OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

SIN WORKING PAPER SERIES

THE IMPORTANCE OF HUMAN CAPITAL FOR THE TRADE-GROWTH LINK

Anders Isaksson

Working Paper No 2
November 2001

Statistics and Information Networks Branch of UNIDO

The author is a staff member of the United Nations Industrial Development Organization (UNIDO), Investment Promotion and Institutional Capacity Building Division, Statistics and Information Networks Branch (correspondence to aisaksson@unido.org). The author thanks Helmut Forstner, Arne Bigsten, Ramos E. Mabugu and Ghislain Robyn for careful reading and commenting, as well as for many inspiring and fruitful discussions on the topic of the paper. The views expressed in the paper are those of the author and not necessarily those of UNIDO or its member states.

Abstract: Trade is important for transporting growth-enhancing factors like technological advances and knowledge. However, the benefits of international trade forego many countries because of a shortage of human capital needed to absorb these knowledge flows. Whereas theory would predict a strong statistical relationship between trade and growth, the robustness of the relation in macro-growth regressions can be disputed. Failure to take into account the importance of human capital for the trade-growth link might explain the weak statistical relationship between trade and growth. A regression analysis, covering 73 countries over the period 1960-94, supports the notion that human capital is an important element in the trade-growth link.

Keywords: Human Capital, International Trade, and Economic Growth
JEL Classification: F1; F43; I20

1 Introduction

There are many proponents for the notion that a country's involvement in international trade activities produces positive growth effects (e.g. Grossman and Helpman, 1991) and that trade openness is good for growth (e.g. Dollar, 1992). Some even go so far as to argue that trade causes growth (e.g. Frankel and Romer, 1999).[1] Such a notion finds considerable support in the theoretical literature. For instance, economic theory suggests that export activities make firms more productive because they have to compete in international markets. It is also asserted that export activities carry so-called learning-effects, which means that firms learn from participating in competition because they encounter products at different or higher technological levels.

Imports too are thought to generate numerous positive effects on growth. For instance, imports of machinery from relatively advanced economies can have spillover effects on the domestic manufacturing of machinery. And more generally, imports often bring technological advances from abroad that can be used effectively in domestic production.

If it is true that international trade activities have significant positive spillover effects on economic growth, growth studies would demonstrate a positive and robust association between trade and growth, and perhaps even causation from the former to the latter. Yet, empirical research indicates that things are not so simple.

It has been found empirically that the statistical link between trade volume and growth is weak or non-existent, particularly once other policy-outcome variables such as inflation are controlled for (Levine and Renelt, 1992; Sala-i-Martin, 1997). One explanation for why there is only a weak link is that trade affects growth only via investment (e.g. Baldwin and Seghezza, 1996). While there are theoretical arguments for the notion that exports and imports enhance growth, some researchers (e.g. Rodrik, 1998) have seriously questioned the over-focus on trade. Their main argument is that trade is merely a means and not an end and that, therefore, the focus needs to shift towards 'real' growth spurs such as investment. They also argue that the

[1] The growth effects dealt with in this paper are the dynamic ones so elegantly treated in Grossman and Helpman (1991). Static effects, such as those obtained from a "textbook" move from autarky to some degree of openness, are not the issue here, simply since they only entail a transition from one state to another, even though the transition can take considerable time.

correlation between trade and growth does not necessarily mean a causal relationship: what causes growth also causes trade. Against such an argument stands the work by Frankel and Romer (1999) who show that trade indeed seems to cause growth.

Since the theoretical arguments in favour of a direct link between growth and trade are strong, it may be unwise to accept without question the returns of the empirical research mentioned above. Maybe this research was simply not perceptive enough. One way to refine our approach to the problem would be to assume that trade would have a conditional impact on growth. Provided that certain pre-requisites are met, trade would have a pro-growth influence; otherwise not. One pre-requisite worth considering concerns technology.

While trade involves a large potential for technological diffusion, what remains unclear is the extent to which a relatively less advanced country can make use of the new technology being offered through trade. It appears that direct adoption or adaptation of relatively advanced technology, as well as imitation, requires a certain level of skill in the recipient country. And therefore, it is quite possible that intensive trading takes place with new technological opportunities bypassing many countries, especially developing ones. If this is the case, the scope for trade to have dynamic growth effects seems limited and the weakness of the statistical association reported in a number of studies becomes understandable.

The hypothesis put at the centre of this paper is that the ability to adopt, adapt, or imitate new technology crucially depends on a country's endowment of human capital.[2] And the prediction is that, on average, countries with a relatively large endowment of human capital enjoy *greater* benefits from trade activities than countries that are relatively poorly endowed with human capital.

The notion that trade interacts with human capital to produce growth effects is supported by the regression analysis presented below. The preferred regression is of

---

[2] This is obviously a simplification because what matters is not necessarily the volume of human capital *per se*, but that a country has the *'appropriate'* kind of human capital. If a country is richly endowed with human capital, but is trading in a commodity in which it has little knowledge, trade might still have a weak association with growth. It might also be the case that a country trading only a few commodities has just a little overall knowledge, but the knowledge it has is 'appropriate' for those few commodities that it trades in. In general, however, it is more likely that a human-capital rich country also possesses the 'appropriate' knowledge, or at least some of it, compared with a country poorly endowed with human capital.

the standard cross-country form. Here it will be performed over 73 countries and with variables expressed as five-year averages over the time period of 1960-94. The specification is novel in that it centres on the inclusion of an interaction term for human capital and trade in order to capture the importance of human capital for benefiting from trade. Another non-standard feature of this paper is that human capital is introduced in a non-linear fashion, which follows the work by Krueger and Lindahl (1999). While the association between growth and human capital is weakened by the non-linearity of human capital, it is at the same time strengthened by the interaction with trade.

Three indicators of trade are examined in this study: total trade, exports and imports. The results obtained show that these measures of trade by themselves cannot be associated statistically with growth of real GDP per capita. However, when it is taken into account that countries are different in their abilities to adopt and adapt knowledge transmitted through trade channels, a statistically significant association between trade and growth obtains for countries that are relatively abundant in human capital. Poor endowment with human capital means that important knowledge spillovers are foregone and, consequently, that the growth potential is reduced. Thus, the results question the view that there is an over-focus on trade. Rather, it seems warranted to pay attention to the relation between trade and growth if at the same time the role of human capital is accounted for.

The paper is organised as follows: In Section 2, the link between GDP growth and trade on one hand, and the interaction between human capital and trade on the other, are discussed. The section also includes a brief, but quite exhaustive, summary of the empirical literature on the human capital-trade interaction. Section 3 describes the data used in the estimations and discusses estimation techniques. This includes the definitions of variables and the presentation of an estimable function. Estimation results are reported and analysed in Section 4. Section 5 concludes the paper and states some policy implications. An Annex discusses the robustness of the estimates.

2 International trade and growth: theory and empirics

This section first presents the conventional view on the dynamic effects of international trade on economic growth. Thereafter, the notion that human capital and trade interact to achieve such positive effects is introduced. A discussion of the

empirical literature on trade and growth in which this interaction has been accounted for concludes the section.

2.1 Static and dynamic effects of trade on growth

Many developing economies embarked on import-substitution (IS) strategies in the 1970s. The goal was to protect domestic industry and to promote production of imported goods. Trade protection was combined with industrial regulation and an over-valued exchange rate to achieve these goals. The inward-orientation was to stimulate domestic production, but it had a clear anti-export, anti-labour, and anti-agriculture bias that deterred these countries from specialising in accordance with their perceived comparative advantages.[3]

When it became clear how poorly the IS strategy was working and that its efficiency costs essentially spelled lower growth and welfare, a shift to an outward-looking policy took place. Industry was de-regulated, trade barriers were reduced, and local currencies devalued. Resources could now be allocated more efficiently and the road was open for a new equilibrium at higher GDP. In a classical growth view, such a move from inward to outward-orientation, and the accompanying GDP increase, is static in that it involves a once and for all shift from one state to another. After the new GDP level has been attained, the economy returns to its previous growth path and there are no further gains.

However, the recent trade and growth literature introduces a dynamic perspective according to which trade feeds growth. Undoubtedly, theory has concentrated on trade openness rather than actual trade, and for that reason the following discussion makes no clear distinction between the two concepts. It is obvious, however, that some dynamic effects pertain to trade openness rather than to actual trade – like those due to increased competition – while other effects are due to goods being transported from one country to another, as in the case with technology embodied in capital goods.

In principle, five dynamic effects can be discerned in the literature on trade and growth: *spillover* effects, *scale* effects, *competition* effects, *imitation* effects, and effects of an *increased variety of intermediates*.

---

[3] See Rodrik (1995) for an excellent overview.

The *spillover* effects from trade can take several forms. For instance, researchers can benefit from discoveries made elsewhere. This creates an incentive to do research rather than dwell on production activities, and such a shift of focus onto research could spur growth. Spillover must, however, fall on fertile ground to produce effects. Therefore, the extent of benefits in terms of knowledge externalities from increased openness depends upon whether the country is specialised in natural-resource based production or in manufacturing. While the former kind of production has a relatively low knowledge intensity, the latter could – depending on the level of development – be knowledge-intensive and more conducive to growth.

Technological differences are often assumed to be a source of comparative advantage. Whether technological advances are international or national decides whether such advantage should be viewed as exogenous, as in traditional trade models, or endogenous as in more recent theories. In the latter models, increased competition in product markets implies that there may be less incentive to do research, and labour would therefore move from research to production. If this happens, openness-induced specialisation may reduce growth rather than promote it (Grossman and Helpman, 1991). Trade liberalisation could also induce countries to specialise in products in which the potential for learning has largely been exhausted. In such a case, dynamic effects from trade may be negligible (Aghion and Howitt, 1998).

Important *scale* effects may follow from trade liberalisation, with the most obvious being that of trade liberalisation leading to a larger market for exports. Another positive growth effect associated with a larger market arises from vacant monopoly rents that can be appropriated by successful innovators. Frankel and Romer (1999) have also suggested that a larger market means a larger number of firms, which creates positive knowledge externalities advantageous to growth.

However, if trade reduces the scale of activities of import-competing firms, and thereby diminishes the expected returns to research and development (R&D), there may be an incentive not to innovate. For the export sector, for which the market is expanded due to the trade liberalisation, the opposite could be true as expected returns to innovation increase with scale.[4] Lucas (1988) has argued that to the extent that learning-by-doing is important for growth, industries producing on a large scale

[4] Scale is important to the returns to R&D spending because of the high fixed cost component.

would grow faster than those producing on a relatively smaller scale. As the workers of exporting (comparative advantage) industries learn and improve production techniques, these industries will expand due to trade. Learning-by-doing, by the same token, would lead to the opposite effect for import-competing sectors. Moreover, as Roberts and Tybout (1997) have documented, entering international markets is not free of cost, and scale effects cannot be capitalised on if such costs cannot be covered.

In the endogenous growth literature focusing on trade, the effect of increased *competition* and its impact on profitability has attracted much attention. Trade introduces competition, which in turn may generate productivity gains and even innovation. Furthermore, expected profits trigger investment in technological change and innovation; at least this may be expected to happen in the export sector. Competition may also lead to improvements in managerial skills due to pressure on managers to perform as sheltering trade barriers are removed. Moreover, the opening of the economy may induce managers to innovate in order to preserve rent mechanisms that had been acquired under less competitive conditions.

However, the effect of competition on growth is ambiguous, since increased competition for the import-competing sector may reduce the returns to some industries, and hence, expected profitability and, as a consequence, spending on R&D may decrease.[5] Furthermore, under imperfect competition, and with firms deriving their profits from existing technologies, there may be an incentive for firms not to innovate (Baldwin, 1992). Grossman and Helpman (1991) have also shown that under certain conditions free trade could instigate a move of labour from research into production, with a consequent reduction of technical change and growth.

Trade facilitates *imitation* and both export and import sectors could improve productivity and accelerate technological change through that channel (Grossman and Helpman, 1991). Trading firms, through their foreign contacts could – at least in theory – take advantage of learning effects (see, for instance, World Bank, 1993).[6]

---

[5] Lawrence and Weinstein (1999) and Aghion and Hewitt (1998) provide good discussions on this ambiguity.

[6] However, it should be noted that in analyses based on plant-level data, neither Clerides *et al* (1998), nor Bernard and Jensen (1999), find evidence of learning effects. Furthermore, Graner and Isaksson (2001) obtain results similar to those of the aforementioned studies, but show that size effects are mistaken for learning effects.

Finally, imports can enhance growth by allowing for an *increased variety of intermediates* and, hence, access to better production techniques (besides allowing for larger quantities). This could happen because intermediate goods from abroad that are not available in the home market may embody advanced foreign technologies, which could impact on technological change (Bayoumi, Coe, and Helpman, 1996).

2.2 The interaction of international trade with human capital

This section reviews papers that focus on the interaction between actual trade and human capital, i.e. their combined effect on growth. The idea that outward-orientation interacts with human capital is not entirely new. Edwards (1992) and Harrison (1996) are two previous sources that mention a possible interaction between openness and human capital, while Frankel (1998) talks about the interaction as if it were obvious. In Keller (1996), an interaction between human capital and trade can be said to be implied by the model. The study shows that outward-orientation is not enough to close the gap between rich and poor countries; for such closure there is also a need to increase the growth rate of skill formation in the labour force.

While the idea of the above interaction has been expressed in several places, there are, it would seem, only two instances of empirical tests having been conducted in a direct way: Harrison (1996) and Miller and Upadhyay (2000). As an introduction to discussing these two papers, the following three issues shall briefly be surveyed: the preference for focusing on actual trade rather than trade openness, the issue of causality, and the role of human capital in the trade-growth link.

It appears as somewhat unfortunate that the trade share has been used as a proxy for openness at the cost of the role of trade itself.[7] No doubt trade openness is

---

[7] If trade were solely the outcome of opening up, it would be a valid proxy for openness. However, Anderson (2000) discusses several cases why countries are unable to capitalise on new trade possibilities and, therefore, tend to trade less than predicted by theoretical models. Furthermore, as indicated above, trade could increase or decrease for many reasons other than policy, for instance, due to exogenous changes in the terms of trade. Opening up may also have distinct growth effects that are not necessarily related to increases in the trade share. For instance, increased competition has effects on the drive to innovate, and hence on growth. The distinction between actual trade and trade policy is also made, for instance, in Rodrik and Rodriguez (1999).

essential to any economy because it provides an enabling environment.[8] However, in order to exploit the full effects of trade liberalisation, trade must occur, for it is mainly through trade that new technology crosses borders. While openness seems to be a necessary condition for the enhancement of growth, actual trade appears to be a sufficient one. Hence, the growth literature would benefit from a shift of attention towards actual trade, at some cost to trade openness *per se*.

The unresolved issue of identifying the direction of causality still plagues the empirical literature on trade and growth. It has been argued at several occasions (for instance, by Baldwin and Seghezza, 1996) that trade affects growth only indirectly through its impact on investment. However, the work of Krishna, Ozyildirim, and Swanson (1998) seems promising in addressing the causality issue. They find that for a majority of countries trade affects growth positively in a direct manner. Furthermore, for 70 per cent of the countries analysed causality was uni-directionally in favour of exports and/or imports causing growth. Likewise, the work by Frankel and Romer (1999) and Frankel, Romer, and Cyrus (2000) points to trade not only being associated with growth, but in fact causing growth.

What is the role of human capital in all this? Although trade is the principal channel for the flows of ideas, knowledge, and advanced technology, it is not clear to what extent the recipient country can make use of these flows. Adoption, adaptation, and imitation crucially depend on the stock of human capital in the recipient country, and also on how the different components of human capital (e.g. on-the-job-training versus academic training) are distributed.[9] To take an extreme example, aerospace technology is less rewarding for, say Zambia, than for France in terms of fuelling growth. Zambia probably benefits more from technical advances closely related to its comparative advantage, which lies in agro- and natural-resource based production. As

---

[8] Edwards (1993; 1998) and Harrison (1996) provide excellent surveys of the literature on trade liberalisation, openness, and growth.

[9] Acemoglu and Zilibotti (2001) present a model where productivity differences between North and South develop because the South cannot make efficient use of the North's (relatively advanced) technologies. The bottleneck in their model is the supply of appropriate skills. Dessy and Pallage (2001) argue that a higher degree of inequality in many poor countries creates an environment conducive to the tolerance of informal and low-productivity activities. This, they argue, could explain why such (poor) countries do not adopt the highly productive technologies available abroad.

a developing country advances and attains higher skill-levels among its labour force, more benefits can be derived also from trade in higher-technology goods.

Empirically, it is hard to show the (theoretical) growth benefits of international trade. In the work on growth, other policy outcome variables often tend to render trade variables statistically insignificant, as shown in Levine and Renelt (1992). Frequently, the conclusion drawn from such results is that trade is not *directly* important to growth. An alternative explanation is that trade is important for investment, which in turn is important for growth, thus saving trade as an, albeit *indirect*, source of growth.

Turning to the review of Harrison (1996) and Miller and Upadhyay (2000), it is important to note that both papers are about trade openness and growth/productivity, and not about actual trade. Harrison (1996) proxies openness with several variables, among them actual trade. In a similar fashion, Miller and Upadhyay (2000) use actual trade as a proxy for trade openness. While human capital is not at the centre of their work, in both papers it is made to interact with openness (and actual trade), and it is towards these results that attention is directed here.

Harrison (1996) uses seven proxies for trade openness, one of them being total trade as a share of GDP. She estimates several specifications for 17 to 51 countries over the sample period 1960-1987. The trade variable is, as are many of the other openness measures, seldom statistically significant. The trade share is statistically significant only with annual data in differences, but the author argues that this result could be due to business cycle effects. In the "robustness part" of the paper, the openness variables are made to interact with the stocks of primary and secondary education. For the estimations — using five-year averages and the level of trade policy — the parameter of the interaction term is statistically significant in only three cases out of ten. Among the three statistically significant parameters, there is that when trade share interacts with secondary education. Among the 12 interactions with change in trade policy, none is statistically significant and the effect on growth from the interaction term with the trade share is negative.

Miller and Upadhyay (2000) first calculate – for 83 countries over the period 1960-1989 – total factor productivity (TFP) levels from an estimated production function, with and without human capital. They attempt to explain TFP by several variables, among them (the log of) the export share, which is their preferred proxy for

openness. For low-income countries, they find that the effect from exports is reinforced when it interacts with human capital, whereas this is not the case for other sub-groups of countries. The parameter for exports is always statistically significant.

Unfortunately, the findings of the paper ought to be viewed with great caution because the ranking of countries by TFP levels appears to be highly surprising. The most plausible TFP calculation – in terms of the resultant ranking – is the one with human capital included in the estimation. In that case, the U.S.A. tops the TFP list, followed by Bangladesh, while Brazil, Iran, and Trinidad & Tobago obtain ranks five to seven. Countries such as Japan, Sweden, Norway, Finland, and Iceland are found on places 17, 27, 44, 47, and 64, respectively. Such TFP ranking is hard to reconcile with actual observations of technological change over the sample period, and this odd ranking of countries makes it difficult to interpret the results outlined above.

3 Data and definitions of variables

This section starts with a description of the data used in this exercise. It goes on to deal with the issues of data frequency and estimation methods. A discussion of the expected signs of coefficients leads up to the presentation of results in Section 4.

3.1 Description of the data

The analysis uses data on 73 developed and developing countries for the sample period 1960-1994, where inclusion of a country is governed by data availability (see Table A1 in Appendix 2 for the coverage of countries). Data come from four different sources: human capital variables from Barro and Lee (2000); real per capita income growth, inflation, and black market exchange rate premium from Levine, Loayza, and Beck (2000); the investment rate, financial depth, and trade variables from World Bank (2000); and the log of real GDP per capita in 1960 (initial income) from Summers and Heston (1991). More detail about how the variables are defined is provided in Table A2 in Appendix 3.

Data were transformed into five-year averages in order to purge them of the influence of business cycle effects, resulting in a maximum of seven data points

across the whole time period.[10] It is sometimes suggested in the literature (e.g. Islam, 1995) that panel-data methods (e.g. the fixed-effects estimator) are superior to average or pooled cross-country regressions. However, a major problem with the fixed-effects estimator is that it removes between-country variation and leaves only within-country variation. Many explanatory variables, like one of the key variables in this paper, human capital, have low within-country variance and may thus fail to explain high within-country growth variation. This is probably the reason why many studies using panel-data analysis have failed to find a statistically significant effect of human capital on growth.

In some cases, notably when cross-sectional variance is large relative to time-series variance and when measurement-error variance is large relative to the cross-sectional one, the fixed-effects estimator will aggravate the degree of measurement error and, therefore, increase the attenuation bias (Pritchett, 2000).[11] In contrast, the main problem of not using panel-data estimators is that the parameter for the convergence variable is rendered biased and inconsistent because the omitted individual (fixed) effects are correlated with the explanatory variable representing convergence. However, since the issue of convergence is not the main focus of this paper, the shortcomings of non-panel analysis seem to be acceptable.

3.2 Definition of Variables and the Estimable Function

The variable to be explained is growth of real GDP per capita. Among the explanatory variables, special attention is paid to the effect of three trade variables on growth: the first is total trade (exports plus imports) as a share of GDP, while imports and exports as shares of GDP, respectively, are the other two variables. Special interest attaches also to the association between human capital and growth, since the paper argues for the importance of an interaction between human capital and trade to benefit growth.

---

[10] For some countries, data availability problems reduced the number of data points to less than seven with the minimum being four. However, for the vast majority of countries in the sample, seven data points were obtained. Balancing the sample – by deleting the countries with less than seven data points – did not have a significant impact on the estimation results.

[11] Pritchett (2000) further argues that the endogeneity bias may be exacerbated and that there are problems with dynamic misspecification. In addition, Durlauf and Quah (1999) argue that panel-data analysis aggravates problems for the interpretation of the convergence parameter.

Human capital is proxied here by the average schooling years of the population aged 15 years and more, although preferably a human capital measure should also capture other various facets of human capital, such as quantity and quality of schooling as well as work experience and specific and general training.

There are good reasons for human capital to enter the regression in non-linear fashion. It is easy to imagine a situation, where after a certain amount of education, the marginal benefit for growth from another "unit" of human capital is negative. And an inverted U-shaped education-growth profile indicates that, from a certain point onwards, private utility derived from education outweighs social utility. This could occur under certain conditions when the government channels resources towards research at the expense of production (Aghion and Hewitt, 1998). Based on a model with human capital as the only explanatory variable, Krueger and Lindahl (1999) show that after 7.5 years of education the education-growth profile is downward-sloping.

In the present paper, a number of control variables are included in the regression as well. These are the initial level of GDP (typically assumed to capture convergence), the investment rate, the black market exchange rate premium (as a measure of openness), financial depth (to account for the effect of financial development on growth), inflation (representing macro policy outcome), and time dummy variables. All variables, except human capital, are calculated as arithmetic averages over five years. Human capital is observed only once in five years and its value is that of average years of schooling for each five-year period.

Except for the squared human capital term, equation (1) below – the first equation to be estimated – is a fairly standard growth regression:

$$\Delta y = \alpha + \beta_1 T + \beta_2 H + \beta_3 H^2 + \delta_i X + \gamma_i t + \varepsilon_{it}. \qquad (1)$$

Suppressing variable subscripts, α denotes the intercept, Δy is growth of real GDP per capita, T represents one of three trade variables (total trade, exports, or imports), H and H^2 constitute a non-linear representation of human capital, X is a vector of control variables, t a vector of time dummy variables, and ε_{it} is a normally distributed error term.

The paper posits that β_1 is higher for high skill countries compared with low skill countries. Hence, for reasons stated earlier in the paper, the positive association between trade and growth is stronger for countries richly endowed with human capital. In other words, the parameter β_1 increases with the stock of human capital in a fashion, which is assumed to be linear:

$$\beta_1 = \varphi_1 + \varphi_2 H \tag{2}$$

Substituting (2) into (1) results in equation (3), which is the main regression around which most of the discussion will evolve:

$$\Delta y = \alpha + \varphi_1 T + \varphi_2 T^* H + \beta_2 H + \beta_3 H^2 + \delta_i X + \gamma_i t + \varepsilon_{it}. \tag{3}$$

Here the crucial interaction term between human capital and trade (H^*T) is included, based on the hypothesis that dynamic growth effects from trade can only be expected in cases where there is sufficient human capital available to the (trade) receiving country.

4 Estimation results

The results of estimating equations (1) and (3) are presented in Table 1 and discussed in the following way: First, the results obtained from regressions without the human capital-trade interaction terms are briefly analysed (columns 1, 3, and 5). Thereafter, the results of regressions including the interaction term are discussed at some length (columns 2, 4, and 6). Finally, a few remarks on testing robustness are added.

Table 1 shows that the control variables enter with the expected signs throughout. In addition, conditional convergence is seen to be slow, at about 0.7 per cent annually.[12] This figure is smaller than the one reported, for instance, in Barro and Sala-i-Martin (1995), but not at all unlikely, given the apparent diverging developments of OECD countries and Least Developed Countries.

The investment rate has a strong impact throughout, where an increase in the investment rate by one percentage point is on average associated with an increase in

[12] The formula for computing the convergence rate is - $(1 - e^{-0.008*T})/T$, where T equals the number of years of the sample.

the growth rate by a tenth of a percentage point. While convergence was comparatively slow, the investment parameter seems quite large. With a magnitude of 0.1, it is between two and three times larger than the (statistically insignificant) parameters reported in Barro and Sala-i-Martin (1995, table 12:3, all columns except *SUR*). By contrast, the estimated parameter here is much smaller than the one obtained in the much-cited study by De Long and Summers (1991), the reason, of course, being that those authors study the effects of equipment investment on growth. For most countries, equipment investment is only a trifle of total investment, the investment variable used in this paper.

Trade openness, measured by the extent of rationing in the foreign-exchange market (the log of the black market premium +1), appears to be conducive to growth. The parameter is statistically significant at the one per cent level and a 10 per cent decrease in the premium is associated with an increase in growth by 0.1 percentage points. It is worth noting that inclusion of the trade openness indicator does not substantially affect the parameters related to the trade variables. This can be taken as support for the claim that actual trade and trade openness have separate associations with growth.[13]

Inflation, approximating macroeconomic imbalances, is negatively associated with growth. An increase in the inflation rate by 10 percentage points retards growth by 0.1 percentage points. Hence, inflation does not seem to be of great concern for growth. The coefficient for financial depth is positive and statistically significant, and a financial deepening of 10 percentage points entails an increase in growth by 0.16 percentage points. Thus, the effect of financial development is positive, albeit not of the order of the effect of, for instance, an increase in investment.

Turning to the variables of central interest — trade and human capital, when no interaction effects are taken into account — the overall impression is that human capital has an independently positive effect on growth. However, this effect is diminishing as higher levels of education are attained. All three versions of a trade variable are statistically insignificant. Such insignificance would almost be expected

[13] That is, to the extent that the black market exchange rate premium is a good proxy for trade openness. Rodrik and Rodriquez (1999) argue that the black market premium is a proxy for macroeconomic problems. In this paper, the latter has been approximated by inflation and still the parameter for the proxy of openness is statistically significant across different specifications.

given the results of Levine and Renelt (1992), who showed that inclusion of the investment share and of policy outcome variables renders the parameters of a trade variable insignificantly distinguishable from zero in a statistical sense.

In contrast to the above, interaction between trade and human capital produces results that demonstrate growth effects in all three cases, but only in countries where there is sufficient human capital available to absorb knowledge flows. This outcome is very much in line with the predictions of the theoretical work started by Nelson and Phelps (1966) and successfully continued by Grossman and Helpman (1991).

Studying the estimation results of human capital and trade more closely, one can start with the columns excluding the interaction terms. They show that human capital enters the relationship in a non-linear fashion. The inverted U-shape of the human-capital growth curve implies that, on average, education is beneficial for growth up to a certain level of education and that, thereafter, growth effects of human capital increases are negative.

An increase in human capital associated with a one-year expansion of education implies a large growth effect of 0.5 percentage points (31 per cent). This effect is twice as large as what is usually obtained from micro studies and regarded as the maximum effect on earnings arising from human capital. Mincerian wage equations tend to produce estimates between 5-15 per cent. And this result obtains despite the introduction of non-linearity, which is almost always ignored by other studies.[14] Although it might be the case that an endogeneity bias exaggerates the human-capital effect, it is a widely held view that measurement errors underestimate the full human-capital effect to the same extent as the endogeneity bias overestimates it. Another argument in favour of the plausibility of a large estimate is that social returns, which cannot be captured in micro studies, may by far exceed private ones. In other words, there may be important externalities involved.[15]

If one assumes a linear growth effect, that is, disregards the squared human capital term, a full percentage-point increase in growth arising from a doubling of human capital is the result. Another important aspect, not covered here, is that an increase of human capital in a poor country probably has a larger effect than a similar

---

[14] An important exception is Krueger and Lindahl (1999).

[15] However, work by Acemoglu and Angrist (2000) suggests that for the case of the U.S.A. externalities are negligible.

increase in an OECD country, where human capital has already attained a high level. Put differently, some OECD countries are likely to be on the downward-sloping part of the curve, whereas all developing countries must be expected to be on the upward-sloping portion. If interaction effects with trade are ignored, the maximum growth effect occurs at 10 years of education.[16]

Taking into account the interaction effects, the effect of human capital on growth is in all three cases smaller than without interaction with trade (columns 2, 4, and 6 of Table 1). It is smaller despite the interaction term parameters because these are not large enough to offset the fall in the point estimate of human capital by 20 per cent (from 0.01 to 0.008). When human capital is made to interact with total trade, an increase of one year in human capital is associated with a 0.54 percentage point (32 per cent) increase in growth. The second largest of the economically significant effects is obtained from the interaction between imports and human capital. There, a year's increase in human capital gives a 0.39 percentage point increase in growth (23 per cent). When human capital interacts with exports, the effect is somewhat smaller (0.35 or 20 per cent).[17] That the effect pertaining to interaction with imports is larger than that for interaction with exports is no surprise; imports of capital goods and intermediates may be assumed to embody a significant amount of (relatively) advanced technology, while exports may be seen more as a means to obtain foreign exchange to allow for imports.[18]

It seems that trade is associated with growth only in countries with a sufficiently high level of human capital, an observation which is in line with the working hypothesis of the paper. Exports and imports have large growth effects, namely, 0.33 percentage points (19 per cent) and 42 percentage points (25 per cent), respectively. In total, imports actually have a minor negative effect of -0.06 percentage points (-3.5 per cent), which is due to a statistically significant parameter for the import share, i.e. larger than the effect from the interaction term. The overall negative association between imports and growth might emanate from the increased competition in import-

---

[16] Due to rounding, Table 1 shows a point estimate of –0.001 for the squared human capital parameter, while in fact the estimated parameter is only half that amount (-0.0005).

[17] Using the actual (as opposed to the rounded) parameters, the corresponding maximum growth effects of human capital interacted with total trade, exports, and imports occur at 9.3, 9.8, and 8 years of educational attainment, respectively.

competing sectors, which should be especially severe in developing countries where these sectors have been heavily protected.[19]

The smallest impact of trade on growth comes from total trade, which is explained by the fact that negative import effects cancel out positive effects of exports. The total effect of a 10-percentage point increase in total trade is negligible (only 0.02 percentage points or one per cent), but for human capital-abundant countries the impact is 19 percentage points (11 per cent).

The results obtained so far suggest that the benefits from trade materialise mainly when there is enough human capital to absorb all new ideas, knowledge, and technology transferred through trading. Countries with scant human capital experience less dynamic growth effects of trade — the typical situation of the developing country. It is sometimes argued that trade affects growth only via its effects on investment. This argument is not supported by the results presented here: investment has been controlled for in these estimations and yet there is a significant association between trade and growth.

Finally, a brief summary of extensive checks of robustness shall be provided here, leaving a detailed discussion for Appendix 1. Robustness was tested against several alternatives: a different definition of human capital that allows trade and human capital to be endogenous; allowing trade to enter non-linearly; and changing the estimation method to that of fixed-effects estimation.

When rates of enrolment in secondary schooling were chosen to replace average years of schooling as a proxy of human capital, the trade-growth link weakened somewhat. This result is not too surprising because enrolment rates represent flows rather than stocks of human capital and theory is concerned more with the relation between the latter and growth. Allowing trade and human capital to be endogenous has qualitatively the same effect as that reported in Table 1. However, this trade- weakens the growth link slightly, while the effect of human capital is strengthened. The most dramatic effect of allowing trade to enter in a non-linear fashion is the

---

[18] For arguments along these lines, see Rodrik (1998)

[19] Without doubt there is a fine line between association and causality. To the extent that Frankel and Romer (1999) as well as Krishna, Ozyildirim, and Swanson (1998) have been able to tackle and resolve the issue of causality, it seems less problematic to adopt a view of trade causing growth.

change to a positive sign for imports. Overall, including trade non-linearly seems to strengthen the association between trade and growth.

Lastly, fixed-effects estimation distorts the results considerably in that human capital tends to be associated negatively with growth. On the other hand, interaction terms are no longer needed to find a strong link between total trade and growth and exports and growth. However, in the case of imports the parameters are no longer statistically significant. For control variables, parameters also tend to shift signs and leads to highly unexpected results. What happens when between-country variation is wiped out is more or less what Pritchett (2000) predicted. Given that the issue of convergence is of negligible interest in this paper, it remains to be the case that the preferred estimation method is that of pooled regression.

5 Conclusions

This paper has looked into the relationships between human capital, international trade, and economic growth. It was argued that trade is an important carrier of technical advances and knowledge across countries and that, therefore, there are reasons to hypothesise a positive trade-growth link. In order for a country to take advantage of the knowledge transfer intrinsic in trading, it must have an adequate level of human capital. If it is poorly endowed with human capital, much of the knowledge bypasses the country and growth does not benefit from trade as much as it could.

A regression analysis was carried out with total trade, exports, and imports as explanatory variables, together with a host of other regressors. In accordance with the results of Levine and Renelt (1992), none of the trade shares was found to be statistically significant. In contrast, when trade was made to interact with human capital there was a clear positive association of all three trade variables with growth. This was, however, the case only for countries with sufficient human capital. These results can be viewed as providing evidence of the importance of human capital for the much discussed trade-growth link.

From the above it seems clear that policies promoting trade have a potential for spurring growth. The results of this paper suggest that dynamic growth effects may be limited by lack of human capital that would be needed to absorb knowledge flows. This hints at some policy options. One of them would be to target countries with the appropriate institutions and human capital already in place. A perhaps better approach

is to adopt strategies that increase a country's human capital for the sake of increasing the benefits arising from expanded trade.

With respect to the results presented here, a few caveats need to be mentioned. One of them has to do with the issue of causality, a topic which has not been specifically dealt with here, but only discussed in terms of results obtained in other research. Another caveat relates to the area of endogeneity bias, where still more work needs to be done. However, preliminary results of this research suggest that in the case of trade, endogeneity tends to only slightly change parameter values. Furthermore, only two human capital variables have been used in this paper, while there is certainly scope for more work here. In particular, it would be interesting to see the effect of an interaction between trade and the *quality* of human capital.

Finally, from a more detailed investigation of the aforementioned interaction, a special role for the manufacturing industry is likely to emerge. First, the kind of human capital receptive to the message of trade is most probably the human capital that sits on modern jobs in firms capable of being fertilised by trade inputs and spillovers. These are typically manufacturing firms. Second, not all trade flows have the same potential to stimulate growth. While this study demonstrated an impact on growth of the most broadly defined trade flows, it is reasonable to expect that a stronger link would be observed between knowledge-intensive trade and growth, or for that matter, between manufacturing trade and growth.

References

Acemoglu, D. and J. Angrist (2000), "How Large Are Human Capital Externalities? Evidence from Compulsory Schooling Laws", *mimeo*, Massachusetts Institute of Technology.

Acemoglu, D. and F. Zilibotti (2001), "Productivity Differences", *Quarterly Journal of Economics*, Vol. 116(2), pp. 563-606.

Aghion, P. and P. Howitt (1998), *Endogenous Growth Theory*, Cambridge: MIT Press.

Anderson, J. (2000), "Why Do Nations Trade (So Little)?", *Pacific Economic Review*, Vol. 5(2), pp. 115-34.

Baldwin, R. (1992), "On the Growth Effects of Import Competition", *NBER Working Paper no. 4045*, Cambridge: NBER.

Baldwin, R. and E. Seghezza (1996), "Trade-induced Investment-Led Growth", *NBER Working Paper no. 5582*, Cambridge: NBER.

Barro, R. and J-H. Lee (2000), "International Data on Educational Attainment Updates and Implications", *NBER Working Paper no. 7911*, Cambridge: NBER.

Barro, R. and X. Sala-i-Martin (1995), *Economic Growth*, New York: McGraw-Hill.

Bayoumi, T., Coe, D.T. and E. Helpman (1996), "R&D Spillovers and Global Growth", *Journal of International Economics*, Vol. 47(2), pp. 399-428.

Bernard, A.B. and J.B. Jensen (1999), "Exceptional Exporter Performance: Cause, Effect, or Both?", *Journal of International Economics*, 47(1), pp. 1-26.

Clerides, S., Lach, S., and J. Tybout (1998), "Is Learning-by-Exporting Important? Micro-Dynamic Evidence from Colombia, Mexico, and Morocco", *Quarterly Journal of Economics*, 113(3), pp. 903-47.

De Long, J. and L. Summers (1991), "Equipment Investment and Economic Growth", *Quarterly Journal of Economics*, 106(2), pp. 445-502.

Dessy, S. and S. Pallage (2001), "Why Don't Poor Countries Adopt Better Technologies?", *Working Paper No. 20-07*, Economics Department, UQAM.

Dollar, D. (1992), "Outward-Oriented Developing Economies Really Do Grow More Rapidly: Evidence from 95 LDCs, 1976-1985", *Economic Development and Cultural Change*, 40(3), pp. 523-44.

Durlauf, S. and D. Quah (1999), "The New Empirics of Economic Growth", in J. Taylor and M. Woodford (Eds.), *Handbook of Macroeconomics vol. 1A*, Amsterdam: North-Holland.

Edwards, S. (1992), "Trade Orientation, Distortions and Growth in Developing Countries", *Journal of Development Economics*, vol. 39(1), pp. 31-57.

Edwards, S. (1993), "Openness, Trade Liberalization, and Growth in Developing Countries", *Journal of Economic Literature*, Vol. 31(3), pp. 1358-93.

Edwards, S. (1998), "Openness, Productivity, and Growth: What Do We Really Know?", *Economic Journal*, Vol. 108(March), pp. 383-98.

Frankel, J. (1998), "Why Economies Grow the Way They Do", *Canadian Business Economics*, Vol. 6(3), pp. 3-13.

Frankel, J. and D. Romer (1999), "Does Trade Cause Growth?" *American Economic Review*, Vol. 89(3), pp. 379-99.

Frankel, J, Romer, D., and T. Cyrus (2000), "Trade and Growth in East Asian Countries: Cause and Effect", forthcoming in H. Singer, N. Hatti, and R. Tandon (Eds.), *NICs After Asian Miracle*, New World Order Series Vol. 23, India: BR Publishing Corporation Ltd.

Graner, M. and A. Isaksson (2001), "Understanding the Link between Exports and Productivity: New Evidence from Kenyan Manufacturing", *mimeo*, Goteborg University.

Grossman, G. and E. Helpman (1991), *Innovation and Growth in the Global Economy*, Cambridge: MIT Press.

Hanushek, E. and D. Kimko (2000), "Schooling, Labour-Force Quality, and the Growth of Nations", *American Economic Review*, 90(3), pp. 1184-1208.

Harrison, A. (1996), "Openness and Growth: a time-series, cross-country analysis for developing countries", *Journal of Development Economics*, 48(2), pp. 419-47.

Islam, N. (1995), "Growth Empirics: a panel data approach", *Quarterly Journal of Economics*, 110(4), pp. 1127-70.

Keller, W. (1996), "Absorptive Capacity: On the Creation and Acquisition of Technology in Development", *Journal of Development Economics*, 49(1), pp. 199-227.

Krishna, K, Ozyildirim, A., and N. Swanson (1998), "Trade, Investment, and Growth: Nexus, Analysis, and Prognosis", *NBER Working Paper No. 6861*, Cambridge: NBER.

Krueger, A. and M. Lindahl (1999), "Education for Growth in Sweden and the World", *NBER Working Paper No. 7190*, Cambridge: NBER.

Lawrence, R. and D. Weinstein (1999), "Trade and Growth: Import-Led or Export-Led? Evidence from Japan and Korea", *NBER Working Paper no. 7264*, Cambridge: NBER.

Levine, R. and D. Renelt (1992), "A Sensitivity Analysis of Cross-Country Growth Regressions", *American Economic Review*, 82(4), pp. 942-63.

Levine, R, N. Loayza, and T. Beck (2000), "Financial Intermediation and Growth: Causality and Causes", *Journal of Monetary Economics*, 46 (1), pp. 31-77

Lucas Jr, R. (1988), "On the Mechanics of Economic Development", *Journal of Monetary Economics*, 22(3), pp. 3-42.

Miller, S. and M. Upadhyay (2000), "The effects of openness, trade orientation, and human capital on total factor productivity", *Journal of Development Economics*, 63(2), pp.399-423.

Nelson, R. and E. Phelps (1966), "Investment in Humans, Technological Diffusion, and Economic Growth", *American Economic Review*, Papers and Proceedings, Vol. 56(2), pp. 69-75.

Pritchett, L. (2000), "Understanding the Patterns of Economic Growth: Searching for Hills among Plateaus, Mountains, and Plains", *The World Bank Economic Review*, 14(2), pp. 221-50.

Roberts, M. and J. Tybout (1996), "The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs," *American Economic Review*, Vol. 87(4), pp. 545-63.

Rodriguez, F. and D. Rodrik (1999), "Trade Policy and Economic Growth: A Skeptic's Guide to the Cross-National Evidence", forthcoming in B. Bernanke and K. Rogoff (Eds.), *NBER Macroeconomics Annual*, Cambridge: MIT Press.

Rodrik, D. (1998), "Trade Policy and Economic Performance in Sub-Saharan Africa", *EGDI Discussion Paper Series*, Swedish Ministry of Foreign Affairs, Stockholm.

Rodrik, D. (1995), "Trade and Industrial Policy Reform", in J. Behrman and T.N. Srinivasan (Eds.), *Handbook of Development Economics Vol. 3B*, Amsterdam: North-Holland.

Sala-I-Martin, X (1997), "I Just Ran Two Million Regressions", *American Economic Review Papers and Proceedings*, Vol. 87(2), pp. 178-83.

Summers, R. and A. Heston (1991), "The Penn World Table (Mark 5): an expanded set of international comparisons, 1950-88", *Quarterly Journal of Economics*, 106(2), pp. 327-68.

World Bank (1993), *The East Asian Miracle*, Oxford: Oxford University Press.

World Bank (2000), *World Development Indicators*, CD-Rom, Washington, DC: World Bank.

Table 1 Pooled cross-country regressions, average growth rates of real GDP, 1960-94

	(1)	(2)	(3)	(4)	(5)	(6)
	Total Trade	Total Trade	Exports	Exports	Imports	Imports
Constant	0.031**	0.041***	0.030**	0.037***	0.032**	0.044***
	(2.418)	(3.222)	(2.229)	(2.653)	(2.512)	(3.373)
Log Initial income	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***
	(3.557)	(3.719)	(3.550)	(3.568)	(3.663)	(3.834)
Investment	0.098***	0.107***	0.096***	0.100***	0.102***	0.118***
	(4.860)	(5.075)	(3.550)	(4.956)	(5.236)	(5.886)
Log of Openness	-0.010***	-0.011***	-0.010***	-0.011***	-0.011***	-0.011***
	(2.850)	(2.986)	(2.746)	(2.832)	(2.835)	(2.936)
Inflation	-0.010**	-0.009**	-0.009**	-0.008**	-0.010**	-0.009**
	(2.241)	(2.102)	(2.160)	(2.105)	(2.348)	(2.287)
Financial depth	0.017***	0.016***	0.016***	0.016***	0.017***	0.017***
	(2.929)	(2.979)	(2.883)	(2.879)	(2.939)	(2.997)
Human capital	0.010***	0.008***	0.010***	0.008***	0.010***	0.007***
	(4.705)	(3.167)	(4.597)	(3.430)	(4.732)	(2.781)
Human capital sq.	-0.001***	-0.000***	-0.001***	-0.001***	-0.001***	-0.000***
	(3.952)	(3.320)	(3.842)	(3.620)	(3.966)	(3.177)
Trade share	-0.000	-0.017*				
	(0.109)	(1.897)				
Export share			0.008	-0.026		
			(0.969)	(1.266)		
Import share					-0.007	-0.048***
					(0.823)	(2.938)
Trade*Human capital		0.004**				
		(2.274)				
Export*Human capital				0.007**		
				(2.108)		
Import*Human capital						0.009***
						(3.266)
N	428	428	428	428	428	428
Adjusted R^2	0.34	0.35	0.35	0.35	0.35	0.36
Joint $\beta = 0$ [a]	17.03***	16.49***	17.12***	16.38***	17.12***	16.82***
Heteroscedasticity [b]	59.82***	62.31***	60.50***	62.96***	58.26***	61.29***

Note: ***, **, and * indicate significance at 1 %, 5 %, and 10 % respectively. Absolute t-values are in parenthesis. Results for time dummy variables are not reported. Covariance-variance matrix has been adjusted for heteroscedasticity. N stands for number of observations.

[a] F test of slope parameters jointly zero, F [df]

b Breusch-Pagan test of H0: no heteroscedasticity, $\chi 2$[df].

Appendix 1

A.1. Check for Robustness

A.1.1. Using an alternative measure of human capital

In the literature, various proxies and data sources have been used to measure human capital. Examples are enrolment rates, life expectancy, and test scores, where the latter is a measure of the quality of human capital (see, for instance, Hanushek and Kimko, 2000). Of those three human capital proxies the ones most commonly used are enrolment rates and life expectancy.[20]

The human-capital measure considered as an alternative to the one used in this paper is enrolment rates. It is included to show whether results change when a flow variable is used instead of a stock variable. For estimation that includes the interaction terms, replacing attainment levels with enrolment rates has different effects depending on the trade variable considered. For total trade, the interaction parameter is 2.5 times larger as compared with attainment levels, whereas the mean enrolment rate is smaller by the same factor compared with the mean for average years of schooling. This implies a growth effect of 0.12 percentage points (7.5 per cent) of a 10-percentage point increase in total trade. However, total trade is statistically significant at the 10 per cent level, and taking that point estimate nullifies the previous results.

An increase in exports by 10 percentage points is related to an increase in growth by 0.13 percentage points (7.5 per cent). Imports are again negatively associated with growth (-0.05 percentage points or 3 per cent), while the effect of the interaction between human capital and imports is quite large (0.25 percentage points or 15 per cent). Hence, the trade-growth link is somewhat weakened when using enrolments instead of attainment levels as proxies for human capital.

A.1.2. Endogenous trade and human capital

If trade variables and interaction terms are endogenous, the estimated parameters will be upward-biased (at least in the present case where trade is assumed to affect growth

---

[20] The reason for not using the quality of human capital instead of quantity — although quality may be more appropriate as a measure of absorptive capacity — is that quality data are available only for a very limited number of countries for the time period under investigation.

positively, and growth, if anything, should have a positive impact on trade). In addition to exaggerating the strength of the trade-growth link, the significance of trade variables would be overestimated. To address potential endogeneity problems, two methods are used: First, predetermined variables (lagged variables) are used as instruments; second, a system of equations is estimated by means of 3SLS.

When predetermined variables of trade are used as instruments, the point estimates of the interaction between human capital and total trade or imports, respectively, drop slightly in magnitude, but are still statistically significant. An increase in total trade by 10 percentage points is negatively associated with growth (-0.04 percentage points or minus two per cent), and significance of the corresponding parameter drops to the 10 per cent level. For countries rich in human capital the growth effect is 12 percentage points (6.3 per cent). A zero total effect is obtained for exports and growth because the exports parameter is statistically significant with a negative sign. Again, for countries rich in human capital the growth effect of exports is 37 percentage points (near 20 per cent). In the case of imports, both the parameter for imports and that for the interaction between imports and human capital are statistically insignificant. Finally, with lagged human capital as an instrument there is no effect on the trade-growth link. These results are hard to explain and may point to some problems associated with lagged instruments.[21]

In the exercise of 3SLS estimation, trade and human capital alongside with growth were allowed to be endogenous. Estimations were carried out in steps: In the first step only one additional variable is assumed to be endogenous; thereafter, all three variables are.[22]

Only the overall 3SLS relating to trade and human capital are presented here.[23] Treating total trade, exports and imports as endogenous variables has the same qualitative effect as shown in Table 1. The association with growth, however, tends to

---

[21] All countries with data for less than all seven periods were deleted. This reduced the number of observations to 331 (compared with the full sample 428), but the results obtained with the full sample hold well also under this restriction. It may be the reduction in the number of observations rather than the correction for endogeneity that causes trade parameters to decrease in magnitude.

[22] A drawback with the exercise is that no other variables, except those already used as explanatory variables, are allowed to enter the system. It is easy to think of additional variables explaining human capital and trade — an issue, however, for another paper.

[23] The results in full can be obtained from the author upon request.

weaken slightly. For total trade, there is hardly any effect on growth of a 10-percentage point increase. As regards exports, the effect is the same as before (0.3 percentage points or 18 per cent), while for imports the negative total effect on growth is larger (-0.15 percentage points or -9 per cent). The effect of the interaction between imports and human capital is slightly stronger (0.38 percentage points or 22 per cent). The growth parameter is not statistically significant in the total trade equation. It is so, however, in the exports and imports equations with a positive and negative sign, respectively.

There are three effects of allowing human capital to be endogenous. First, growth is statistically significant in the human capital equation (as argued in Bils and Klenow, 2000). Second, while a weaker growth effect of human capital may be expected due to endogeneity, a slightly stronger effect is obtained instead. Third, the negative total effect of imports on growth is somewhat mitigated, while the effect upon countries rich in human capital is the same as before. Finally, estimating a system of three equations in which trade and human capital are determined endogenously has the same effect as allowing only human capital to be endogenous.

In summary, the conclusions on the trade-growth link are not changed substantially when adjusting for an endogeneity bias. Endogeneity in human capital, on the other hand, results in a stronger human-capital effect on growth. Predetermined trade variables operating as instruments strengthen the trade-growth association.

A.1.3. Non-Linearity in the data

Does trade enter the regressions in a non-linear fashion? Do interaction terms simply capture non-linearity in the data? These are the questions posed in this section.

At first, squared terms were included not only for human capital, but also for trade. The purpose of this was to check whether the interaction terms between human capital and trade simply pick up non-linearity in the data. If so, the message the interaction terms conveys would be different from the objective of the paper. As regards human capital, there was also a theoretical purpose, although *a priori* it was not clear whether returns to education would be increasing or decreasing.[24] Moreover,

[24] It may be the case that the social returns to education are higher for higher education, since higher education is more closely related to R & D activities. On the other hand, there is a trade off between R

Krueger and Lindahl (1999) show that the squared human capital term is statistically significant.

To start with, squared total trade did not enter the specification with a statistically significant parameter, and it had no effect on the parameters for the interaction term or for total trade. The inclusion of squared exports and imports does have significant repercussions. In the case of exports, the parameter for the interaction term is statistically significant only at the 12 per cent level. Thus, at a first glance, it seems that the interaction between human capital and exports may only capture non-linearity in the data. However, a 10-percentage point increase in exports yields an implausibly strong association with growth so that no further interpretation can be ventured. Finally, the parameter for squared imports is statistically insignificant and renders the parameter for imports statistically insignificant as well. A 10-percentage point increase in imports has a positive association with growth (0.38 percentage points or 22 per cent), an effect that is entirely due to interaction with human capital.

A.1.4. Fixed Effects Estimation

As has been argued earlier in this paper, there are strong objections against using a fixed-effects estimator. Nevertheless, in order to control for unobserved country-specific effects — if that is what should be done — the regressions were re-run to account for fixed effects and hence, wiping out all between-country variation. The consequences of using a fixed-effects estimator are often quite "dramatic" with respect to parameter magnitudes, signs, and statistical significance. This is also the case here.

Two large and, from a theoretical viewpoint, unfortunate shifts of signs and statistical significance occur. First, only the interaction between total trade and human capital survives the "test", whereas the parameters for other interaction terms turn statistically insignificant. In fact, imports are not at all statistically significant anymore, which could be a sign that import variation between countries is more important than variation within countries when it comes to explaining inter-country differences of growth. In contrast, two results are much stronger than before: the

---

& D and production and too much of the first may retard growth of the second (see, for instance, the discussion in Aghion and Howitt, 1998).

parameter for total trade is statistically insignificant, which means that a 10-percentage point increase in total trade is entirely due to the interaction term producing a strong association with growth (0.33 percentage points or 19 per cent); in the case of exports the interaction term is no longer statistically significant, while the exports parameter is. A 10-percentage point increase in the export share is associated with a full percentage point increase in growth (56 per cent).

Second, human capital now enters with a negative sign, while the squared human capital term enters positively. In the total trade specification, the effect of a year's increase in human capital decreases to 0.06 percentage points (3 per cent), while for the models with exports and imports the effect is slightly negative, -0.13 (-7.8 per cent) and –0.14 percentage points (–8.1 per cent), respectively.

Another result worth noting here is that implied convergence increases to 2.5 per cent. This matches with the estimate of the speed of convergence normally obtained from studies using pooled regressions, but is still lower than that usually obtained from fixed-effects estimations. The importance of investment increases by at most around 30 per cent to a point estimate of between 0.15 and 0.17 depending on the trade variable used. Trade openness turns statistically insignificant in all models, the negative effect on growth from inflation is somewhat strengthened, and the parameter of financial depth both changes its sign and turns statistically insignificant.

Appendix 2

Table A1: Countries included in the sample (73 countries).

Argentina	Iran	Sudan
Australia	Israel	Sweden
Austria	Italy	Switzerland
Belgium	Jamaica	Syria
Bolivia	Japan	Togo
Brazil	Kenya	Thailand
Cameroon	Mexico	Trinidad and Tobago
Canada	Korea	Venezuela
Central African Republic	Lesotho	Uruguay
Chile	Malta	USA
Colombia	Malawi	Zimbabwe
Congo	Malaysia	
Costa Rica	Mauritius	
Cyprus	Nepal	
Dem Rep. of Congo	Netherlands	
Denmark	New Zeeland	
Dominican Republic	Nicaragua	
Ecuador	Niger	
Egypt	Norway	
Finland	Pakistan	
France	Papua New Guinea	
Gambia, The	Paraguay	
Ghana	Peru	
Great Britain	Philippines	
Greece	Portugal	
Guatemala	Rwanda	
Haiti	Senegal	
Honduras	Slovakia	
India	South Africa	
Indonesia	Spain	
Ireland	Sri Lanka	

Appendix 3

Definition and Sources of Variables

All variables are taken from Barro and Lee (2000), Levine, Loayza, and Beck (2000), World Bank (2000), and Summers-Heston (1991) as indicated by (BL), (LLB), (WB), or (SH) in the third column. The definitions are according to the second column.

Table A2: Definition and Sources of Variables.

Variable name	Definition	Source
Real per capita growth	-----	LLB
Initial income	Log of GDP per capita 1960	SH
Investment rate	Gross fixed capital formation / GDP	WB
Black exchange rate premium	Log of the ratio of black market exchange rate and official exchange rate minus one	LLB
Inflation	Average annual inflation	LLB
Financial depth	Liquid liabilities / GDP	WB
Trade share	(Exports + Imports) / GDP	WB
Export share	Exports / GDP	WB
Import share	Imports / GDP	WB
Human capital1	Enrolment into secondary schooling	BL
Human capital2	Average years of schooling for population aged 15+	BL
Interaction Human * Trade	Human Capital1*Trade share	BL, WB
Interaction Human * Exports	Human Capital1*Exports share	BL, WB
Interaction Human * Imports	Human Capital1*Imports share	BL, WB