mainly because of sample coverage and methodology. As for sample coverage, estimates of returns to education are not always based on a survey of households representative of the entire population but rather on a survey of large firms with many employees. As for methodology, a major limitation is that researchers use different sets of controls in their regressions. Moreover, some studies rely on OLS estimates, while others appeal instead to an IV strategy (it seems, however, that the estimation method makes little difference for the results). Finally, some estimates are rated as being of 'poor quality' by Banerjee and Duflo (2005). Our dataset does not include any of these low quality estimates. However, some of the variation in the data we use may be spuriously driven by methodological heterogeneity. We partly address this problem by relying on fixed-effects within regressions, as methodological differences may be partly absorbed by country and time-specific effects.

Table 2  
*Descriptive Statistics of the Datasets on Inequality (Selected variables)*

	Returns to Education (various years)	Manufacturing Skill Premia (1990)	Gini Coefficients of Inequality (1990)
Index of inequality	9.70 (5.28)	2.10 (0.87)	43.17 (10.63)
Per capita income \$	10,484 (8,030)	11,295 (8,346)	7,733 (7,319)
Openness ratio	0.54 (0.19)	0.58 (0.42)	0.75 (0.60)
Labour force (thousands)	34,894 (115,122)	26,479 (58,337)	15,140 (42,153)
Average years of schooling	6.68 (2.62)	6.74 (2.76)	5.26 (2.76)
Capital stock per worker \$	56,404 (47,146)	55,740 (43,899)	38,727 (43,504)
No. of countries	39–40	35	60–68

The Table displays the mean and standard deviation (in parenthesis) of selected variables included in the datasets on inequality.

Table 2 provides descriptive statistics for selected variables in the three datasets. Note that the countries in the first two datasets are similar in terms of average income, openness and endowments, whereas the average country is smaller and more open in the panel of Gini coefficients.

A second challenge is the choice of appropriate measures of market size. As mentioned earlier, for most of the analysis we follow the empirical literature in using measures of country size (alternatively, labour force or GDP) and trade openness as joint proxies for a country's overall market size.<sup>34</sup> Although natural, this identification strategy may raise some concerns. In particular, we recognise that trade openness may affect relative wages through mechanisms other than the scale effect. Domestic market size, instead, is likely to capture a pure scale effect. Still, it varies little over short time spans. Moreover, one may argue that domestic variables lose significance when small countries become integrated with a much larger world economy. We are not too worried about the latter issue because roughly 70% of production in our sample is destined to domestic markets and factor price equalisation clearly does not hold in reality. Nonetheless, we check the robustness of our results by using a synthetic scale variable that captures simultaneously the size of the internal and external markets and the degree of international integration. This will also allow us to get a measure of the overall scale elasticity of the skill premium.

In particular, we construct a synthetic scale variable,  $\bar{L}_i^{tot}$ , defined as a weighted average of domestic ( $\bar{L}_i$ ) and world ( $\bar{L}_w$ ) size, where the weight is given by a country's trade openness ( $Op_i$ ):  $\bar{L}_i^{tot} = (1 - Op_i)\bar{L}_i + Op_i\bar{L}_w$ .<sup>35</sup> To compute it, we only need an operational definition of foreign size ( $\bar{L}_f = \bar{L}_w - \bar{L}_i$ ). Here, we follow Harrigan (2000) by

<sup>34</sup> Indeed, the joint importance of these two components is easily understood in our model, where trade integration between identical countries is isomorphic to an increase in the domestic labor force. More in general, this is a feature of the models ascribed to the so-called new trade theory.

<sup>35</sup> This variable is given a theoretical foundation in Alesina *et al* (2000).

defining foreign size as the sum of the economic sizes of all foreign countries multiplied by their openness.<sup>36</sup>

$$\bar{L}_f = \bar{L}_w - \bar{L}_i = \sum_{j \neq i}^N Op_j \bar{L}_j, \quad (26)$$

where  $j = 1, \dots, N$  are countries in the world,  $\bar{L}_j$  is country  $j$ 's total labour force (or GDP) and  $Op_j$  is its openness.  $\bar{L}_f$  can be thought of as a proxy for the amount of foreign resources engaged in international markets.<sup>37</sup> Substituting (26) into  $\bar{L}_i^{tot}$  and rearranging terms gives our operational definition of country  $i$ 's total market size:

$$\bar{L}_i^{tot} = \bar{L}_i + Op_i \sum_{j \neq i}^N Op_j \bar{L}_j. \quad (27)$$

This scale variable implies that a country's market size rises due to a greater domestic and foreign exposure to international trade or to a rise in domestic and foreign economic size.<sup>38</sup> Data on openness, labour force and GDP come from the Penn World Tables (Marks 5.6 and 6.1). The average correlation across datasets between  $\bar{L}_i^{tot}$  and labour force equals 0.58, whereas the average correlation between  $\bar{L}_i^{tot}$  and the openness ratio equals 0.43.

A final concern is with the estimation method. Although our model predicts a relationship between market size and the skill premium both across countries and overtime, throughout the article we have emphasised the latter implication. The main reason for this choice of emphasis is our motivation to explain the observed increase in the skill premia. In the following, we will therefore appeal to fixed-effects within regressions, thereby mainly relying on the temporal variation in the data to estimate the coefficients of interests.<sup>39</sup> An advantage of this strategy is that it allows us to avoid spurious results due to omitted time-invariant determinants of the wage structure (such as institutional factors that are absent in our model) and thus focus on a more parsimonious set of controls. In particular, we first control for the skill endowment using standard proxies of schooling (average years of schooling and the share of labour force with some secondary education, from the Barro-Lee dataset). Second, we control for capital endowment, because it is part of the economic size of a country and because in the presence of complementarity among inputs (e.g., capital-skill complementarity) its omission may lead to biased results. The series on capital stock are computed using the perpetual inventory method, as in Hall and Jones (1999). Third, to control for the effects of technology on the wage structure, we compute the total factor productivity (TFP) for each country in the sample. In this, we again follow Hall and Jones (1999). Fourth, we control for

<sup>36</sup> As argued by Harrigan (2000), the relevant world market is composed by that part of countries' endowments 'which is engaged in producing goods that are traded internationally'.

<sup>37</sup> To compute  $\bar{L}_f$  we have considered all the countries in the world (about 100) with available data on labour force (or GDP) and openness over the period of analysis.

<sup>38</sup> Note that, in order for  $\bar{L}_i^{tot}$  to make sense, openness must lie in the range [0,1]. Therefore, in computing  $\bar{L}_i^{tot}$ , we define openness as  $[(imports + exports)/2]/GDP$ . For a few outliers (Hong Kong, Singapore and Luxembourg), this measure is greater than one. In these cases, we set it equal to one.

<sup>39</sup> An earlier version of the article, available upon request, discusses the cross-sectional evidence.

real *per capita* GDP to capture the effect of omitted or mismeasured variables correlated with *per capita* income (e.g., education, technology etc.). Finally, we control for time dummies to account for the potential correlation of our covariates with time-specific effects.

3.1. *Scale and Mincerian Returns to Education: Results*

We start with a panel of Mincerian returns to education. Figure 4 illustrates some interesting features of the dataset. It reports the period change in the openness ratio on the horizontal axis and the period percentage change in the Mincerian returns to education on the vertical axis. Note that countries such as Mexico, China, Korea, Philippines, Guatemala and Nicaragua experienced a substantial increase in the returns to education in periods of greater exposure to international trade. In contrast, for other countries in the dataset, periods of falling trade exposure are generally associated with falling returns to education.

Table 3 summarises the main results of our fixed-effects within regressions. Time-specific effects are always included. In column (1), we regress the log of returns to education on the two scale variables, i.e., the openness ratio and the log of labour force. The coefficients of the two proxies are positive, as expected, and are significant at the 1 and 5% levels, respectively. Next we control for the skill endowment, proxied by years of schooling in column (2) and by secondary education in column (3). Note that the size and significance of the coefficients of the two scale variables are unaffected,

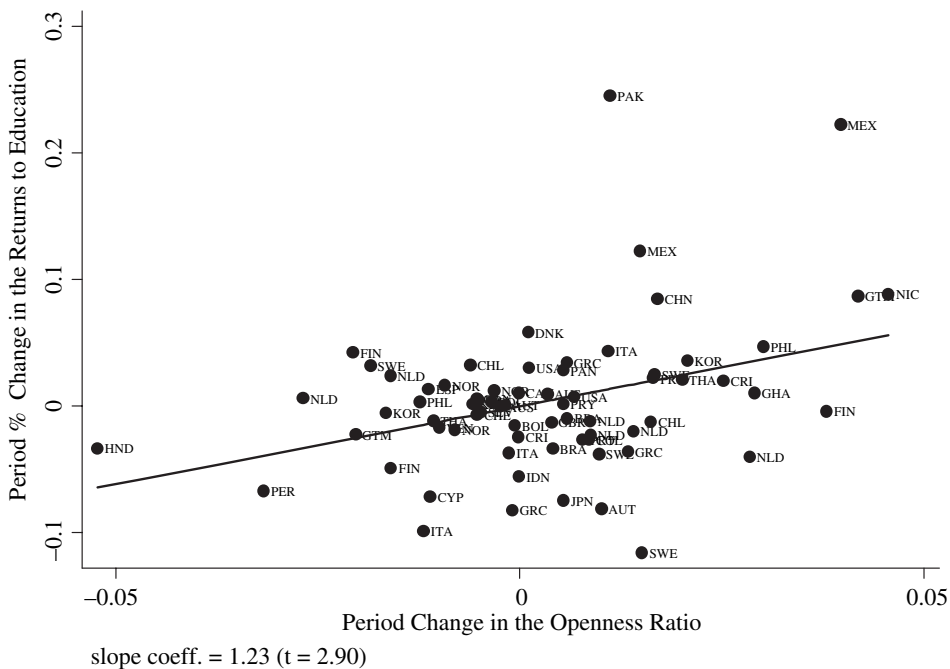


Fig. 4. *Openness and Returns to Education*

Table 3  
*Scale and Returns to Education*  
 Dependent variable: log of Mincerian returns to education

	(1) <i>Baseline</i>	(2) <i>Adding years of schooling</i>	(3) <i>Secondary schooling</i>	(4) <i>Adding more controls</i>	(5) <i>Country size = GDP</i>	(6) <i>Dropping outliers</i>	(7) <i>Synthetic scale var. (lab. force)</i>	(8) <i>Synthetic scale var. (GDP)</i>
<i>Openness</i>	1.78*** (0.443)	1.84*** (0.440)	1.78*** (0.445)	2.16*** (0.449)	2.15*** (0.449)	1.64*** (0.381)	0.565** (0.278)	1.06*** (0.260)
<i>Log country size</i>	0.983** (0.471)	0.961** (0.466)	1.02** (0.476)	1.65*** (0.528)	1.47*** (0.472)	1.32*** (0.436)		
<i>Schooling</i>		0.112 (0.072)	0.004 (0.006)	0.277*** (0.099)	0.198** (0.094)	0.242*** (0.080)	0.109 (0.109)	0.143 (0.466)
<i>Log capital stock</i>				0.703* (0.387)	0.184 (0.371)	0.514 (0.318)	0.100 (0.429)	0.187 (0.391)
<i>Log TFP</i>				1.68** (0.736)	0.675 (0.669)	1.51*** (0.601)	0.108 (0.769)	0.398 (0.706)
<i>Log Income</i>				-2.08** (1.04)	-2.04** (1.04)	-1.64* (0.855)	0.023 (1.12)	-0.725 (1.03)
No. obs.	110	110	110	108	108	106	108	108
Groups	40	40	40	39	39	38	39	39
R-squared	0.34	0.37	0.35	0.43	0.43	0.44	0.20	0.33

Fixed-effects within estimates with standard errors in parentheses. \*\*\*, \*\*, \* = significant at the 1, 5 and 10% levels, respectively. All equations include time dummies, whose coefficients are not reported in the table. Country size is proxied by labour force in columns (1)–(4) and (6), by GDP in column (5), and by the scale variable defined by (27) in columns (7)–(8). Openness is measured at current prices. Schooling is proxied by secondary education in column (3) and by the average years of schooling otherwise. In column (6), two outlier observations (Pakistan and Mexico) are excluded from the sample. Data sources: Banerjee and Duflo (2005), Psacharopoulos and Patrinos (2004), PWT and Barro-Lee.

whereas both proxies for the skill endowment are insignificant.<sup>40</sup> In column (4), we add our main controls, namely, the logs of the capital stock per worker, TFP and *per capita* income. Interestingly, the coefficients of the capital stock and TFP are positive and significant at the 10 and 5% levels, respectively, which is consistent with both capital-skill complementarity and skill-biased technical change. Note also that the coefficient of *per capita* GDP is negative and significant, while that of schooling is now positive, probably suggesting that with this data *per capita* income might be a better proxy for the skill endowment than standard measures of schooling. More importantly, column (4) shows that the coefficients of the two scale variables are large, positive and significant at the 1% level. The point estimate suggest that a one percentage point increase in the openness ratio is associated with a 2% increase in the return to education, while the elasticity of the returns to education to country size is roughly equal to 1.5. In column (5), we proxy country size with the log of GDP instead of labour force. The simple correlation between GDP and labour force is not too high (0.48), yet the results are virtually identical. Figure 4 suggests that two observations, Pakistan and Mexico (1990–5), may have a disproportionate impact on the coefficient of the

<sup>40</sup> Banerjee and Duflo (2005) also find that returns to education are unrelated to schooling in a cross-sectional context.

openness ratio. In column (6), we therefore re-run regression (4) after dropping these two observations. Note that the significance of our coefficients of interest is unaffected.

Finally, in columns (7) and (8) we proxy for scale with the log of our synthetic scale variable  $\bar{L}_i^{tot}$ , instead of controlling for country size and openness separately. In particular, in column (7) we use labour force to compute  $\bar{L}_i^{tot}$ , whereas in column (8) we use GDP instead.<sup>41</sup> The coefficient of this synthetic scale variable has the expected sign and is significant at the 5% or 1% level. It is also large in magnitude, suggesting that the overall scale elasticity of returns to education is roughly between 0.5 and 1.

3.2. *Scale and Skill Premia: Results*

We now test for skill-biased scale effects using a panel of manufacturing skill premia observed during the 1980s. Figure 5 reports the change in the openness ratio on the horizontal axis and the percentage change in the skill premium on the vertical axis. It shows that countries such as Turkey, Mexico, Chile, Malaysia, that increased their outward orientation substantially during the 1980s, also experienced a concomitant increase in the skill premium. In contrast, countries such as Japan, Korea, Finland, Egypt, whose trade exposure fell, experienced a fall in the skill premium as well. This is suggestive of a positive association between openness and skill premia, which is confirmed by the formal econometric analysis summarised in Table 4. Here we follow the same steps as before by running fixed-effects within regressions of the log of

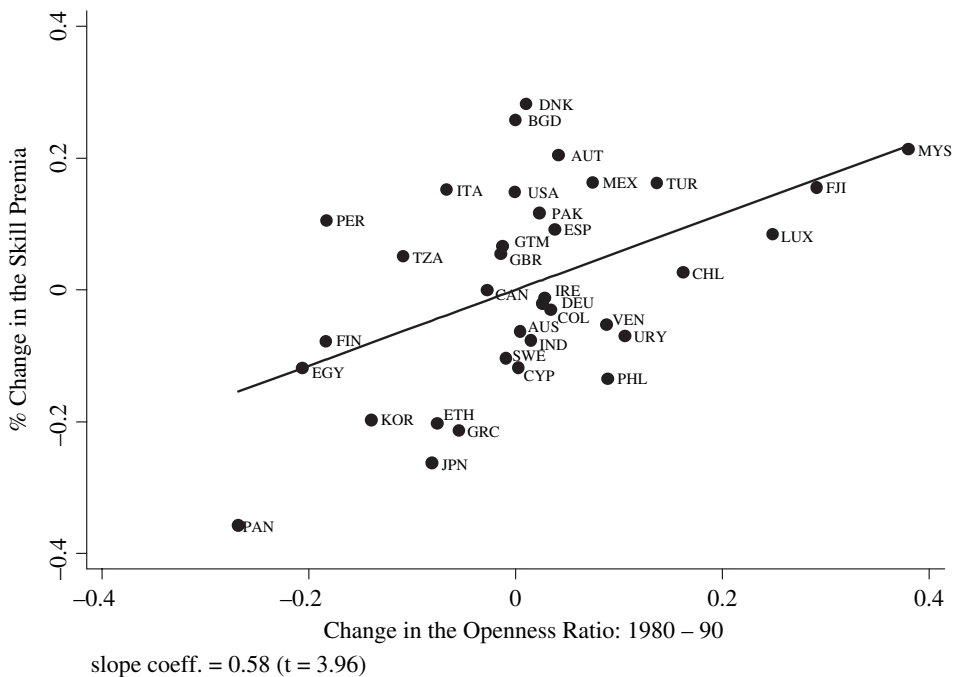


Fig. 5. *Openness and Skill Premia*

<sup>41</sup> The simple correlation between the two variables is 0.53.



Table 4  
*Scale and Skill Premia* Dependent variable: log of manufacturing skill premia

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	<i>Baseline</i>	<i>Adding years of schooling</i>	<i>Secondary schooling</i>	<i>Adding more controls</i>	<i>Country size = GDP</i>	<i>Dropping outliers</i>	<i>Synthetic scale var. (lab. force)</i>	<i>Synthetic scale var. (GDP)</i>
<i>Openness</i>	0.568*** (0.186)	0.569*** (0.189)	0.568*** (0.189)	0.543*** (0.193)	0.541*** (0.193)	0.608** (0.286)	0.322*** (0.091)	0.285*** (0.093)
<i>Log country size</i>	0.309** (0.130)	0.303 (0.188)	0.308* (0.169)	0.312* (0.176)	0.282* (0.160)	0.335* (0.186)		
<i>Schooling</i>		0.001 (0.036)	0.004 (0.333)	-0.346 (0.458)	-0.490 (0.494)	-0.414 (0.513)	-0.705 (0.455)	-0.581 (0.466)
<i>Log capital stock</i>				0.027 (0.163)	-0.075 (0.185)	-0.024 (0.201)	0.033 (0.159)	0.011 (0.167)
<i>Log TFP</i>				-0.055 (0.193)	-0.256 (0.209)	-0.035 (0.207)	-0.010 (0.192)	-0.074 (0.197)
<i>Income</i>				0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)	0.000 (0.000)
No. obs.	70	70	70	70	70	64	70	70
Groups	35	35	35	35	35	32	35	35
R-squared	0.34	0.34	0.34	0.38	0.38	0.30	0.37	0.32

Fixed-effects within estimates with standard errors in parentheses. \*\*\*, \*\*, \* = significant at the 1, 5 and 10% levels, respectively. Country size is proxied by labour force in columns (1)–(4) and (6), by GDP in column (5), and by the scale variable defined by (27) in columns (7)–(8). Openness is measured at current prices. Schooling is proxied by the average years of schooling in columns (1) and (2) and by secondary education otherwise. In column (6), three outliers are excluded from the sample (Malaysia, Fiji and Luxembourg). Data sources: UN-GIS, PWT and Barro-Lee.

manufacturing skill premia on various measures of market size, skill endowment and other controls. In column (1), the log of the skill premium is regressed on the openness ratio and the log of labour force only. The coefficient of openness is positive, large and significant beyond the 1% level. It suggests that a one percentage point increase in the openness ratio brings about a 0.5% increase in the skill premium. The coefficient of country size is also large and positive, suggesting that the elasticity of the skill premium to the country size is roughly equal to 0.3. However, it is significant at the 10% level only, which is not surprising, since there is little variation in the growth of country size over a time span of a decade only and hence its effect can hardly be estimated with great precision. In columns (2) and (3), we add years of schooling and secondary education and find, again, that schooling is unrelated to the skill premium. Note, also, that the coefficients of our two scale variables are unchanged across specifications, although in column (2) the coefficient of country size is significant at the 12% level only. In column (4), we add the logs of the capital stock per worker, TFP and *per capita* income. These controls turn out insignificant, whereas the coefficients of openness and country size are unaffected and still significant at the 1 and 10% levels, respectively. Similar results are obtained using the log of GDP instead of labour force as a proxy for country size.

As shown in Figure 5, there are three countries (Malaysia, Luxembourg and the Fiji islands) that may have a disproportionate impact on the estimated coefficient of the openness ratio. In column (6), we therefore re-run the regression in column (4) after

dropping these observations. In this case, the coefficient of the openness ratio becomes larger, although slightly less precisely estimated (but still significant at the 5% level). The coefficient of country size is also slightly larger and significant at the 10% level.

Finally, in columns (7) and (8) we replace country size and the openness ratio with the log of our synthetic scale variable  $\bar{L}_i^{tot}$  (using, respectively, labour force and GDP to compute it). We find that the coefficient of the scale variable is stable and significant beyond the 1% level in the two specifications, implying an overall scale elasticity of the skill premium around 30%. Note also that the overall scale elasticity of the skill premium estimated in columns (7)–(8) is almost identical to the elasticity of the skill premium to country size estimated in columns (1)–(6). This suggests that, consistent with our model, either the growth of country size or a greater trade openness may have a similar impact on the skill premium as long as they bring about a similar expansion in market size.

3.2. Scale and Income Inequality: Results

As a final step, we confront our mechanism with a panel of Gini coefficients of the net income distribution. Figure 6 reports the period change in the openness ratio on the horizontal axis and the period percentage change in the Gini coefficients on the vertical axis. It suggests, again, a positive association between openness and inequality. Table 5 summarises the main results of the fixed-effects within regressions. Time-specific effects are always controlled for. We follow the same steps as in the previous two

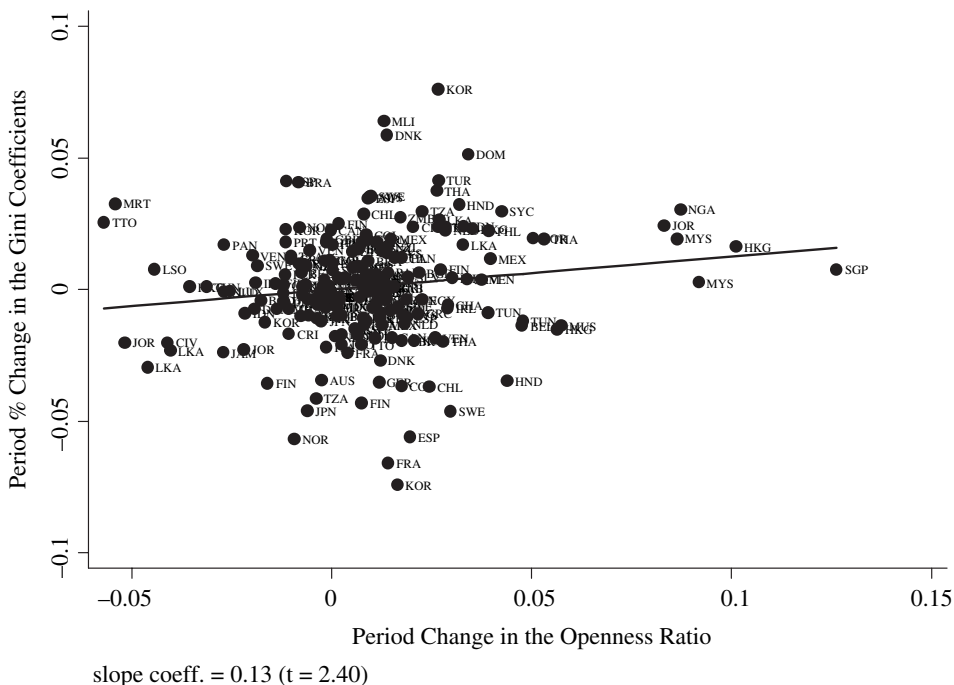


Fig. 6. Openness and Income Inequality

Table 5  
*Scale and Income Inequality*  
 Dependent variable: log of Gini coefficients of the net income distribution

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	<i>Baseline</i>	<i>Adding years of schooling</i>	<i>Secondary schooling</i>	<i>Adding more controls</i>	<i>Adding income squared</i>	<i>Country size = GDP</i>	<i>Synthetic scale var. (lab force)</i>	<i>Synthetic scale var. (GDP)</i>
<i>Openness</i>	0.097** (0.046)	0.104** (0.047)	0.111** (0.046)	0.107** (0.049)	0.106** (0.050)	0.109** (0.049)	0.097*** (0.038)	0.133*** (0.038)
<i>Log country size</i>	0.233*** (0.061)	0.230*** (0.063)	0.166*** (0.063)	0.293*** (0.073)	0.296*** (0.093)	0.251*** (0.068)		
<i>Schooling</i>		-0.039*** (0.013)	-0.005*** (0.001)	-0.018 (0.017)	-0.018 (0.017)	-0.036** (0.017)	-0.035** (0.017)	-0.035** (0.017)
<i>Log capital stock</i>				0.119*** (0.045)	0.120*** (0.051)	0.023 (0.041)	0.051 (0.043)	0.027 (0.041)
<i>Log TFP</i>				0.159 (0.099)	0.161 (0.108)	-0.034 (0.088)	-0.003 (0.093)	-0.036 (0.089)
<i>Log income</i>				-0.278** (0.131)	-0.294 (0.358)	-0.245* (0.130)	-0.078 (0.126)	-0.054 (0.122)
<i>Log income squared</i>					0.001 (0.017)			
No. obs.	277	257	257	257	257	257	257	257
Groups	68	60	60	60	60	60	60	60
R-squared	0.14	0.17	0.21	0.21	0.21	0.20	0.14	0.16

Fixed-effects within estimates with standard errors in parentheses. \*\*\*, \*\* \* = significant at the 1, 5 and 10% levels, respectively. All equations include time dummies, whose coefficients are not reported in the Table. Country size is proxied by labour force in columns (1)–(5), by GDP in column (6) and by the scale variable defined by (27) in columns (7)–(8). Openness is measured at current prices. Schooling is proxied by secondary education in column (3) and by the average years of schooling otherwise. Data sources: Dollar and Kray (2002), PWT and Barro-Lee.

Sections. In particular, in column (1) we regress the log of the Gini coefficient on the openness ratio and the log of labour force; in columns (2) and (3), we add proxies for the skill endowment (years of schooling and secondary education, respectively); in column (4), we add the main controls, namely, the logs of the capital stock per worker, TFP and *per capita* income; in column (5), we add the square of the log of income to control for a Kuznets-type relationship between income and inequality; in column (6), we use the log of GDP instead of labour force as a proxy for country size. Table 5 shows that the coefficient of country size is fairly stable across specifications and always significant beyond the 1% level. It suggests that the elasticity of inequality to country size is roughly equal to 25%. The coefficient of the openness ratio is also stable across specifications and always significant at the 5% level, suggesting that a one percentage point increase in the openness ratio brings about a 0.1% increase in income inequality. Finally, in columns (7) and (8) we proxy for scale with our synthetic variable  $\bar{L}_i^{tot}$  (using labour force and GDP, respectively, to compute it). In both specifications, the coefficient of the scale variable is positive and significant at the 1% level, implying an overall scale elasticity of inequality of about 10%. As for the other variables, the coefficient of the proxies for the skill endowment is now always negative, as expected, and significant in most specifications. The coefficient of the capital-labour ratio is positive, large and

also highly significant in some specifications. There is also evidence of a negative correlation between *per capita* income and inequality, but not of a Kuznets curve. Finally, the coefficient of TFP is large and significant at the 12% level in one specification.

To conclude, the evidence suggests that scale is skill-biased and that the scale elasticity of wage inequality may be large. In fact, it is generally larger than the elasticity computed from the theoretical model in the previous section, confirming that our calibration was conservative. Yet, we recognise that our article does not necessarily provide the only potentially relevant explanation for these findings. In particular, Thoenig and Verdier (2003), Dinopoulos *et al.* (2001) and Neary (2002) provide mechanisms where market size is also linked to skill premia through skill-biased technical change, which is consistent with our own evidence. To address this issue, we have controlled for TFP and found that it does not affect (indeed, it often increases) the size and significance of the coefficients of our scale variables. However, TFP is far from being a perfect proxy for skill-biased technical change and our scale variables may still capture some technological elements if a larger market promotes skill-biased innovations. Therefore, we do not read our results as evidence against some of the most credited alternative theories for the increase in skill premia. Indeed, we believe that disentangling the relative merits of these competing theories using micro-level evidence represents an exciting avenue for future research.

### 3.4. Evidence from Other Studies

Other empirical studies lend indirect support to our results. Antweiler and Trefler (2002), using trade data for 71 countries and 5 years, show that a rise in output tends to increase the relative demand for skilled workers. Our theoretical model provides an explanation for their finding. Historical evidence seems consistent with a skill-biased scale effect too: Lindert and Williamson (2001), for example, show that inequality widened during globalisation booms and after massive immigration, whereas it decreased in the period 1914–50 of protectionism and in the presence of massive emigration. Likewise, Goldin and Katz (1999) show that periods of narrowing of the wage structure in the US during the first half of the twentieth century coincided with major economic disruptions. After the wage compression that followed immediately the Second World War (1939–49), returns to skill were fairly stable (or even increasing) in the US and fell again during the turbulent years of the 1970s. Since then, skill premia have been on the upward trend. Note that such a behaviour of relative wages would be hard to explain, given the steady increase in the supply of skilled workers throughout the century, unless some other mechanism, like the one we suggest, had continuously raised the demand for skill. Finally, Hine and Wright (1998) report indirect evidence in support of the mechanism illustrated in the article. With reference to the UK, they estimate the magnitude of trade-induced productivity effects. Their most interesting result is that trade with other OECD countries has a much stronger effect on productivity than trade with developing countries. This is consistent with our model, *in primis*, because the economic size of the OECD countries (and therefore the trade-generated scale effect) is larger than that of developing countries; *in secundis*, because the UK trade with advanced countries is mainly intra-industry trade in

skill-intensive goods characterised by strong scale economies (thereby the more pronounced productivity gain).

**4. Concluding Remarks**

The most original result of our analysis is to show that the scale of an economy can be a key determinant of the skill premium. This is a general result that applies to different contexts. In this article, we have emphasised the role played by a trade-induced scale effect, instead of country-specific scale effects, such as factor accumulation or technical progress. A first reason for this focus is policy relevance. Trade is the only scale variable that can change abruptly as a consequence of policy reform. Second, if globalisation goes far enough, factor prices will mainly be determined at the world level and country-specific variables will lose their importance. Third, trade is fundamental in our story because the scale effect operates through the increase in the number of available intermediates made possible by some form of trade. Finally, our framework shows that a ‘new trade theory’ explanation based on intra-industry trade may reconcile the increase in skill premia with the empirical evidence often used to discredit more traditional trade explanations. We consider this as an important result *per se*.

We have derived our results for a specific market structure (monopolistic competition) and specific functional forms on the basis of our reading of the empirical evidence, to have a sense of the quantitative significance of the effect we discuss. Much of the debate on trade and wages is, in fact, centred on the magnitude of the trade-induced effects. But our model is an example of a more general principle, surprisingly neglected in the debate: as long as the activities performed by skilled workers enjoy stronger returns to scale than those performed by the unskilled and the elasticity of substitution among them is non-unitary, any increase in market size is non-neutral to income distribution.

**Appendix**

*A.1. The General Model*

We study now the more general case in which each good is a Cobb-Douglas composite of  $H$ ,  $L$  and  $K$ . We assume that the total cost function of a single variety produced in sector  $i$  is:

$$TC_i = (F_i + c_i y_i) r^\gamma (w_h^{\alpha_i} w_l^{1-\alpha_i})^{1-\gamma}, \tag{28}$$

where  $r$  is the rental rate,  $\gamma$  is the share of capital in total cost, and  $\alpha_i$  ( $i = h, l$ ) is the wage-bill share of skilled workers in sector  $i$ . We assume that  $\alpha_h > \alpha_l$  namely that sector  $h$  is skill-intensive relative to sector  $l$ . The relative price of skill-intensive varieties implied by (28) and profit maximisation becomes:

$$\frac{p_h}{p_l} = \frac{r^\gamma (w_h^{\alpha_h} w_l^{1-\alpha_h})^{1-\gamma}}{r^\gamma (w_h^{\alpha_l} w_l^{1-\alpha_l})^{1-\gamma}} = \omega^{(1-\gamma)(\alpha_h - \alpha_l)}. \tag{29}$$

Free-entry and the simplifying assumption  $F_i = 1/\sigma_i$  fix the scale of production of each variety to one:  $y_i = 1$ . Equations (2), (9) and (10) are unchanged; together with (28) they imply:

$$n_h^{\frac{\sigma_h - \epsilon}{\epsilon(\sigma_h - 1)}} \omega^{(1-\gamma)(\alpha_h - \alpha_l)} = n_l^{\frac{\sigma_l - \epsilon}{\epsilon(\sigma_l - 1)}}. \tag{30}$$

The demand for each factor can be found using Shephard’s lemma on the total cost function (28). After setting  $w_l$  as the numeraire, the conditions for full employment of capital, skilled and unskilled workers become:

$$\begin{aligned}
 K &= \gamma r^{\gamma-1} \omega^{(1-\gamma)\alpha_h} n_h + \gamma r^{\gamma-1} \omega^{(1-\gamma)\alpha_l} n_l \\
 H &= (1-\gamma)\alpha_h r^\gamma \omega^{(1-\gamma)\alpha_h-1} n_h + (1-\gamma)\alpha_l r^\gamma \omega^{(1-\gamma)\alpha_l-1} n_l \\
 L &= (1-\gamma)(1-\alpha_h)r^\gamma \omega^{(1-\gamma)\alpha_h} n_h + (1-\gamma)(1-\alpha_l)r^\gamma \omega^{(1-\gamma)\alpha_l} n_l.
 \end{aligned}$$

Solving for  $n_h$  and  $n_l$  gives:

$$\begin{aligned}
 n_i &= \frac{(1-\alpha_j)H\omega - \alpha_j L}{(1-\gamma)(\alpha_i - \alpha_j)\omega^{\alpha_i(1-\gamma)}} \left( \frac{\gamma}{1-\gamma} \frac{L + H\omega}{K} \right)^{-\gamma} \\
 &= \frac{\bar{L}^{1-\gamma} K^\gamma [(1-\alpha_j)\theta\omega - \alpha_j(1-\theta)](1-\theta + \theta\omega)^{-\gamma}}{(1-\gamma)^{1-\gamma} \gamma^{\gamma} (\alpha_i - \alpha_j)\omega^{\alpha_i(1-\gamma)}},
 \end{aligned}$$

for  $i, j = l, h, i \neq j, \bar{L} = H + L$  and  $\theta = H/\bar{L}$ . Simple derivation yields:

$$\frac{\partial n_h}{\partial \omega} > 0, \frac{\partial n_l}{\partial \omega} < 0, \frac{\partial n_h}{\partial \theta} > 0, \frac{\partial n_l}{\partial \theta} < 0. \tag{31}$$

These partial derivatives come from the production side of the economy. They imply that the higher the supply of one factor, the larger the size of the sector which uses that factor intensively, and that the larger the size of one sector, the higher the relative reward for the factor which is used intensively in that sector. Using the expressions for  $n_h$  and  $n_l$  in (30) and differentiating it with respect to  $\theta, K$  and  $\bar{L}$ , we find the elasticity of the skill premium:

$$\frac{d\omega}{\omega} = \frac{\frac{(\epsilon - 1)(\sigma_l - \sigma_h)}{(\sigma_h - 1)(\sigma_l - 1)} \left[ \gamma \frac{dK}{K} + (1-\gamma) \frac{d\bar{L}}{\bar{L}} \right] - \left( \frac{\sigma_h - \epsilon}{\sigma_h - 1} \frac{\partial n_h}{\partial \theta} \frac{\theta}{n_h} - \frac{\sigma_l - \epsilon}{\sigma_l - 1} \frac{\partial n_l}{\partial \theta} \frac{\theta}{n_l} \right) \frac{d\theta}{\theta}}{(1-\gamma)(\alpha_h - \alpha_l)\epsilon + \frac{\sigma_h - \epsilon}{\sigma_h - 1} \frac{\partial n_h}{\partial \omega} \frac{\omega}{n_h} - \frac{\sigma_l - \epsilon}{\sigma_l - 1} \frac{\partial n_l}{\partial \omega} \frac{\omega}{n_l}}. \tag{32}$$

Given the inequalities in (31) and our assumption  $1 < \epsilon < \sigma_h < \sigma_b$  it can be seen that the skill premium is increasing in the scale and decreasing in the share of skilled workers. Equations (14) and (20) are all special cases of this formula.

Finally, it is possible to show that, with non-extreme factor intensities, the aggregate elasticity of substitution between skilled and unskilled workers (holding the other variables constant) is given by:

$$\varepsilon_w = - \frac{d(H/L)}{d\omega} \frac{\omega}{H/L} \Big|_{n_h, n_l, K, K_l} = \frac{(\alpha_h - \alpha_l)(\epsilon - 1)}{\left( \frac{\alpha_h}{1 - \alpha_h} \frac{L}{H\omega} - 1 \right)^{-1} + \left( 1 - \frac{\alpha_l}{1 - \alpha_l} \frac{L}{H\omega} \right)^{-1}} + 1.$$

Rearranging, we can write the elasticity of substitution in consumption ( $\epsilon$ ) as a function of the elasticity of substitution in production ( $\varepsilon_w$ ):

$$\epsilon = 1 + \frac{(\varepsilon_w - 1)}{\alpha_h - \alpha_l} \left[ \left( \frac{\alpha_h}{1 - \alpha_h} \frac{L}{H\omega} - 1 \right)^{-1} + \left( 1 - \frac{\alpha_l}{1 - \alpha_l} \frac{L}{H\omega} \right)^{-1} \right]. \tag{33}$$

Note that  $\varepsilon_w > 1$  implies  $\epsilon > 1$  (also,  $\varepsilon_w = \epsilon$  if  $\alpha_h = 1$  and  $\alpha_l = 0$ ). Further, (33) shows that, for a given value of the elasticity of substitution between workers of different types ( $\varepsilon_w$ ), the elasticity of substitution between goods ( $\epsilon$ ) is higher the lower the factor intensity differences across sectors. To give a concrete example,  $\varepsilon_w = 1.5$  (as in most labour market studies),  $\sigma_h = 6, \sigma_h \rightarrow \infty$  together with  $\alpha_h = 0.75$  and  $\alpha_l = 0.25$  imply an  $\epsilon$  of 3 and an increase in the skill-premium of 14% after a doubling of all factors. This suggests that even in this model the scale effect can be quantitatively large.

## A.2. *The Data*

Data on Mincerian returns to education are drawn from Banerjee and Duflo (2005) and Psacharopoulos and Patrinos (2004). Our sample comprises the following 40 countries: (in parenthesis we specify the years in which Mincerian returns are collected for each country; an asterisk denotes the countries for which we do not have data for some of our independent variables): Australia (1980, 1985, 1989), Austria (1981, 1985, av(1989–91)), Bolivia (1981, 1990), Brazil (1970, 1980, 1989, 1995), Canada (1981, 1986, 1989), Chile (1974, 1980, 1989), China (1988, 1993), Colombia (1965, 1974), Costa Rica (1980, 1985, av(1988–91)), Cyprus (1984, 1994), Denmark (1980, 1990), El Salvador (1985, 1990), Finland (1980, 1987, av(1989–91), 1993), Ghana (1989, 1995), Greece (1964, 1977, 1985, av(1987–93)), Guatemala (1977, 1986, 1989), Honduras (1986, 1990), Indonesia (1981, 1995), Italy (1977, 1983, 1985, 1987), Japan (1975, 1988), Kenya (1970, 1986), Korea (1974, 1979, 1986), Mexico (1984, av(1989–91), 1995), Netherlands (1962, 1965, 1972, av(1979–82), 1985, 1989, 1994), Nicaragua (1985, 1996), Norway (1980, av(1983–87), av(1989–91), 1995), Pakistan (1986, 1991), Panama (1983, 1990), Paraguay (1983, 1990), Peru (1985, 1991), Philippines (1982, 1988, av(1994–98)), Poland\* (1992, 1996), Portugal (1977, 1985, 1991), Spain (1985, 1990), Sweden (1968, 1974, 1981, 1984, 1990), Switzerland (1987, 1990), Thailand (1971, 1986, 1989), United Kingdom (1975, 1984), USA (1976, 1987, 1995), Venezuela (1975, 1984).

Data on manufacturing skill premia come from the UN - General Industrial Statistics database. Our sample comprises the following 35 countries (in parenthesis, we specify the years in which skill premia are collected for each country): Australia (1980, 1987), Austria (1980, 1990), Bangladesh (1979, 1989), Canada (1980, 1990), Chile (1978, 1990), Colombia (1980, 1990), Cyprus (1980, 1990), Denmark (1980, 1990), Egypt (1980, 1988), Ethiopia (1980, 1988), Fiji (1979, 1990), Finland (1980, 1990), Greece (1977, 1990), Guatemala (1978, 1988), India (1978, 1988), Ireland (1978, 1989), Italy (1980, 1989), Japan (1981, 1990), Korea (1979, 1990), Luxembourg (1980, 1990), Malaysia (1983, 1990), Mexico (1986, 1990), Pakistan (1981, 1988), Panama (1979, 1989), Peru (1980, 1988), Philippines (1977, 1987), Spain (1980, 1990), Sweden (1980, 1990), Tanzania (1981, 1985), Turkey (1980, 1990), USA (1980, 1990), United Kingdom (1980, 1990), Uruguay (1980, 1988), Venezuela (1979, 1990), West Germany (1980, 1990).

Data on Gini coefficients of the net income distribution come from Dollar and Kray (2002). Our sample comprises the following 68 countries (in parenthesis, we specify the years in which Gini coefficients are collected for each country; an asterisk denotes countries for which we do not have data for some of our independent variables): Australia (1976, 1981, 1986, 1993), Belgium (1979, 1985, 1992), Bangladesh (1963, 1973, 1978, 1983, 1988, 1995), Bolivia (1968, 1990), Brazil (1960, 1970, 1976, 1981, 1986, 1993), Canada (1965, 1971, 1977, 1982, 1987, 1994), Chile (1968, 1980, 1987, 1992), Cote d'Ivoire\* (1985, 1993), Colombia (1964, 1970, 1978, 1988, 1995), Costa Rica (1961, 1969, 1977, 1982, 1989, 1996), Denmark (1963, 1976, 1981, 1986, 1991), Dominican Republic (1976, 1984, 1989, 1996), Ecuador (1968, 1988, 1994), Egypt (1965, 1975, 1991), Spain (1965, 1973, 1980, 1985, 1990, 1996), Ethiopia\* (1981, 1995), Finland (1962, 1971, 1977, 1982, 1987, 1995), Fiji (1968, 1977), France (1962, 1970, 1975, 1981, 1989), Gabon\* (1960, 1975), United Kingdom (1961, 1966, 1971, 1976, 1981, 1986), Germany (1989, 1994), Ghana (1992, 1997), Greece (1974, 1981, 1988), Guatemala (1979, 1987), Hong Kong (1971, 1976, 1981, 1986, 1991), Honduras (1968, 1986, 1991, 1996), Indonesia (1964, 1970, 1976, 1981, 1987, 1993, 1999), India (1964, 1969, 1977, 1983, 1988, 1993), Ireland (1973, 1980, 1987), Iran (1969, 1984), Italy (1974, 1979, 1984, 1989), Jamaica (1971, 1988, 1993), Jordan (1980, 1986, 1991, 1997), Japan (1962, 1967, 1972, 1977, 1982, 1989, 1994), Korea (1961, 1966, 1971, 1976, 1982, 1988, 1993), Sri Lanka (1963, 1970, 1979, 1985, 1990, 1995), Lesotho (1986, 1993), Luxembourg\* (1985, 1991), Madagascar\* (1960, 1980, 1993), Mexico (1963, 1968, 1975, 1984, 1989, 1995), Mali (1989, 1994), Mauritania\* (1988, 1993), Mauritius (1980, 1986, 1991), Malaysia (1970, 1976, 1984, 1989, 1995), Niger (1960, 1992), Nigeria\* (1985, 1991, 1997), Netherlands (1962, 1975, 1981, 1986, 1991), Norway (1962, 1967, 1973, 1979, 1984, 1989, 1995), New Zealand (1973, 1978, 1983, 1989),

Pakistan (1964, 1969, 1979, 1985, 1990, 1996), Panama (1969, 1979, 1989, 1995), Peru (1961, 1971, 1981, 1986, 1994), Philippines (1965, 1971, 1985, 1991, 1997), Portugal (1973, 1980, 1989, 1994), Senegal (1960, 1991), Singapore (1978, 1983, 1988, 1993), Sierra Leone (1968, 1989), El Salvador (1965, 1989, 1995), Sweden (1963, 1975, 1980, 1985, 1990, 1995), Seychelles\* (1978, 1984), Thailand (1962, 1969, 1975, 1980, 1986, 1992, 1998), Trinidad & Tobago (1971, 1976, 1981, 1988), Tunisia (1965, 1971, 1980, 1985, 1990), Turkey (1973, 1987, 1994), Tanzania (1964, 1969, 1977, 1991), Venezuela (1962, 1971, 1976, 1981, 1987, 1993), Zambia (1959, 1976, 1991, 1996).

Finally, to compute the total factor productivity (TFP), we follow Hall and Jones (1999). First, we estimate the capital stock using the perpetual inventory method (we assume a depreciation rate of 6%), and then compute, for each country  $i$  and year  $t$ , the log of TFP as:  $\ln TFP_{it} = \ln (y_{it}) - \alpha / (1 - \alpha) \ln (K_{it} / Y_{it}) - \ln (h_{it})$ , where  $y$  is GDP per worker,  $K/Y$  is the capital/output ratio,  $\alpha = 1/3$ , and  $h$  is human capital per worker ( $h_{it} = e^{\phi(E_{it})}$ , where  $E$  stands for years of education and  $\phi$  is a piecewise linear function specified as in Hall and Jones).

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