SKILL, TRADE AND INTERNATIONAL INEQUALITY*

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Summary

Heckscher-Ohlin trade theory suggests that greater openness enlarges inter-country differences in stocks of skill (or human capital), which new growth theory suggests would cause inter-country divergence of per capita incomes. Econometric analysis of data on about 90 countries during 1960-90 confirms that greater openness tends to cause divergence of secondary and tertiary enrolment rates between more-educated and less-educated countries, and also between land-scarce and land-abundant countries. These findings may have implications for the optimal choice of trade policies by poor countries.

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Are differences in per capita income between countries reduced or increased by trade, and what are the mechanisms involved? These old questions have surfaced again recently in two related contexts: the debate over new growth theory, and the debate over development policy - and particularly over the right choice of trade policies by poor countries. In both contexts, there are sharp divisions of opinion.

The current conventional wisdom is that trade tends to cause *convergence*. This view is advanced in its strongest form by Sachs and Warner (1995) and the World Bank (e.g. 1996), who argue that openness to trade is a necessary condition for poor countries to catch up, and that the widening income gap between rich countries and most poor countries over the past few decades (Pritchett, 1995; Salah-i-Martin, 1996) is due largely to the restrictions which the latter have imposed on trade and other economic contacts with the rest of the world. A more focused version of this view is advanced by Ben-David (e.g. 1994, 1996, and with Loewy, 1996, and Rahman, 1996), who argues that reduction of trade barriers within specific groups of countries, such as the European Union, has caused their incomes to converge. The usually-suggested underlying mechanism is that trade speeds the transfer of modern technology to backward countries.

However, there is also a long tradition of argument in economics that trade between unequal partners causes *divergence*, starting with Tucker's critique of Hume in the 18th century (Elmslie, 1995), and continued by List (1841), Singer (1950) and Kaldor (1981). The usually-suggested mechanism - formalised by Dutt (1986), Matsuyama (1992), Findlay (1995) and Redding (1996) - is that trade shifts the structure of production towards (for the richer partner) or away from (for the poorer partner) sectors of greater growth potential - with faster technical progress or more opportunities for learning by doing. The most frequently quoted example of such a sector is manufacturing, to which agriculture is unfavourably compared. The policy implication is that poor countries should protect or promote sectors with more growth potential, an approach which many observers believe to have contributed to East Asia's exceptional success in catching up.

We shall suggest a rather different sort of divergence hypothesis, grounded in the skill-based version of Heckscher-Ohlin theory which has been widely used to analyse the effects of developed-developing country trade on wage inequality (e.g. Wood, 1994). The mechanism is that trade-induced changes in the relative wages of skilled workers - upwards in developed countries, downwards in developing countries - stimulate supply responses which widen the initial gap in skill endowments between the two sorts of countries, making it harder for developing countries to catch up in terms of income, because the availability of skilled labour (or human capital) is a crucial determinant of economic growth. This mechanism thus combines an idea from old trade theory with an idea from new growth theory. Unlike the models of divergence cited in the previous paragraph, which assume that some *sectors* have greater growth potential, it emphasises that some *factors* have greater growth potential - which has rather different implications for policy.

In this paper, we shall examine only the first part of this mechanism: the divergent response of skill supplies to greater openness to trade. Section 1 sets out the theory more fully, and the following three sections test it. Section 2 discusses the available data, with some preliminary descriptive statistics. Section 3 explains our econometric specification, and section 4 presents our regression results. Section 5 concludes.

1. Theory

This section starts with a brief review of the demand-side effects of trade on relative wages, moves on to examine supply-side responses, and concludes by discussing the impact of skill supply changes on income convergence.

Effects of trade on relative wages

Consider initially a simple Heckscher-Ohlin (H-O) model with two countries (developed and developing), two factors (skilled and unskilled labour), and two goods (skill-intensive machinery and labour-intensive clothing). The developed country has a relatively large supply of skilled labour, giving it a comparative advantage in machinery, while the developing country's relative abundance of unskilled labour gives it a comparative advantage in clothing. Increased openness to trade in the developed country thus raises its output of machinery and reduces its output of clothing, boosting the demand for skilled labour relative to unskilled labour, and at the same time raising the price of machinery relative to clothing, and the wage of skilled workers relative to unskilled workers. In the developing country, the consequences of greater openness are exactly the opposite.

The effects on relative wages can be illustrated in a diagram adapted from Leamer (1995) and discussed further in Wood (1995, 1996). The vertical axis of Figure 1 measures the skilled wage, relative to the unskilled wage, and the horizontal axis measures the number of skilled workers, relative to the number of unskilled workers. In the absence of trade, the demand curve for skilled labour would be the downward-sloping line, *dd*, and wages would be determined by its intersection with a supply curve (assumed for the time being to be completely inelastic), whose position depends on the country's endowments of skilled and

Figure 1. Two goods, inelastic supply

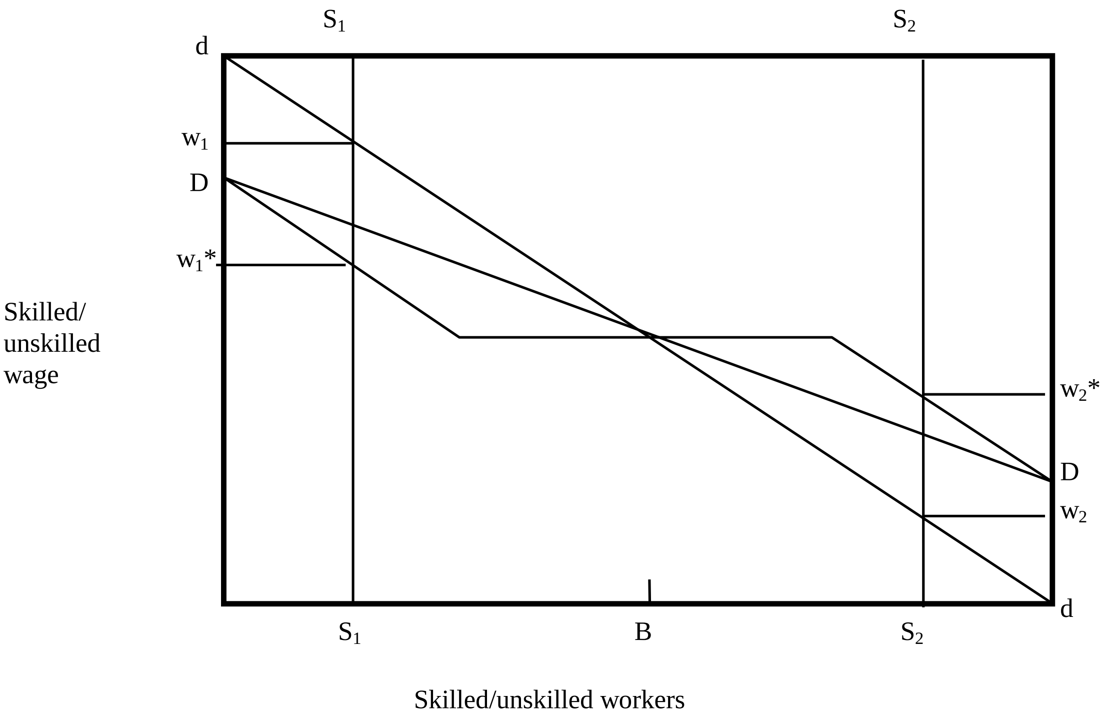
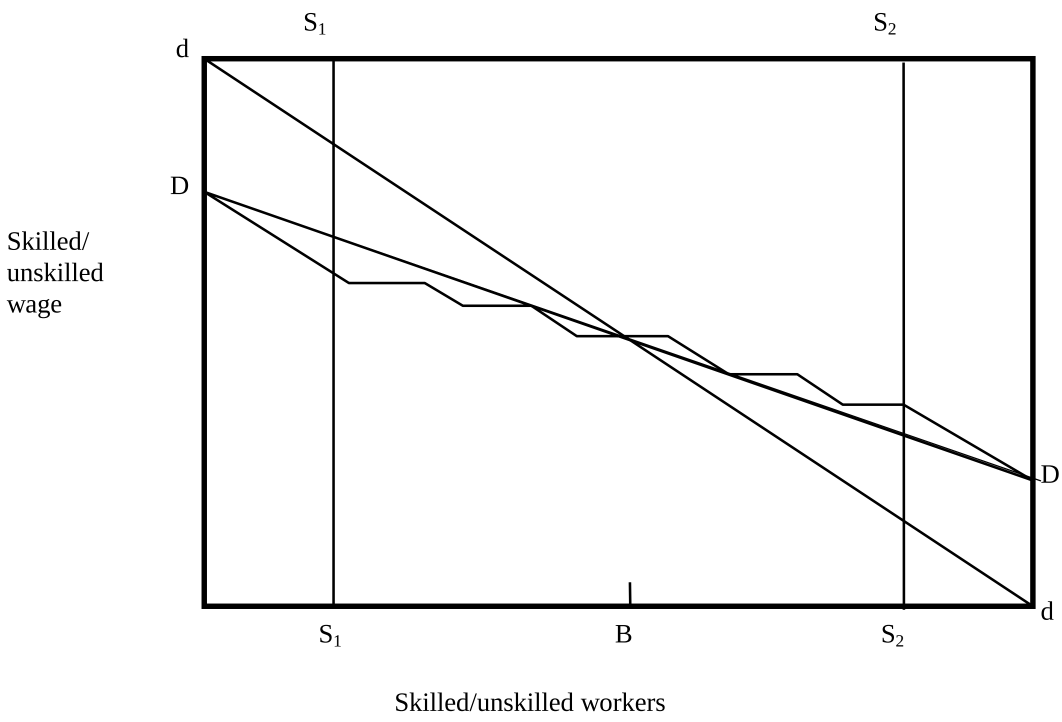


Figure 2. Many goods, inelastic supply



unskilled labour. With supply S_1, say, as in a developing country, the relative wage of skilled labour would be w_1.

The open-economy demand curve is the line *DD*, with three distinct segments: the flat segment in the middle covers the range of skill supplies in which a trading economy would be "diversified", in the sense of producing both clothing and machinery; the downward-sloping segments at each end cover the ranges in which an economy would be a "specialised" producer of only one of the goods (machinery at the right, clothing at the left). More importantly in the present context, *DD* cuts *dd* from below, at point B on the horizontal axis. Thus in a developing country, to the left of B, opening to trade reduces the relative demand for skilled labour, and its relative wage (from w_1 to w_1^*), while in a developed country, to the right of B, opening raises the relative demand for, and wage of, skilled labour (from w_2 to w_2^*).[1]

The model and diagram extend easily to a more realistic world of many goods (differentiated by skill intensity), and many countries (differentiated by skill supplies). Figure 2 depicts the case of six goods, in which the open-economy demand curve, *DD*, has five flat segments (on each of which countries produce two goods, adjacent in skill intensity), alternating with downward-sloping segments (on which only one good is produced). And with a large number of goods, *DD* can conveniently be approximated by a continuous line (shown with dashes in Figure 2). The size of the effect of opening on relative wages is then a steadily increasing function of the distance of a country's relative skill supply from the world average (point B), with the sign of the effect depending on which side of the average the country lies. Skilled workers gain most from trade where they are most abundant, and lose most from trade where they are most scarce.

This two-factor (skilled and unskilled labour) version of the model is a reasonable approximation for manufactures and services, but to extend it to cover primary products, which still dominate the exports of many developing countries, requires the introduction of a third factor, land (or natural resources). Primary production is usually both more land-intensive and less skill-intensive than manufacturing (Wood and Berge, 1994; Owens and Wood, 1995). Opening to trade in a country with a relatively large supply of land thus shifts the structure of output away from manufacturing towards primary production (in which the country has a comparative advantage, given its greater land intensity), but also reduces the demand for, and wages of, skilled workers, relative to unskilled workers, because the

[1]. Relative wages in the two countries thus converge, in the general spirit of the H-O factor price equalisation theorem, and would be equalised if the trading equilibria of both countries were diversified.

expanding primary sector uses a lower ratio of skilled to unskilled labour than the contracting manufacturing sector.

The easiest way to accommodate primary trade in the diagram is to draw two open-economy demand curves (Figure 3), one for land-abundant countries (DD_p), the other for land-scarce countries (DD_m). This conveys that trade tends to raise the relative wage of skilled workers most in countries with the combination of abundant skilled labour and scarce land, and to lower it most in countries which have both little skilled labour and a lot of land.

Supply responses

We now abandon the simplifying assumption that skill supply curves are completely inelastic, and allow, more realistically, the relative supply of skilled workers in each country to depend positively on the relative wage (Figure 4). Other things being equal, that is, it seems hard to doubt that an increase in the wage differential between skilled and unskilled workers would induce more people to participate in education and training, and give the government and firms more of an incentive to provide it. However, the supply curve is not horizontal, as in many human capital models, but has an upward slope, because people vary in their trainability and in their access to finance for investment in skill acquisition (Wood, 1994: 53-4).

If supply is elastic in this way, greater openness to trade tends to widen initial differences in skill supplies among countries. Thus, in Figure 4, the developed country's relatively large supply of skilled labour, n_2, is increased by trade to n_2^*, while the developing country's relatively small supply of skilled labour, n_1, is reduced by trade to n_1^*.[2] (Figure 4 omits land for clarity, but a glance up at Figure 3 reveals that the widening of the gap in skill supplies would be particularly marked between high-skill countries with little land and low-skill countries with much land.)

This proposition is not new, but neither is it widely appreciated. Ohlin himself (1933, 1967: 81-2) noted that trade tends to amplify differences in factor endowments among countries as a result of supply responses to factor price changes. However, little attention has been paid to this mechanism subsequently. It is mentioned with specific reference to skill supplies in recent papers by Harris (1994) and Stokey (1994), but even Stokey dismisses it as

[2]. If allowance were made for the income gain from trade, and if the supply of skill were income-elastic, the developing country's skill supply might not fall absolutely, as in the diagram. However, since this income effect occurs also (and to an extent which there is no reason to suppose would be smaller) in the developed country, the conclusion that trade tends to widen the gap in skill supplies between the two countries is unaffected.

Figure 3. Many goods, with land, inelastic supply

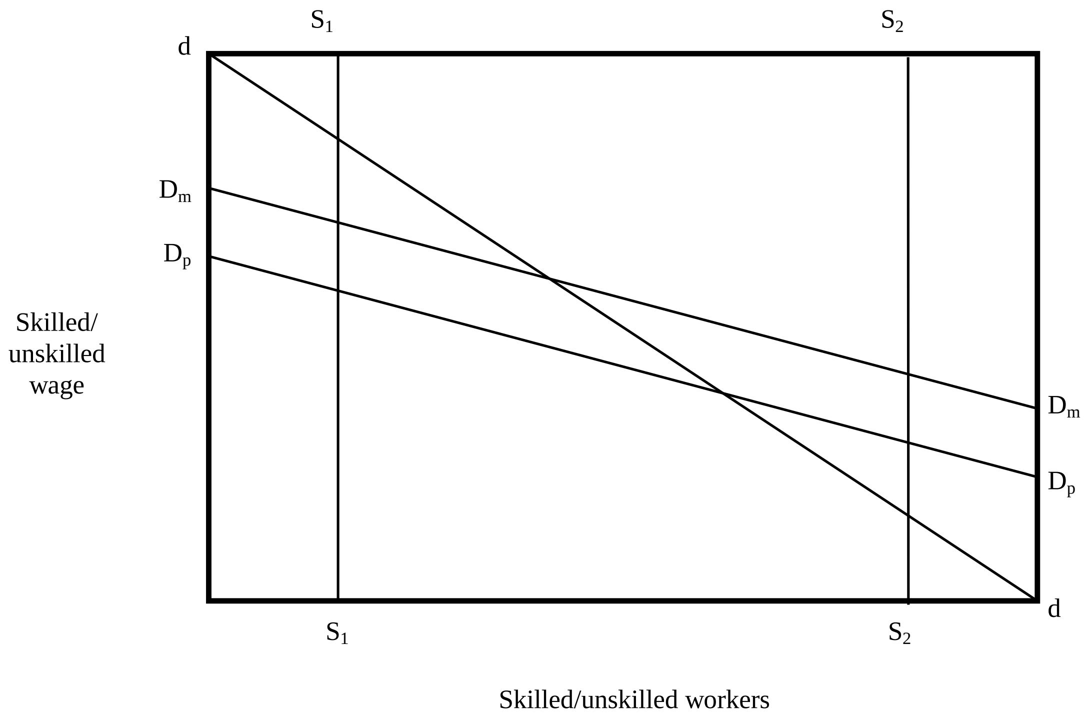
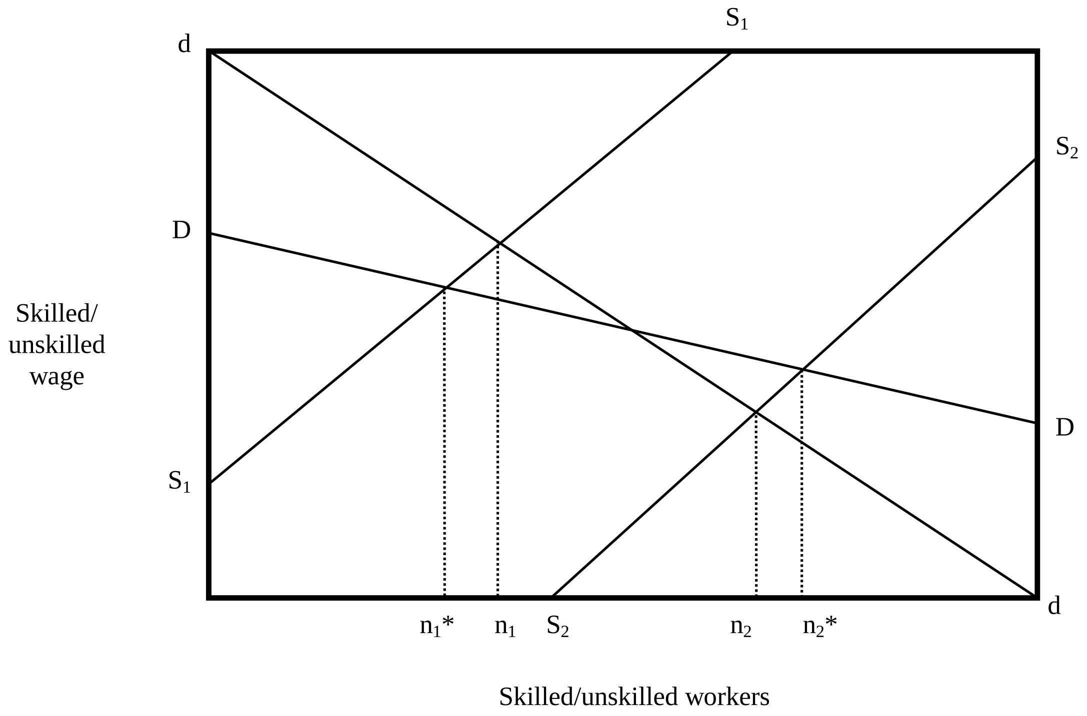


Figure 4. Many goods, no land, elastic supply



implausible (on the grounds that enrolment in secondary and tertiary education rose rather than fell in the more backward countries which became members of the European Union).

What are the underlying causes of the initial differences in skill supplies - the reasons for the horizontal difference between the two supply curves in Figure 4? Why does the developing country start with a lower relative supply of skill than the developed country, despite a higher relative wage for skilled labour, and thus stronger incentives to acquire skills? What restricts opportunities to acquire skills in response to these incentives? These questions are unanswerable in a timeless choice-theoretic equilibrium framework: the reasons must be sought under headings such as "history" or "path dependency" (and, of course, include social and political attitudes towards education and training).

Consequences for international income inequality

This paper started with a question about the effects of trade on inter-country differences, not in skill supplies, but in per capita incomes, to which the analysis above yields no answer. Our H-O model, like other old trade theory, predicts that both the developed and the developing country will gain from trade (i.e. achieve higher per capita incomes), and provides no general reason for supposing that the high-skill country gains more than the low-skill country, or vice versa. Nor, according to old trade theory, does the introduction of supply elasticity alter this conclusion: the fall in the skill supply of the developing country, like the rise in that of the developed country, should increase its income gain from trade.

New growth theory suggests otherwise: it portrays skill (or human capital) accumulation as a vital ingredient of income growth, not just by increasing the quantity of inputs to production, but more fundamentally as a source of innovation and productivity improvement, involving externalities and spill-over effects. Skill acquisition is clearly cumulative and interactive: the more skills people have to begin with, and the more skilled the people around them (parents, classmates, colleagues), the better their chances of acquiring more skills. Moreover, in the world of work, learning-by-doing makes the use and acquisition of skills two sides of the same coin, so that specialisation in skill-intensive activities is self-reinforcing. It thus seems rather likely that trade-induced divergence of skill supplies among countries would cause long-run divergence of their per capita incomes.

This paper, though motivated by the plausibility of such a linkage between divergence of skill supplies and of incomes, will not explore it further. In particular, we shall not embody it in a formal growth model, nor will we try to test it empirically (i.e. to add to the already large econometric literature on the contribution of human capital to growth - but see Ridao-Cano and Wood, 1996). Instead, the rest of this paper will be confined to testing the hypothesised connection between increased openness to trade and divergence in skill supplies. For unless and until this connection, which is the distinctive element of our argument, is shown to exist and to be quantitatively important, there seems little point in trying to build upon it a larger story about openness and international income inequality.

Even this larger story about openness and income inequality would not be the whole story. Whether incomes converge or diverge depends on aspects of openness other than trade (for example, direct foreign investment), and on mechanisms other than skill accumulation, especially transfer of technology (which H-O theory rules out by assumption). Indeed, those who argue that openness causes convergence define openness broadly, and stress technology transfer - as does Quah (1996), who argues that trade may cause divergence. These other linkages have also been tested empirically, with mixed results (Aitken and Harrison, 1994; Coe, Helpman and Hoffmaister, 1995; Blomstrom and Kokko, 1996). But whether they are more or less powerful than our divergence mechanism, and in what contexts, remains to be investigated.

2. Description of the data

In this section, before proceeding to econometric analysis of the effects of changes in openness on skill supplies, which will use data on about 90 countries during 1960-90, we discuss the two key variables involved - skill and openness - and examine their movement over this period.

Measures of skill

The only measures of skill available for large country samples refer to the length of time people spend in formal education. We thus lack information on how much (and what) they learned during their time in school, and on all the skills acquired in other ways - through formal training and experience. These gaps may not be too serious for single-period cross-country analysis: length of schooling is strongly correlated across countries with school quality and post-school skill acquisition (e.g. France is far above Uganda on all three dimensions), and is thus a reasonable proxy for all aspects of skill. They are more worrying in analysis, such as ours, which deals with changes over time: there is no reason, for example, to suppose that large rises in length of schooling are generally associated with big improvements in school quality (which may fall), or in post-school skill acquisition. Cross-country variation in changes in length of schooling is thus likely to be a poor proxy for variation in the extent of the increase in skill in an economically relevant sense - but it is the only proxy we currently have.

Two sorts of data on length of education are available: the average years of schooling of the adult (over-15)[3] population, from Barro and Lee (1996); and school enrolment rates, from the UNESCO Yearbook. We shall use the former as our measure of a country's initial skill endowment, since it refers to the whole stock of education. As our dependent variable, though, we shall use enrolment rates (which refer only to young people), because the mechanism by which trade-induced changes in the relative demand for, and wages of, skilled workers affect the supply of educated labour must be by encouraging more (or fewer) people to enrol (or stay longer) in school.[4] We shall examine separately the effects on enrolments at different levels of education (primary, secondary and tertiary).[5]

To make a preliminary visual examination of the data, in relation to our hypotheses, we divide countries into six groups, according to their initial (1960) resource endowments. The first split is into three groups of equal size, on the basis of average adult years of schooling, labelled LE, ME and HE (for low, medium and high education).[6] Each of these three skill groups is then divided into two on the basis of natural resource endowments, and more specifically according to whether land area per adult in the country concerned is above or below the mean (in logs) for all countries, appending the labels HL and LL (for high land and low land). Land area is obviously not an ideal measure of natural resources, but it performs remarkably well - absolutely, and by comparison with more complex measures - in explaining cross-country differences in the share of primary products in exports (Wood and Berge, 1994), and thus seems adequate for the purposes of this paper.

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[3]. Data for the over-25 population are also available from the same source. Neither accurately measures the education level of the labour force, which is the variable of economic interest, but, of the two, the over-15 data are a better approximation for most countries.

[4]. Eventually, changes in enrolment rates translate into changes in average adult years of schooling, but the lags are long and variable, depending on birth and death rates. We tried using the change in average adult years of schooling over the whole period 1960-90, adjusted for demographic dynamics, as an alternative dependent variable (with results available on request). This variable is positively correlated across countries with whole-period changes in secondary enrolment rates (R = 0.55) and in tertiary enrolment rates (R = 0.34), but is inversely correlated with whole-period changes in primary enrolment rates (R = -0.20).

[5]. In all cases, our data refer to *gross* enrolment rates, meaning that the numerator includes pupils at the level of schooling concerned who are above or below the normal age range for that level (and hence not included in the population cohort in the denominator).

[6]. Inspection of Appendix 1 should arouse some concern about the quality of the years of schooling data: for example, it is hard to believe that Zambia was a more educated country in 1960 than Portugal, or Guyana than Austria.

For each of the six groups, whose membership is listed in Appendix 1, we plot (unweighted) average time series of primary, secondary and tertiary enrolment rates. Figure 5 shows strong convergence at the primary level. Three country groups (HELL, HEHL, and MELL) had already achieved almost 100% enrolment by the start of the period, and MEHL caught them up by 1980. Both LE groups also rapidly closed the large initial gap between them and the HE groups, at least until 1985. These movements were probably driven largely by autonomous political pressure for universal basic education.

Figure 6, which refers to secondary enrolments, shows a pattern mainly of divergence. The gaps between the HE and ME groups increased slightly, and those between the ME and LE groups more substantially. Within the HE group, land-scarce countries made more progress than land-abundant ones, at least in the latter part of the period. Within the ME group, too, the LL countries did better than the HL ones, except in the 1970s, when there was a primary commodity price boom. This difference between decades is more pronounced within the LE group, where the LL countries made somewhat more progress than the HL ones in the 1960s and 1980s, but the changes over the whole period are dominated by what happened in the 1970s, when enrolment growth slowed in LL countries and accelerated in HL ones.

The data on tertiary enrolments in Figure 7 also show a pattern mainly of divergence. The initial gaps between the three education groups widened in all cases. Within both the middle and lower education groups, land-scarce countries made more progress than land-abundant countries over the period as a whole, though (as with secondary enrolments) the opposite happened in the 1970s, especially for the ME group. By contrast, within the HE group, tertiary enrolments rose less over the whole period in land-scarce than in land-abundant countries.

In summary, as between groups with different initial levels of education, divergence over time in secondary and tertiary enrolment rates was offset by convergence in primary enrolments (average adult years of schooling rose by roughly the same absolute amount in each education group). As between groups with different natural resource endowments, land-scarce countries in most cases made more educational progress than land-abundant ones, although the latter did better during the commodity price boom of the 1970s.

Figure 5. Primary enrolment rates

Figure 6 Secondary enrolment rates

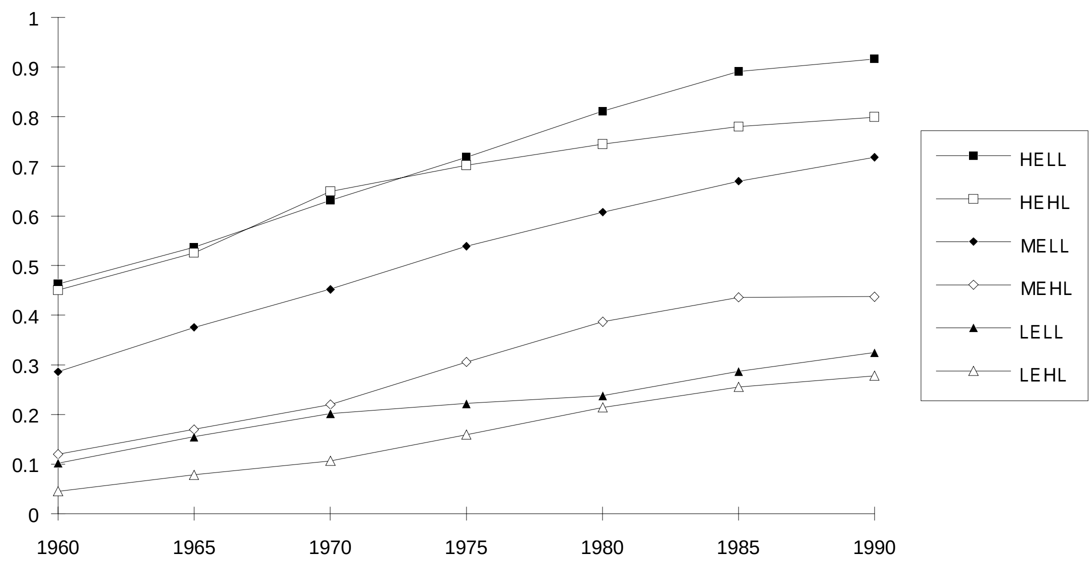
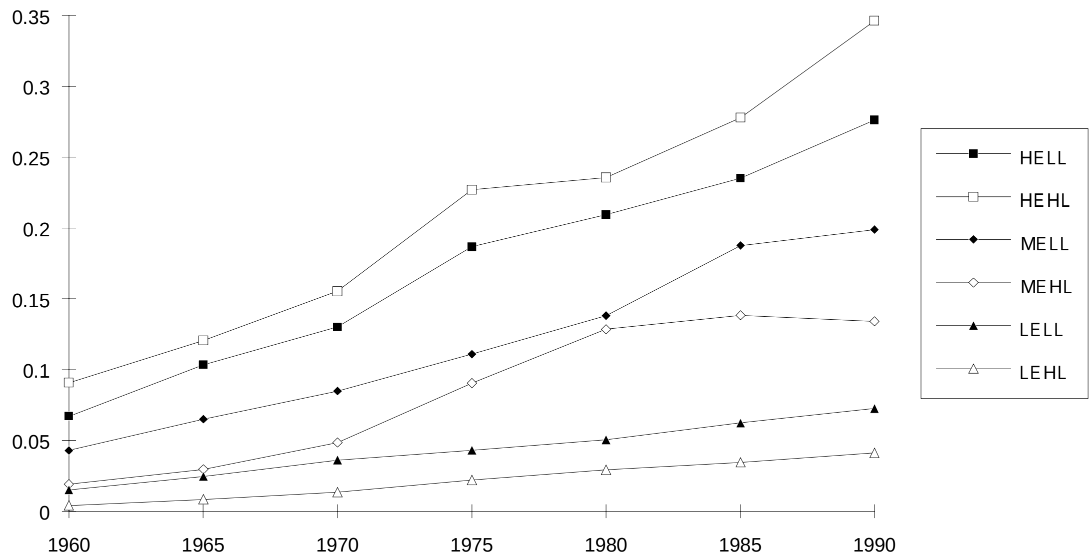


Figure 7. Tertiary enrolment rates



Measures of openness

Indicators of openness fall into two broad categories: those based on trade flows, and those based on trade barriers.[7] One example of each will now be described, and its behaviour over time in our six country groups examined. Because these indicators vary from year to year, the points in the figures are based on averages of several years, as specified on the horizontal axes (e.g. 7074 is an average of the years 1970 to 1974).

The flow measure is the ratio of exports to GDP (in current PPP prices from the Penn world tables).[8] Figure 8, using this indicator, shows a general but uneven increase in openness after the late 1960s. The biggest and most sustained rises were in the HELL and (particularly) MELL groups. Openness also increased over the whole period in all three of the high land groups, but by less, partly because two of them (HEHL and LEHL) became more closed after the late 1970s. The LELL group (the least open, because it contains all the large South Asian countries) became gradually more open between the late 1960s and the early 1980s, but then experienced a reversal.

The barrier measure is that constructed by Sachs and Warner (1995), which for each country and year takes the value zero (closed) or one (open), on the basis of a battery of trade policy indicators.[9] Figure 9, which shows the evolution of the average scores in each of our groups, again suggests a general rise in openness, but with considerable variation. The HELL group, the most open, became somewhat more so in the 1960s and 1980s. The MELL group also became more open (except in the late 70s), as did the LELL group (after the late 1960s). All three land-abundant groups markedly increased their openness during the 1980s; prior to that, openness had risen for most of the period in the HEHL group, but the MEHL and LEHL groups had become more closed, especially between the early 1960s and the early 1970s.

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7. In our H-O model, we do not need to measure explicitly the *direction* of trade, which is determined by resource endowments. By contrast, in a model concerned with technology transfer (e.g. Quah 1996), the direction of trade would require a fuller treatment.

8. As is well known, this measure of openness varies inversely with country size, and is sometimes adjusted for this (e.g. by using deviations from a cross-country regression of the export ratio against size). We decided not to make such an adjustment, partly because our interest is in changes over time within countries, and partly because the higher value of this ratio in smaller countries may well correctly be capturing the fact that trade has a larger impact on their labour markets. Our barrier measure of openness, by contrast, is independent of country size - but this could be viewed either as a strength or as a weakness.

9. A country is classified as closed if it has one or more of the following characteristics: non-tariff barriers covering 40% or more of trade; average tariff rates of 40% or more; a black market exchange rate discount of 20% or more; a socialist economic system; or a state monopoly on major exports.

Figure 8. Ratio of exports to GDP (PPP values, current international prices)

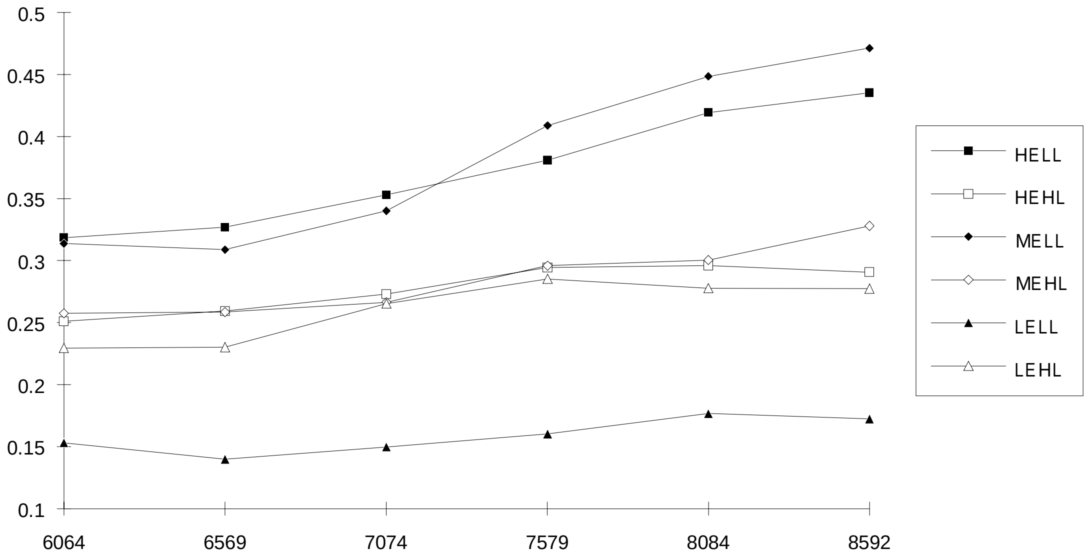
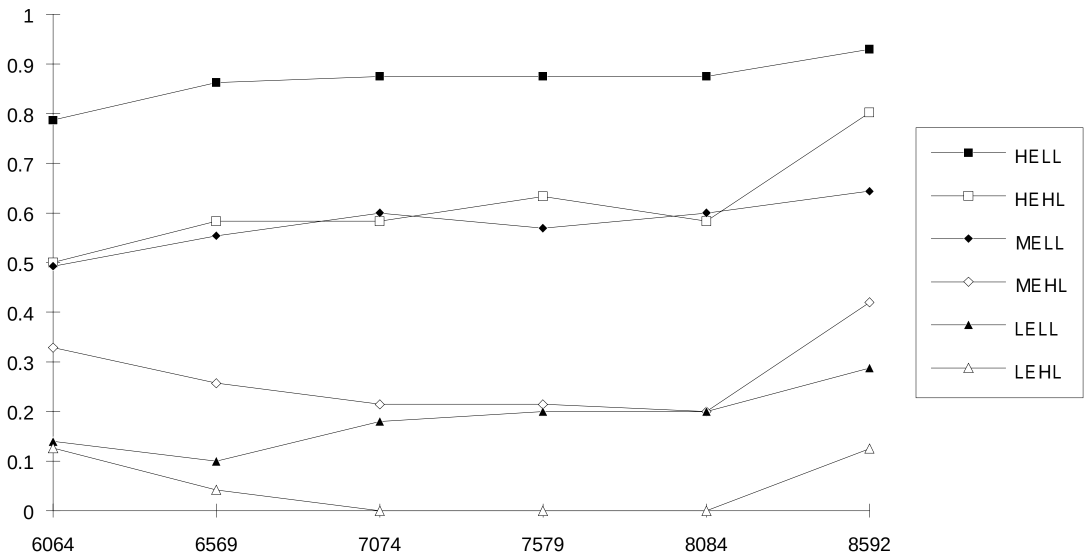


Figure 9. Barrier measure of openness to trade (OPEN)



Both the flow measure and the barrier measure suggest that most of our six groups became more open over the whole period, and that the increases were generally more sustained in the land-scarce countries. However, there are some differences between the two measures as regards the timing of events, particularly for the land-abundant groups. The flow measure suggests that MEHL and LEHL became more open in the first half of the period, whereas the barrier measure suggests they became more closed. Moreover, at the end of the period the flow measure suggests a decline in openness for two of the HL groups, whereas the barrier measure shows a rise for all three, with a similar contradiction for the LELL group.

3. Econometric specification

To derive an appropriate specification for testing our hypothesis about the effects of changes in openness on skill supplies, we return to the model in Figure 4, which involves two equations (a demand curve and a supply curve)

$$w = D(n,\ TO) \tag{1}$$

$$w = S(n,\ ET) \tag{2}$$

where *w* is the wage of skilled workers, relative to unskilled workers, *n* is the number of skilled workers, relative to the number of unskilled workers, *TO* is a measure of openness to trade, which affects the slope of the demand curve, and *ET* (for "education and training") is a measure of opportunities for skill acquisition, which affect the horizontal alignment of the supply curve. *ET* is intended to capture all influences on the relative supply of skilled workers which are independent of the current level of demand, such as government policies, history, and culture.

Estimating equations

Assuming that labour markets clear, equations (1) and (2) can be reduced to a single equation

$$D(n,\ TO) = S(n,\ ET) \tag{3}$$

from which we can derive and estimate a reduced form

$$n = f\,(TO,\ ET) \tag{4}$$

In this equation, the partial derivative with respect to *ET* must always be positive. With respect to *TO*, however, its sign varies, depending on the resource endowments of the country concerned: for countries with high initial levels of skill (and/or scarce land), the sign is positive, because greater openness to trade increases the relative demand for skilled labour; but for countries with low initial levels of skill (and/or abundant land), it is negative, because openness reduces the demand for skilled labour.[10]

To allow for this variation in sign, we interact each country's *TO* with its deviations from world average skill and land endowments, measured as

$$\tilde{E}_{it} = \frac{E_{it} - E_t}{\sigma_{E_t}} \quad \text{and} \quad \tilde{L}_{it} = \frac{L_{it} - L_t}{\sigma_{L_t}}$$

where *E* is average years of schooling, *L* is land area per worker (expressed in logs, because its distribution is skewed), and *i* and *t* index countries and time periods respectively. E_t and L_t are the cross-country means of *E* and *L* in each period, and σ_{E_t} and σ_{L_t} are the cross-country standard deviations (to make the scales of $\tilde{E}_{it}$ and $\tilde{L}_{it}$ comparable). The sign of $\tilde{E}_{it}$ depends on whether the skill endowment of the country concerned is above the world average (positive) or below it (negative), while the absolute size of $\tilde{E}_{it}$ depends on how far above or below the world average the country's endowment lies (and similarly for $\tilde{L}_{it}$). Our specification is thus

$$ER_{it} = \alpha + \beta_1 (TO_{it} * \tilde{E}_{it}) - \beta_2 (TO_{it} * \tilde{L}_{it}) + \delta ET_{it} + \mu_{it} \qquad (6)$$

where *ER*, the dependent variable, is the enrolment rate (to be denoted more specifically later by *PER*, *SER* and *TER*, for primary, secondary and tertiary enrolment), and μ is the error term. We expect the sign of the coefficient on the first interaction term, β_1, to be positive, because greater openness should raise enrolments in countries with above-average skill endowments (i.e. with positive values of $\tilde{E}_{it}$) and lower them in countries with below-average endowments (negative values of $\tilde{E}_{it}$). Conversely, the sign on the second interaction term should be negative, because greater openness should lower enrolments in countries with above-average land abundance. We shall also try combining skill and land into a single endowment measure, the skill/land ratio (*E/L*), making the specification

[10]. Sachs and Warner (1995, Table 12) have a skill accumulation regression with openness to trade as an independent variable, but do not allow for the possibility that its sign might vary with resource endowments, which may explain why the coefficient is small and statistically insignificant.

$$ER_{it} = \alpha + \beta(TO_{it} * (E\tilde{/}L)_{it}) + \delta ET_{it} + \mu_{it} \quad (6a)$$

where $(E\tilde{/}L)_{it}$ is the deviation from the world average skill/land ratio, and the sign of the coefficient on the interaction term should be positive.

An alternative way of allowing for the expected variation in the sign on *TO* is to use dummy variables to distinguish groups of countries with different resource endowments. In the simplest case of two such groups, and thus one dummy, *D* (= 1 for skill-abundant countries and 0 for skill-scarce ones), the regression would be of the form[11]

$$ER_{it} = \alpha + \gamma_1 D_{it} + \gamma_2 TO_{it} + \gamma_3 (TO_{it} * D_{it}) + \delta ET_{it} + \mu_{it} \quad (7)$$

The test of our hypothesis in this specification concerns the sign of the coefficient, γ_3, on the interaction of the dummy and the openness variable: it should be positive, since greater openness increases enrolments more in countries with initially greater skill endowments.[12]

The dummy specification is in some ways more attractive than the continuous specification (equation 6). Grouping countries in different ways allows us to explore non-linearities and discontinuities in the effects of endowments on enrolment rates, and the effects of particular combinations of skill and land endowments. However, the dummy specification also has disadvantages: it throws away information on within-group variation in endowments, and it is subject to downward (truncated regression) bias for coefficients such as γ_3, because the basis of the country grouping (average years of schooling) is correlated with the dependent variable (the enrolment rate). We shall thus focus most of our attention on the continuous specification.

As proxies for *ET*, we use three variables (derived from UNESCO and World Bank data, the Penn World Tables, and other sources already mentioned):

TSAP: the number of teachers divided by the school age population of the country concerned (at all levels of education), a volume measure of the availability of education, and

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[11]. We omit slope dummy interactions with *ET*, but always include intercept dummies, whose omission can distort slope dummy interaction coefficients.

[12]. The model in Figure 4 also implies that γ_2 should be negative, but this is less vital: the key point of our hypothesis is that greater openness to trade tends to widen inter-country differences in skill supplies, and to establish this tendency a positive value of γ_3 would be sufficient.

of government commitment to education (since in most countries most teachers are hired by the government);[13]

REEY: the ratio of recurrent public expenditure on education to GDP, a value measure of the quantity and quality of education available, and of government commitment;

PCY: per capita (actually, per adult) real PPP GDP, which is intended to capture the many ways in which richer countries offer their inhabitants more and better opportunities for learning of all sorts.[14]

These are not ideal measures, but we could not improve on them.[15] Among other problems, *TSAP* and *REEY* are unlikely to be strictly independent of current demand for education (which emerges in the form not only of higher enrolments but also of political pressure for educational expansion and improvement), and so their inclusion tends to bias downwards our estimates of the effects of openness on skill supplies.

Panel data techniques

Our data are in the form of a panel of about 90 countries and six five-year time periods (data on enrolments and on the barrier measure of openness are not available on an annual basis). The values of *ER*, *TO*, *TSAP* and *REEY* are averages within each five-year period (which for *ER* are simply the means of the opening and closing values), while the values of the resource endowment variables and of *PCY* refer to the start of each period.

Most of our estimates are based on a two-way error component model which allows for both country-specific and time-specific fixed effects. In such a model, each coefficient shows the relationship between changes over time in the dependent variable (other than those common to all countries in each period) and changes over time in the independent variable. This

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13. This variable differs from (the inverse of) the pupil/teacher ratio, or class size, which depends also on the (total) enrolment rate of the school age population. There is an accounting relationship between *T/SAP* and the enrolment rate (pupils/*SAP*) via class size (pupils/*T*). Thus if class size were fixed, it would make no sense to use *TSAP* in a regression explaining the enrolment rate. The justification for including it is that class size, within limits, is endogenous, determined by the interaction of a given supply of teachers and the demand for school places.

14. *PCY* could be combined with *REEY* into one variable (*REE* per person), but this would imply, probably wrongly, that inter-country income differences affect learning opportunities only via public expenditure on education.

15. Nor was our specification improved by adding other variables which have been used in cross-country regressions explaining differences in schooling (e.g. political instability and output growth variability).

approach seems the right one for our purposes, since our hypothesis is fundamentally about movements over time - i.e. that increases or decreases in openness in particular countries raise or lower their enrolment rates. There may also be cross-country associations between levels of openness, enrolment rates and endowments, but these are open to other causal interpretations.

For estimation purposes, we transform the data by subtracting individual country means, so eliminating the country-specific fixed effects. However, we include time dummies, to test for the presence of trends in enrolment rates common to all countries. We then apply OLS to the transformed data to obtain the "within" estimates of our coefficients. This fixed-effects approach yields estimates which are consistent, whether or not the country effects are correlated with the independent variables, but if there is no such correlation (as appears to be the case for our data, on the basis of a Hausman test), more efficient estimates are yielded by a random-effects GLS model, which allows the cross-country dimension of the data, as well as its time-series dimension, to play a role. We therefore also experimented with this approach, but (as will be shown) it did not much affect the results.

Because we are, in effect, estimating time-series regressions in levels, we must address the possible problem of spurious correlation among data series which are not in fact cointegrated. We tested *SER* and our flow measure of *TO* for order of integration, and found them to be I(0) and cointegrated.[16] However, in panels with few periods and many countries, such as ours, older methods for dealing with autocorrelation in the error term are argued to be more appropriate than the newer time-series approach (MaCurdy, 1982; Hsiao, 1995), so it was on these older methods that we focused our efforts.

A Durbin-Watson test of "within" residuals developed by Bhargava, Franzini and Narendranathan (1982), reveals significant positive first-order serial correlation in regressions based on equation (6). This might be because we are omitting some variable which affects enrolment rates - for instance, the quality of governance, which might vary over time within countries - or because we are somehow mis-specifying the dynamics of the model. However, the first-order autogressive coefficient, ρ, is significantly less than unity, indicating that the residuals do not contain a unit root (and thus that first-differencing the data would not be the

[16]. The tests, using the methods in Levin and Lin (1993), used annual data for 30 years, which involved interpolating secondary enrolment rates within five-year periods (an approach used also by Coe, Helpman and Hoffmaister, 1995, but which raises doubts about the validity of the test). We tested for cointegration between the residuals of a regression of *SER* on *PCY* (as a proxy for *ET*) and our flow measure of *TO* (the ratio of exports to GDP).

right response). We corrected for the autocorrelation by applying a maximum likelihood iterative method for panel data to the ρ-differenced series (Baltagi, 1995).[17]

Two other aspects of our estimation techniques deserve mention. One is our experiments with instrumental variables to correct for measurement errors in our resource variables: we failed to find an adequate instrument for our natural resource variable (land area per adult), and were thus unable to apply this method to regressions based on equation (6); but we were able to apply it to equation (6a), by using the ratio of manufactured to primary exports as an instrument for *E/L*. The other is that our regressions based on the dummy specification (equation 7) were fitted by minimising the sum of absolute deviations (MAD) rather than of squared deviations (as in OLS). We did this to reduce the influence of outliers, which have more influence in the dummy specification (since it divides the sample into small groups), although we also tried applying MAD to the continuous specification.

4. Results

Table 1 presents the results of six regressions based on the continuous specification (equation 6) - two for each of our three dependent variables, the enrolment rates in primary, secondary and tertiary education (*PER*, *SER*, and *TER*), of which one uses the flow measure of openness to trade (*XY*) and the other the barrier measure (*OPEN*). All these regressions are estimated by OLS (on within-transformed data). The means, standard deviations, and units of the variables are given in Table 2.

Looking first at the *secondary* enrolment results in columns 1 and 2, the coefficients on the time dummies (*t2* to *t6*) show a global upward trend of about 4 percentage points per five-year period. The coefficients on the *ET* measures (*TSAP*, *REEY* and *PCY*) all have the expected positive signs, and are statistically significant, which indicates that the upward trend was faster in countries whose governments made greater efforts to expand education and where incomes rose more. The coefficients on the interactions between both openness variables and the skill-deviation variable are also positive and statistically significant, in accordance with our hypothesis: the effect of more trade on secondary enrolment rates was more favourable, the higher the initial education level of the country concerned. (The smaller size of the coefficient with the barrier measure of openness than with the flow measure reflects the different scales of these two measures.)[18]

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[17]. This method requires the errors to be homoscedastic. White's general test, which is robust to non-normality of the error distribution, revealed no significant (at the 10% level) heteroscedasticity in our data.

[18]. This difference is not apparent from the summary statistics in Table 2: however, the policy changes required to alter the *OPEN* measure from 0 to 1 (see note 9) would usually cause much less change in the ratio of exports to GDP (for example, a rise of 0.2).

Table 1. Regression results: continuous specification

Dep.var. =	SER		TER		PER	
TO =	XY (1)	OPEN (2)	XY (3)	OPEN (4)	XY (5)	OPEN (6)
t2	0.04 (4.0)	0.03 (3.3)	0.01 (1.2)	0.005 (0.8)	0.03 (2.8)	0.04 (3.1)
t3	0.08 (7.7)	0.07 (6.6)	0.02 (3.7)	0.02 (3.1)	0.06 (5.0)	0.07 (5.6)
t4	0.12 (10.8)	0.12 (9.7)	0.04 (5.7)	0.03 (5.0)	0.10 (7.3)	0.11 (8.1)
t5	0.16 (12.3)	0.15 (11.1)	0.05 (6.5)	0.04 (5.7)	0.13 (8.0)	0.14 (8.9)
t6	0.20 (13.6)	0.19 (12.8)	0.06 (7.4)	0.06 (6.8)	0.15 (8.6)	0.16 (9.3)
$TO*\tilde{E}$	0.17 (4.5)	0.04 (2.6)	0.08 (3.3)	0.01 (1.3)	-0.07 (-2.5)	-0.01 (-1.0)
$TO*\tilde{L}$	0.01 (0.6)	-0.03 (-2.1)	0.04 (2.9)	0.001 (0.1)	0.05 (2.2)	-0.05 (-3.4)
TSAP	1.65 (3.2)	2.02 (3.6)	2.45 (8.2)	2.43 (8.1)	-2.68 (-6.5)	-2.36 (-5.4)
REEY	0.78 (1.9)	0.74 (1.7)	-0.07 (-0.4)	0.09 (0.4)	1.07 (2.6)	1.16 (2.7)
PCY	0.10 (6.7)	0.11 (6.2)	0.03 (2.5)	0.04 (3.3)	0.02 (0.8)	-0.03 (-1.7)
$\overline{R}^2$	0.79	0.78	0.67	0.67	0.38	0.36
No. obs.	522	486	522	486	522	486

Notes: SER, TER and PER refer to secondary, tertiary and primary school enrolment rates respectively. The numbers is parentheses are t-ratios (based on White's heterocedasticity-consistent S.E's). The method of estimation is OLS on the within-transformed data. See table 2 for definition of variables, and text for further details.

Table 2. Description of regression variables

	mean	std.dev	units
SER	0.44	0.29	ratio
TER	0.11	0.11	ratio
PER	0.87	0.20	ratio
$\tilde{E}$	0	1	standard deviations of E
$\tilde{L}$	0	1	standard deviations of L
$\widetilde{E/L}$	0	1	standard deviations of E/L
E	4.47	2.66	years
L	3.74	1.63	$\log_e$ (sq km per thousand adults)
E/L	4.44	2.00	$\log_e$ (thousand school-years per sq km)
XY	0.30	0.21	ratio
OPEN	0.44	0.48	1=open, 0=closed
TSAP	0.03	0.02	ratio
REEY	0.03	0.01	ratio
PCY	8.33	0.86	$\log_e$ (real PPP GDP per adult)

Notes: $\tilde{E}$, $\tilde{L}$ and $\widetilde{E/L}$ are transformations of E, L and E/L respectively, each being the deviation from the cross-country mean in each period, divided by the standard deviation in each period. OPEN is calculated for each country as the average of 1s (open) and 0s (closed) for each five-year period. All the variables are defined as averages over each five year period, except for E, L, E/L and PCY, which are the values at the start of each period.

Table 3. Secondary enrolment rates: alternative estimation techniques

	Random GLS		MAD		MLAR1	
TO =	XY (1)	OPEN (2)	XY (3)	OPEN (4)	XY (5)	OPEN (6)
TO*$\tilde{E}$	0.23	0.06	0.20	0.06	0.08	0.03
	(7.5)	(4.9)	(7.2)	(6.1)	(3.0)	(3.0)
TO*$\tilde{L}$	0.01	-0.03	-0.01	-0.03	-0.01	-0.01
	(0.8)	(-2.8)	(-0.4)	(-2.3)	(-0.6)	(-1.0)
TSAP	2.51	3.03	1.60	2.29	2.43	2.51
	(5.4)	(6.3)	(4.8)	(6.5)	(4.8)	(4.9)
REEY	0.81	0.80	0.56	0.76	0.68	0.69
	(2.3)	(2.1)	(2.1)	(2.7)	(2.2)	(2.1)
PCY	0.13	0.14	0.11	0.12	0.08	0.08
	(10.4)	(9.8)	(8.8)	(8.8)	(4.8)	(4.7)
$\bar{R}^2$	0.79	0.78	0.78	0.77	0.70	0.70
No. obs.	522	486	522	486	522	486

Notes: The numbers in parentheses are t-ratios. All regressions include time dummies. The random GLS regressions include a constant term not reported in this table. MLAR1 refers to maximum likelihood iterative estimation of the ρ-differenced data. The estimates of ρ for (5) and (6) are 0.62 (s.e. = 0.04) and 0.64 (s.e. = 0.04) respectively. See Table 2 for definition of variables, and text for further details.

The interaction of *OPEN* with the land-deviation variable again has the sign predicted by our hypothesis: negative (and significant), which implies that lowering barriers to trade tended to reduce secondary enrolment rates in land-abundant countries, compared to land-scarce ones. However, using the flow measure of openness (*XY*), the land-deviation interaction is positive (albeit insignificant). This difference in the coefficients reflects the contradictions between the time paths of the two measures of openness in land-abundant developing countries shown earlier in Figures 8 and 9.

The results for *tertiary* enrolments in columns (3) and (4) of Table 1 are similar in most respects to those for secondary enrolments, with a global upward trend (of about 1 percentage point per period), and positive and statistically significant coefficients on two of the three *ET* proxies. The interactions between both measures of openness and the skill-deviation variable are positive, as expected, though only the coefficient based on *XY* is statistically significant. However, the coefficients on the interaction between openness and the land-deviation variable are both positive, counter to our hypothesis, significantly so for the one based on the flow measure (*XY*). This outcome reflects the large rise in tertiary enrolments in land-abundant HE countries shown earlier in Figure 7, which may have arisen from autonomous pressures for which our *ET* measures do not adequately control.

The results for *primary* enrolments in columns (5) and (6) are fundamentally different from those for secondary and tertiary enrolments. In particular, the interactions between both measures of openness and the skill-deviation variable are negative, one of them significantly so. The interactions with the land-deviation variable have different signs, depending on the measure of openness (as with secondary enrolments, but unlike tertiary enrolments, where both measures yielded the wrong sign). Primary enrolments, as at the other two levels, show an upward trend, but with odd coefficients on the *ET* proxies, particularly *PCY* and *TSAP* (the primary regressions also fit much less well). These differences reflect those shown in Figures 5-7: general convergence of primary enrolment rates, contrasting with general divergence at the secondary and tertiary levels.

Use of the alternative specification based on deviations of the skill/land ratio (equation 6a), rather than of skill and land endowments separately, does not change the outcome for any level of education (Appendix 2a). The coefficients on the time dummies and the *ET* proxies are almost identical in all cases. For secondary enrolments, both coefficients on the interaction of openness with skill/land ratio deviations are, as expected, positive and significant. For tertiary enrolments, both are close to zero (because of the conflict of signs between skill and land deviations taken separately). For primary enrolments, the interaction with *XY* has the wrong sign (because the signs using skill and land deviations separately are both wrong), while that with *OPEN* has the right sign only because (in column 6 of Table 1) the rightly-signed land deviation outweighs the wrongly-signed skill deviation.

Alternative estimation techniques

Table 3 presents the results of secondary enrolment regressions using three different estimation techniques mentioned earlier. The use of random GLS does not much alter the results, though it makes most of the coefficients, including that on the interaction of openness with the skill-deviation variable, larger and statistically more significant. Fitting on the basis of minimum absolute deviations also makes the skill interaction coefficient larger, and, unlike OLS, produces a correctly signed (but insignificant) coefficient on the interaction between *XY* and the land deviation variable. Maximum-likelihood estimation with autocorrelation-correction (MLAR1), too, produces the expected signs on the interactions of both openness variables with land deviations, but neither is significant (as had been the case with *OPEN* using the other techniques). The coefficients on the interaction of the openness measures with skill deviations become smaller (that based on the *XY* measure halves), but both remain statistically significant.[19]

Using these alternative techniques with the skill/land ratio specification and secondary enrolments has similar effects (Appendix 2b). Random GLS and MAD yield somewhat larger coefficients on the interaction between openness and skill/land ratio deviations, and MLAR1 somewhat smaller coefficients. However, the use of an instrumental variable (the ratio of manufactured to primary exports) for the skill/land ratio more than doubles the size of the interaction coefficient, with both measures of openness.

For tertiary enrolment rates, the use of random GLS and MAD again make the - expected positive - interactions between openness and skill deviations more significant, especially for the *OPEN* measure, while correcting for autocorrelation makes them smaller and less significant (Appendix 3a). The interactions between openness and land deviations, which are wrongly signed with OLS (though significantly so only for *XY*) remain wrongly signed and/or insignificant with the other estimation techniques. For primary enrolments (Appendix 3b), likewise, all three alternative estimation techniques leave us with consistently wrong signs

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[19]. We also estimated the regressions by OLS with first-differenced data (though this is inappropriate, because ρ is significantly less than unity). The coefficients on the interaction of the openness variables with skill deviations were smaller than in columns 5 and 6 of Table 3, but still just significant, while the interactions with land deviations remained much the same. Using an alternative method of first-differencing the interaction terms (differencing only the openness component, rather than its product with the resource deviation), the size and significance of the coefficients on the interactions with skill were further reduced (and that based on *XY* became insignificant), but the interactions with land were almost unaffected.

(some significantly so) on the interaction between openness and skill deviations, and the variation in the sign of the interaction between openness and land deviations, depending on the measure of openness used, is consistent across all estimation methods.

Dummy variable specification

Table 4 presents the results of regressions for secondary enrolments using the alternative dummy variable specification (equation 7), estimated by MAD for reasons noted earlier. Each of the regressions uses a different set of dummy variables - i.e. six alternative ways of grouping countries according to their skill and land endowments.[20] The main objective is to investigate the effects of particular *combinations* of skill and land (beyond the simple skill/land ratio used in the continuous specification). In other respects, these results resemble those of the continuous specification - with similar coefficients on the *ET* proxies and the time dummies (not shown). However, only the flow measure of openness (*XY*) is used in these regressions: this is because the infrequency of changes in the barrier measure (*OPEN*) causes the results for some groups to be driven by just one or two countries.

In all six regressions, the coefficient on *XY*, which measures the effect of greater openness on secondary enrolments in the control group, is negative (and statistically significant). Since the dummy variables are defined in such a way that the control group is always the one with least skill and/or most land, this result is clearly consistent with our hypothesis. However, the main focus of our hypothesis is not on the absolute effects of openness in unfavourably endowed countries, but on how openness affects the gaps in skill supplies between them and more favourably endowed countries. These differential effects are measured by the coefficients on the interactions between *XY* and the dummy variables (defined in such a way that the effects are incremental, reading down each column).[21]

The first two regressions divide countries into two skill groups, according to whether their average years of schooling are above or below the global mean, labelled HME (for high and higher-middle education) and LME (for low and lower-middle education). In regression 1, the interaction between *XY* and HME is positive and statistically significant, confirming that greater openness tended to widen the gap in secondary enrolment rates between more and less

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[20]. Resource endowments are measured at the start of each five-year period, and thus particular countries can move between endowment groups over time. The numerical criteria for allocating countries to groups (e.g. average land area per worker) are also recalculated each period. Appendix 1 shows the movement of countries among endowment groups between 1960 and 1990.

[21]. Intercept dummies corresponding with the slope (*XY*) interaction dummies were included in all regressions. The values of their coefficients are not shown in the table, but were in almost all cases very small.

Table 4. Secondary enrolment rates: dummy specification

	(1)	(2)	(3)	(4)	(5)	(6)
XY	-0.09 (-2.5)	-0.10 (-2.4)	-0.19 (-3.1)	-0.20 (-4.1)	-0.17 (-3.8)	-0.22 (-4.5)
XY*LMELL		0.14 (1.6)				
XY*HME	0.26 (4.9)	0.14 (1.3)				
XY*LL			-0.03 (-0.5)			
XY*LELL				0.16 (1.2)		0.19 (1.5)
XY*ME			0.27 (3.8)	0.18 (1.3)	0.34 (5.3)	0.21 (1.5)
XY*MELL					-0.11 (-1.6)	-0.15 (-2.1)
XY*HE			0.20 (3.0)	0.12 (1.9)	0.19 (2.7)	0.22 (3.1)
TSAP	2.10 (6.1)	2.09 (6.1)	2.06 (6.0)	2.16 (6.3)	2.14 (6.3)	2.15 (6.3)
REEY	0.57 (2.1)	0.54 (2.0)	0.11 (0.4)	0.21 (0.8)	0.29 (1.1)	0.29 (1.1)
PCY	0.11 (7.9)	0.11 (8.1)	0.11 (8.7)	0.11 (8.2)	0.11 (8.5)	0.11 (8.1)
$\overline{R}^2$	0.78	0.77	0.78	0.77	0.77	0.77

Notes: t-ratios are in parentheses. The definitions of the dummy variables with which XY is interacted are as follows. HME is 1 for HME countries, 0 otherwise. LMELL is 1 for HME and LMELL countries, 0 otherwise. LL is 1 for LL countries, 0 otherwise. ME is 1 for HE and ME countries, 0 otherwise. HE is 1 for HE countries, 0 otherwise. LELL is 1 for HE, ME and LELL countries, 0 otherwise. MELL is 1 for HE and MELL countries, 0 otherwise. The method of estimation is MAD (minimum absolute deviations) on the within-transformed data. All regressions include time dummies and resource-dummy intercepts. The number of observations is 522. See Table 2 for definition of variables, and text for further details.

educated countries. In regression 2, the LME group is sub-divided between countries with land area per adult above the global mean (in logs), who are the control group, and those with below-average land (identified by the dummy LMELL). The interactions of *XY* with both dummies are positive (albeit not significant): among poorly-educated countries, greater openness has a more favourable effect on enrolments where land is scarce, but not such a favourable effect as in better-educated countries.

Regressions 3-6 are all based on a division of countries into three skill groups (labelled HE, ME and LE), combined in various ways with the division between land-abundant (HL) and land-scarce (LL) countries. In regression 3, the skill and land divisions are independent of each other: the positive and significant interactions between *XY* and both ME and HE reconfirm that greater openness has a more favourable effect on secondary enrolments, the more educated the country; but the insignificantly negative interaction of *XY* with LL shows that, across countries at all skill levels, land scarcity does not have the predicted favourable effect on enrolments (just as with the continuous specification using *XY*). When the two lowest skill groups are subdivided between HL and LL countries, as in regressions 4-6, allowing the effects of skill and land to be interdependent, land scarcity does have a favourable effect within the LE group (as it did in the LME group), but it has the opposite effect within the ME group - enrolments benefited more from greater openness in land-abundant than in land-scarce ME countries.

We applied the dummy specification also to enrolments at other levels (Appendix 4). For tertiary enrolments, as with secondary enrolments, the coefficients on *XY* are negative in all cases, and the interactions between *XY* and HME, ME and HE are positive in all cases, confirming that openness had a more favourable effect in countries which were initially more highly educated. The interactions between *XY* and land scarcity within the skill groups, however, are all wrongly (negatively) signed, again confirming the results with the continuous specification. For primary enrolments, too, the dummy specification, like the continuous specification, yields wrongly signed coefficients on almost all the openness and interaction variables.

To summarise, the results for secondary and tertiary education are broadly consistent with our hypothesis. With all specifications, greater openness has had more favourable effects on enrolment rates in more-educated than in less-educated countries, thus tending to widen the gap in skill endowments between them. Indeed, greater openness seems to have lowered the absolute level of enrolments in less-educated countries. The effects of differences in land endowments vary with the specification, the measure of openness, and the level of education: land scarcity causes greater openness to have a favourable effect on secondary enrolments, particularly in poorly-educated countries, but if anything the opposite effect on tertiary enrolments. The results for primary education are almost entirely inconsistent with our hypothesis, but could plausibly be reconciled with it by arguing that enrolment changes at this level have been driven by autonomous variations in political will and capacity for which we are unable to control.

6. Conclusions

The hypothesis of this paper, derived from a skill-based Heckscher-Ohlin model with elastic supply, is that greater openness to trade tends to widen initial inter-country differences in skill endowments. This hypothesis is of practical interest because new growth theory (and evidence) suggest that such a widening of skill endowments would cause long-term growth rates of per capita income to diverge. In this way, greater openness might increase international income inequality, contrary to what is now widely believed.

Our statistical analysis gives some support to this hypothesis, except for primary education, where the marked catching-up of enrolment rates that has occurred in poor countries over the past three decades appears to have had little or nothing to do with trade. For secondary and tertiary education, however, the results of our regressions suggest that greater openness does tend to increase differences in enrolment rates between more-educated and less-educated countries (especially land-abundant less-educated countries, such as those in sub-Saharan Africa). Moreover, these econometric results seem consistent with global changes over the past three decades: the world has become more open to trade, and gaps in secondary and tertiary enrolment rates have widened.

It is important to consider the *magnitude* of the divergent effects implied by our regressions, since even statistically significant coefficients might still be trivially small. Rough calculations (in Appendix 5a) based on the three-dummy variable specification suggest that a world-wide increase of 20 percentage points in export/GDP ratios (which would be a large rise in this measure of openness) would widen the gap in secondary enrolment rates between low-education and high-education countries by 9 percentage points, and in tertiary enrolment rates by 11 percentage points. Together, these enrolment changes would eventually widen the gap in average adult years of schooling between the LE and HE groups by about one year of secondary and tertiary education.[22] Calculations based on the continuous specification (in

[22]. Primary education is omitted from this summary, on the grounds that the estimated coefficients are misleading, but is included in the calculation in Appendix 5a. The effects of differing land endowments are also omitted.

Appendix 5b) suggest a widening of between a quarter and a half of one year of secondary and tertiary schooling.

Are these big changes? The figures for the widening of the enrolment rate gaps seem substantial when compared to "world" average enrolment rates of 44 percent for secondary education and 11 percent for tertiary education, and for the change of one year in average years of schooling in comparison to the "world" mean of 4.5 years (Table 2). The key issue, however, is how much difference such a widening would make to growth rates (and hence divergence) of per capita incomes: this question is beyond the scope of our paper, but we can hazard an answer to it on the basis of existing research. In a Barro-type regression explaining growth of per capita GDP during 1960-85, the coefficient on 1960 average years of schooling is 0.005 (Berge et al, 1994, Table A1).[23] This implies that the one-year widening of the gap in average years of schooling between HE and LE countries would cause their growth rates of per capita income to diverge by half a percentage point per year - which is not trivially small when compounded over long periods.

Of course, these numbers should not be taken too seriously. The regression results on which they are based are subject to at least the usual number of doubts and qualifications, and the magnitude calculations are in the back-of-an-envelope class, not proper simulations. That does not mean, however, that these numbers necessarily overstate the divergent effects of greater openness on skill supplies: on the contrary, they may understate them, for two reasons. One is their omission of primary education, where there could be an effect similar to that on secondary and tertiary education, though we have been unable to measure it: the association in sub-Saharan Africa over the past decade between rising openness and falling primary enrolments may not be just a coincidence. The other is their neglect of all the skills acquired outside formal education, on which we lack systematic data. There is thus much scope for further research: on the skill supply mechanism, on its linkage to growth rates, and on other connections between openness and growth from which we have abstracted, such as technology transfer.

It is even more of a leap to consider possible implications for policy, but let us suppose for the sake of argument that our hypothesis is correct, and ask how governments ought to respond. The main message is that free trade may not be the developmentally best policy for backward countries, since it retards their accumulation of skills by causing them to specialise in goods of low skill intensity. To some extent, this retardation can be offset by other measures to increase the stock of skills, but people and firms will not invest in education and

[23]. The regression in question is identical to that in Barro (1991, Table 1, column 1), except that the 1960 primary and secondary enrolment rates are replaced by 1960 over-25 average years of schooling.

training unless there is a financial return: government supply-side efforts at expansion would therefore be uneconomic or even ineffective in a country whose pattern of trade was such that there was little demand for skilled labour. It is futile to build more schools if parents see no economic advantage to enroling their children, or more training facilities if firms require few skilled workers.

What sorts of interference with free trade might be optimal from this point of view? No single specific policy could be right for all poor countries. The general criterion is "whatever interferences are most likely to promote skill accumulation in the long run", but the details will vary from country to country, depending on its starting point - its initial stock of skills - and on its likely economic destination, given such unchangeable features as its natural resources and location. The experience of the successful East Asian developing countries provides some general lessons: their combination of rapid educational expansion and temporary protection of a sequence of industries of increasing skill intensity, followed by strong incentives for these industries to export, was effective in expanding the stock of skills because it caused the demand for educated labour to rise in line with its supply and gave educated young people opportunities for employment in which they could add vital practical training and experience. However, East Asia had a good educational base, and few natural resources: for countries where half the population is still illiterate, or natural resources are abundant, different sets of specific trade policies would be more appropriate.

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Appendix 1. Countries grouped by 1960 levels of education (over-15 average years of schooling) and land area per (over-15) adult

High education

Low land

Barbados
Belgium
Cyprus
Denmark
France (MELL)
Germany, West
Greece
Hong Kong
Ireland
Israel
Italy (MELL)
Japan
Netherlands
Switzerland
Trinidad & Tobago
United Kingdom

High land

Argentina
Australia
Bolivia (MEHL)
Canada
Chile (MEHL)
Fiji
Finland
Guyana (MEHL)
Iceland
New Zealand
Norway
Panama (MEHL)
Sweden
United States
Uruguay

Medium education

Low land

*Austria (HELL)
Dominican Rep.
El Salvador (LELL)
Jamaica
*Korea (HELL)
Mauritius
*Philippines (HELL)
*Singapore
*Spain
*Sri Lanka
*Taiwan (HELL)
*Thailand
*Yugoslavia (HELL)

High land

Brazil (LEHL)
Colombia
*Costa Rica (MELL)
Ecuador
Jordan
Lesotho (LEHL)
Malaysia
Mexico
Nicaragua (LEHL)
Paraguay
Peru
*South Africa
Swaziland
Tanzania (LEHL)
Venezuela
Zambia

Low education

Low land

Bangladesh
Guatemala
Haiti
India (MELL)
Indonesia (MELL)
Myanmar (Burma)
Pakistan
Portugal (MELL)
Sierra Leone (LEHL)
Turkey

High land

Algeria
Botswana
Cameroon
Central African Rep.
Ghana
Honduras (MEHL)
Iran
Kenya
Malawi (LELL)
Mali
Mozambique
Niger
Papua New Guinea
Senegal
Syria (MEHL)
Togo
Tunisia
Uganda (LELL)
Zaire
Zimbabwe

Notes: The medium education countries marked with an asterisk are in the HME group (with the high education countries), while unmarked medium education countries are in the LME group (with the low education countries). In cases where a country's group membership changed between 1960 and 1990, its 1990 group is indicated in parentheses after its name.

Appendix 2a. Continuous specification (using the skill/land ratio)

Dep.var. =	SER		TER		PER	
TO =	XY (1)	OPEN (2)	XY (3)	OPEN (4)	XY (5)	OPEN (6)
TO*$\tilde{E/L}$	0.06 (2.9)	0.05 (2.9)	-0.01 (-1.1)	-0.005 (-0.4)	-0.05 (-2.4)	0.04 (2.5)
TSAP	2.09 (3.9)	2.10 (3.8)	2.66 (8.6)	2.41 (7.9)	-2.86 (-6.7)	-2.36 (-5.3)
REEY	0.91 (2.2)	0.87 (2.1)	-0.01 (-0.07)	0.12 (0.6)	1.05 (2.6)	1.06 (2.5)
PCY	0.10 (6.3)	0.11 (6.2)	0.03 (2.4)	0.04 (3.5)	0.01 (0.7)	-0.03 (-1.8)
$\bar{R}^2$	0.78	0.78	0.66	0.67	0.37	0.36
No. obs.	522	486	522	486	522	486

Notes: SER, TER and PER refer to secondary, tertiary and primary school enrolment rates respectively. The numbers in parentheses are t-ratios (based on White's heterocedasticity-consistent S.E's). All regressions include time dummies. The method of estimation is OLS on the within-transformed data. See Table 2 for definition of variables, and text for further details.

Appendix 2b. Secondary enrolment rates (using the skill/land ratio): alternative estimation techniques

	Random GLS		MAD		IV		MLAR1	
TO =	XY (1)	OPEN (2)	XY (3)	OPEN (4)	XY (5)	OPEN (6)	XY (7)	OPEN (8)
TO*$\tilde{E/L}$	0.06 (3.3)	0.06 (4.2)	0.08 (5.1)	0.07 (5.0)	0.14 (2.4)	0.13 (3.2)	0.05 (2.1)	0.03 (2.0)
TSAP	3.27 (7.0)	3.15 (6.5)	2.66 (7.9)	2.68 (7.6)	2.01 (3.7)	2.42 (4.2)	2.61 (5.1)	2.57 (5.0)
REEY	1.03 (2.8)	1.04 (2.7)	0.53 (2.0)	0.80 (2.8)	1.01 (2.4)	1.06 (2.5)	0.72 (2.4)	0.73 (2.3)
PCY	0.15 (11.1)	0.15 (10.4)	0.10 (8.3)	0.11 (8.1)	0.09 (4.2)	0.09 (4.8)	0.07 (4.6)	0.08 (4.7)
$\bar{R}^2$	0.77	0.77	0.77	0.77	0.77	0.77	0.70	0.69
No. obs.	522	486	522	486	522	486	522	486

Notes: See notes to Table 3. IV refers to instrumental variable technique, with the ratio of manufactured exports to primary exports as the instrument for E/L. The estimates of ρ for (7) and (8) are 0.63 (s.e. = 0.04) and 0.64 (s.e. = 0.04) respectively. See Table 2 for definition of variables, and text for further details.

Appendix 3a. Tertiary enrolment rates: alternative estimation techniques

	Random GLS		MAD		MLAR1	
TO =	XY	OPEN	XY	OPEN	XY	OPEN
	(1)	(2)	(3)	(4)	(5)	(6)
TO*$\tilde{E}$	0.07	0.02	0.08	0.02	0.03	0.005
	(4.1)	(3.1)	(5.3)	(3.4)	(1.8)	(1.0)
TO*$\tilde{L}$	0.03	0.01	0.03	-0.006	0.01	0.006
	(2.9)	(2.0)	(3.6)	(-0.9)	(0.1)	(0.8)
TSAP	2.27	2.22	3.23	3.27	2.38	2.29
	(8.6)	(8.5)	(17.9)	(17.4)	(8.7)	(8.2)
REEY	-0.03	0.02	-0.09	-0.07	-0.007	0.06
	(-0.1)	(0.1)	(-0.6)	(-0.4)	(-0.04)	(0.4)
PCY	0.03	0.04	0.02	0.03	0.03	0.04
	(4.7)	(5.8)	(3.2)	(4.6)	(3.3)	(4.1)
$\overline{R}^2$	0.65	0.70	0.66	0.65	0.56	0.57
No. obs.	522	486	522	486	522	486

Appendix 3b. Primary enrolment rates: alternative estimation techniques

	Random GLS		MAD		MLAR1	
TO =	XY	OPEN	XY	OPEN	XY	OPEN
	(1)	(2)	(3)	(4)	(5)	(6)
TO*$\tilde{E}$	-0.004	-0.004	-0.10	-0.01	-0.06	-0.009
	(-0.1)	(-0.3)	(-3.7)	(-1.2)	(-1.9)	(-0.8)
TO*$\tilde{L}$	0.02	-0.04	0.03	-0.03	0.04	-0.02
	(0.9)	(-2.7)	(1.7)	(-2.8)	(1.5)	(-1.7)
TSAP	-1.77	-1.45	-2.20	-2.26	-2.36	-2.21
	(-3.4)	(-2.8)	(-6.7)	(-6.7)	(-4.4)	(-4.1)
REEY	1.02	1.10	0.93	0.71	0.65	0.63
	(2.6)	(2.7)	(3.6)	(2.6)	(2.1)	(1.9)
PCY	0.08	0.06	0.01	-0.02	0.02	-0.01
	(5.6)	(3.9)	(0.9)	(-1.7)	(0.9)	(-0.6)
$\overline{R}^2$	0.40	0.43	0.37	0.35	0.28	0.26
No. obs.	522	486	522	486	522	486

Notes: See notes to Table 3. The estimates of ρ in (5) and (6) for tertiary enrolments are 0.72 (s.e. = 0.03) and 0.73 (s.e. = 0.03) respectively, and for primary enrolments 0.64 (s.e. = 0.04) and 0.62 (s.e. = 0.04). See Table 2 for definition of variables, and text for further details.

Appendix 4. Dummy specification: tertiary and primary enrolments

Dep.var. =	TER			PER		
	(1)	(2)	(3)	(4)	(5)	(6)
XY	-0.06	-0.13	-0.13	0.11	0.25	0.38
	(-3.0)	(-4.1)	(-5.1)	(2.9)	(4.3)	(8.2)
XY*LMELL	-0.14			-0.21		
	(-3.0)			(-2.5)		
XY*HME	0.29			-0.11		
	(5.4)			(-1.1)		
XY*LL		-0.24			0.07	
		(-7.7)			(1.2)	
XY*LELL			-0.12			-0.34
			(-1.8)			(-2.7)
XY*ME		0.24	0.33		-0.42	-0.13
		(6.7)	(4.4)		(-6.2)	(-1.0)
XY*MELL			-0.18			-0.007
			(-5.0)			(-0.1)
XY*HE		0.29	0.28		-0.23	-0.18
		(8.8)	(7.6)		(-3.7)	(-2.8)
TSAP	3.16	2.71	2.68	-1.83	-1.87	-1.77
	(6.1)	(15.5)	(15.2)	(-5.6)	(-5.8)	(-5.5)
REEY	-0.14	-0.17	-0.19	0.67	1.09	0.90
	(-1.0)	(-1.3)	(-1.3)	(2.6)	(4.3)	(3.6)
PCY	0.02	0.03	0.03	0.02	0.03	0.02
	(3.0)	(3.9)	(4.0)	(1.3)	(2.1)	(1.8)
$\bar{R}^2$	0.65	0.68	0.67	0.38	0.40	0.38

Notes: t-ratios are in parentheses. HME is 1 for HME countries, 0 otherwise. LMELL is 1 for HME and LMELL countries, 0 otherwise. LL is 1 for LL countries, 0 otherwise. ME is 1 for HE and ME countries, 0 otherwise. HE is 1 for HE countries, 0 otherwise. LELL is 1 for HE, ME and LELL countries, 0 otherwise. MELL is 1 for HE and MELL countries, 0 otherwise. The method of estimation is MAD (minimum absolute deviations) on the within-transformed data. All regressions include time dummies and resource-dummy intercepts. The number of observations is 522. See Table 2 for definition of variables, and text for further details.

Appendix 5a. Magnitude of divergence of enrolment rates caused by increased openness

			Primary	Secondary	Tertiary
A.	Estimated coefficients on interaction of education dummy variables with openness (measured by the ratio of exports to GDP, or XY). The control group is LE. (From Table 4, col 3, and App 4, cols 2 and 5)	ME	-0.42	0.27	0.24
		HE	-0.23	0.20	0.29
		ME+HE	-0.65	0.47	0.53
B.	Divergence between LE and HE caused by a 0.2 (i.e. 20 percentage point) increase in XY (ME + HE coefficients x 0.2)		-0.13	0.09	0.11
C1.	Mean value of variable (Table 2)		0.87	0.44	0.11
C2.	Divergence as percentage of mean value (row B divided by row C1 x 100)		-15	21	96
D1.	Duration of each level of schooling (years)		6	6	4
D2.	Divergence of steady-state years of schooling (row B x row D1): see note below		-0.78	0.56	0.42
	Secondary plus tertiary			0.99	
	Sum of all three levels			0.21	

Notes: This table, the first of two containing the illustrative calculations referred to in section 5 of the paper, is based on the dummy variables which divide countries into low, middle and high education groups (LE, ME, HE), and on the flow (XY) measure of openness. In a demographic steady state, the average length of schooling of the adult population (e.g. 5.6 years) is simply the maximum duration of schooling (e.g. 16 years), multiplied by the average enrolment rate at all levels of schooling (e.g. 0.40). Similarly for each level of schooling separately: for example, for secondary schooling, with maximum duration of six years, a rise from zero to 100% enrolment would add 6 years to average adult years of schooling. Hence, in the present calculation, a difference of 0.094 (i.e. 9.4 percentage points) in the secondary enrolment rate would result in a steady-state difference of 0.094*6 (= 0.56) average adult years of schooling.

Appendix 5b. Magnitude of divergence of enrolment rates caused by increased openness

		OLS on within-transformed data (from Table 1, cols 1-4)				ML on ρ-differenced data (from Table 3, cols 5-6, and App 3a)			
		XY		OPEN		XY		OPEN	
		SER	TER	SER	TER	SER	TER	SER	TER
A.	Estimated coefficients on TO*Ẽ	0.17	0.08	0.04	0.01	0.08	0.03	0.03	0.005
B.	Divergent effect of greater openness, assuming (a) increases of 0.2 in XY and of 1 in OPEN (b) a 2-standard-deviation difference in skill endowments (i.e. Ẽ = 2): see note below	0.07	0.03	0.08	0.02	0.03	0.01	0.06	0.01
C1.	Mean value of variable (Table 2)	0.44	0.11	0.44	0.11	0.44	0.11	0.44	0.11
C2.	Divergence as percentage of mean value (row B divided by row C1 x 100)	15	29	18	18	7	11	14	9
D1.	Duration of each level of schooling (years)	6	4	6	4	6	4	6	4
D2.	Divergence of steady-state years of schooling (row B x row D1)	0.41	0.13	0.48	0.08	0.19	0.05	0.36	0.04
	Secondary plus tertiary		0.54		0.56		0.24		0.40

Notes: This table, the second of the two containing the illustrative calculations referred to in section 5 of the paper, is based on the continuous specification, using two different measures of openness and two different estimation techniques. The 2-standard deviation difference used in row B shows how much the assumed increase in openness would widen the gap in enrolment rates between a country one standard deviation above the world average level of skill endowments and a country one standard deviation below the average. With a normal distribution of skill endowments, this would correspond to the difference between the 16th and the 84th percentiles, approximately in the middle of the HE and LE groups, the difference between which provides the basis for the calculations in Appendix 5a (which are thus roughly comparable).