Are Imports from Rich Nations Deskilling Emerging Economies? Human Capital and the Dynamic Effects of Trade

Raphael Auer

The views expressed in this paper are those of the author(s) and do not necessarily represent those of the Swiss National Bank. Working Papers describe research in progress. Their aim is to elicit comments and to further debate.

Are Imports from Rich Nations Deskilling Emerging Economies?
- Human Capital and the Dynamic Effects of Trade[*]

Raphael Auer[†]

October 13, 2010

Abstract

This paper starts by documenting that during the last decades, the human capital embodied in imports from skill abundant nations has noticeably reduced skill accumulation in the less developed world. To identify the causal relation between these variables, the analysis utilizes over-time variation in the supply of skilled labor and the extent to which this variation affects the skill content of trade given the bilateral distance between im- and exporter. In a panel estimation covering 41 non-OCED members, a one standard deviation higher geographic pressure to import human capital is associated with a 12% reduction in the national average length of schooling. The paper next develops a model to analyze the income and welfare consequences of such trade-induced human capital disaccumulation. The model is based on heterogeneous workers who make educational decisions in the presence of complete markets. When heterogeneous workers invest in schooling, high type agents earn a surplus from their investment. Trade shifts this surplus to rich countries that can use skills more efficiently. Consequently, the dynamic effects of liberalization tend to occur to initially rich countries, thus leading to divergence.

1 Introduction

Among economists and policymakers alike, there is agreement that import competition from low-wage countries has caused a decline in the relative wage of unskilled workers in rich nations.[1] Much less discussed is the flipside of this argument, namely that trade with richer nations tends to depress the relative wage of skilled workers in less developed countries.

A straightforward implication of this factor price equalization is that trade reduces the incentives to invest in human capital in less developed countries; i.e. trade with rich nations essentially "deskills" emerging economies.[2] How relevant is this argument empirically and are there important welfare implications that policy makers should consider?

The first part of this paper aims to quantify the causal effect of trade on human capital investment decisions. I combine insights from the literature analyzing the factor content of trade with the methodology developed by Frankel and Romer (1999), who isolate the geographic component of trade to establish a causal relation between trade and growth. In particular, I isolate the geographic component of imported skills, i.e. the human capital content other countries are likely to export to a given nation conditional on its geographic location.

To address potential concerns with the Frankel and Romer methodology brought forward by Rodrick et al. (2004) and Dollar and Kray (2003), I use panel estimations that control for country-charachteristics and also over time variation in general geographic openness to trade; the empirical specifications thus exploit variation in how some countries tend to be relatively – compared to their relative openness to all other goods – closer to supply of skilled labor and in how this relative proximity to skilled labor varies throughout time.

It is shown that geographic proximity to skilled labor has both statistically and economically significant effects on domestic education decisions. For example, comparing two otherwise identical nations, a one-standard deviation difference in geographic proximity to skilled labor is associated with a 12% reduction in the national average length of schooling and a 15% reduction in the national average length of higher education.

The second part of the paper analyzes the welfare and income consequences of trade-induced (dis-)accumulation of human capital in a model featuring within-country worker heterogeneity and across-country differences in the relative productivity of human capital.

The first assumption of the model is that workers are heterogeneous in their relative ability to provide skilled versus unskilled labor. Such worker heterogeneity has recently been shown to

---

[1] See the recent discussion in Krugman (2008), who reconsiders his earlier verdicts that such effects are negligible. Bernard et al. (2006) quantify the effect of low wage import competition on employment, while Auer and Fischer (2010) and Auer et al. (2010) estimate the price dynamics in sectors that are subject to a high degree of low-wage import competition.

[2] The literature has extensively analyzed the case of trade-induced accumulation of physical capital, see foremost Baldwin (1992). Stiglitz (1970) has used the factor price equalization insight to argue that complete specialization is indeed unavoidable in a dynamic context. Ventura (1997) and Atkeson and Kehoe (2007), in turn, argue that differences in factor abundance may be large (or even persist eternally) in an open world if countries specialize into sectors with varying factor intensities.

have important implications for within-country inequality and unemployment (see Helpman et al. (2010a and b) and Helpman and Itskhoki (2010)). Here, I document that such within-country heterogeneity also has important implications for the world distribution of income and welfare, i.e. for across-country heterogeneity. The second assumption of the model is that countries differ in their level of human capital augmenting technology. The latter assumption is based on the findings of Caselli and Coleman (2006), who provide evidence that while the productivity of unskilled labor is similar across the world, there are huge differences in the efficiency with which different nations use skilled labor.[3]

Together, these two assumptions imply that liberalization is associated with divergence of the world distribution of income because it shifts educational investment to already skill abundant (and thus rich) nations. At the moment of trade liberalization, educational investment diverges. Since educational investments take the form of forgone earnings, the dynamic path of income is first characterized by a phase of convergence during which poor countries send a smaller fraction of young workers to the educational sector,[4] while their older cohorts are still relatively skilled. Richer countries start sending a larger fraction of young workers into schooling, while their supply of skilled labor is stable for a while. The resulting medium term response of income to liberalization thus displays absolute convergence of income levels. This pattern prevails until the first cohort of workers who started schooling at the moment of opening markets to trade enters the labor force. From then on, earlier changes in educational investment start to pay off and the GDP of rich countries increases, while the opposite is true in poor countries. The resulting long term dispersion of income is larger than at the moment of opening to trade.

The model also shows that due to the underlying worker heterogeneity, the dynamic gains from trade may favor already rich nations: when heterogeneous workers invest in schooling, higher type workers make a surplus from their investment. A trade-induced higher relative wage increases the expected lifetime income for the workers who already would have chosen schooling in the autarky economy. In addition, an increase in the relative wage induces more entry into the skilled labor force. In total, the net return from education – taking into consideration the opportunity cost of forgone unskilled labor – responds more than proportionally to changes in the relative wage. Skill scarce nations, in contrast, have their comparative advantage in labor, a factor that is in fixed supply and cannot be accumulated. Thus, trade may create divergence of welfare since richer nations gain proportionally the most from liberalization.[5]

---

[3]In fact, Caselli and Coleman even argue that such differences in human capital augmenting technology can account for a substantial part of the variation in the world income distribution.

[4]The mechanism at work is similar to the one in Galor and Mountford (2006), who - in a Malthusian setting - analyze how trade can influence population growth and therefore result in an less educated workforce in initially poor countries.

[5]It is noteworthy that the model does not feature any externalities such as monopolistic competition or matching imperfections in the labor market. Rather, it is the nature of the worker heterogeneity itself that causes the gains from trade to be distributed asymmetrically across rich and poor countries. This documents an important difference in the welfare effects of human as opposed to physical capital accumulation. Baldwin (1992) establishes that trade-induced capital accumulation has no welfare consequences in the absence of externalities. His main insight is simple:

The last part of the model evaluates the general equilibrium response of simultaneously opening many countries to trade. In the model, since trade equates good prices across the world, the dynamic response of education decisions tends to concentrate human capital in countries that can use skills efficiently. With open markets, the typical skilled worker thus works in a country with a higher level of human capital augmenting technology than in the closed economy. Thus, trade increases the relative output of skill intensive goods, i.e. trade liberalization creates skill bias.

The structure of the paper is as follows. Section 2 presents the empirical analysis. Section 3 describes a model featuring heterogeneous and finitely lived workers investing in their human capital. Section 4 characterizes the resulting autarky equilibrium. Section 5 establishes the path of income as well as the welfare effects of opening a small economy to trade. Section 6 endogenizes world prices and establishes the skill bias of world trade. Section 7 concludes.

2 Empirical Evidence

This section presents evidence that the skill content of imports has sizeable effects on domestic education decisions and human capital levels. The methodology I propose has two steps. In the first step, I isolate the geographic component of the factor content of trade. The variable - termed "geographic proximity to skilled labor" is obtained by running gravity style regressions on the factor content of imports and then isolating the geographical component of the skill content of imports in a way following Frankel and Romer (1999). Doing so, I tackle the following problem: even in a static world with fixed supply of skilled and unskilled labor, any measure of the factor content of trade would be correlated with domestic education levels. To deal with this endogeneity, I only use the information of a country's geographic proximity to international supply of skilled and unskilled labor to instrument for the observed factor content of trade. In this way, I isolate the component of international trade that is not stemming from domestic supply and demand, but exclusively from the factor supply of other nations.

Frankel and Romer construct measures of how much other nations are likely to export to a given nation conditional on the geographic bilateral distance to establish a causal relation between trade and growth. Similarly, the measures constructed in this paper reflect how much skilled labor content other countries are likely to export to a given nation. I subsequently test whether this measure of geographic proximity to skilled and unskilled labor has significant effects on domestic education decisions and the stock of human capital.

In the second step, I use the constructed measures of "geographic proximity to skilled labor" to identify whether trade affects human capital decisions. The strategy I adopt tackles two key critiques. A first potential problem is that the geographic instrument for trade is collinear with

---

since the marginal cost of accumulating capital is constant and in equilibrium, the return to capital equals the cost of accumulation, investors do not record a net gain from the additional accumulated capital (as the envelope theorem would predict). The latter is different for the case of human capital accumulation, since the education decision is private and some workers may well earn a net surplus from their educational investment.

country-specific determinants of development such as institutional quality (see, in particular the critiques by Rodrick et al. (2004) and Dollar and Kray (2003)). This issue is tackled following the methodology of Dollar and Kray (2003): I do not rely on the cross-sectional information as in Frankel and Romer's original analysis, but rather use the time-series variation. A second problem is that countries that are close to supply of skilled labor also tend to be geographically open to trade in general. I thus also include a country's general level of geographic openness to trade – again varying over time – in all specifications. Overall, the strategy thus exploits variation in how some countries tend to be relatively – compared to their relative openness to all goods – closer to supply of skilled labor and in how this relative proximity to skilled labor varies throughout time.

In a panel spanning the years 1972 to 1992 in 41 non-OECD nations, I find that proximity to skilled labor has a detrimental effect on domestic human capital accumulation. For example, I find that a one standard deviation difference in geographic proximity to skilled labor is associated with a roughly 12% difference in overall education.

2.1 Factor Supply and Bilateral Trade: Constructing the Instrument

In a first step, I use bilateral trade flow data from Feenstra et al. (1997) and the US productivity matrix (obtained from Antweiler and Trefler (2002)) to translate 3-digit industry level trade flows into the net factor content of trade. I then use factor endowment data from Antweiler and Trefler to relate domestic factor endowments to the factor content of trade. The data of Antweiler and Trefler is available for 5 periods (1972, 77, 82, 87, and 92) and 63 countries.

Let $i \, \epsilon \, I$ index importing countries and let $o \, \epsilon \, I - 1$ index countries of origin, let $f \, \epsilon \, F$ index factors and let $j \, \epsilon \, J$ index industries. Let V be the (I, F) matrix summarizing international factor endowments, so that $V_{i,f}$ denotes the endowment of factor f in country i. Let A^* be the (F, J) unit requirement matrix that is common to all countries once factor augmenting productivity differences are taken into account.[6] Finally, let $M_{i,o}$ be the (J) vector of good imports from country o to country i. A country's imports can be converted into the factor content by applying the unit requirement matrix. I denote the factor content of bilateral imports from country o to country i by $FCT_{i,o}$, which is given by

$$FCT_{i,o} = A^* \times M_{i,o} \tag{1}$$

Testing the original Hecksher-Ohlin-Vaneck (HOV) hypothesis would boil down to testing whether the net vector of the factor content of trade (i.e. imports to country i minus exports from country i) equals the national endowment minus a constant share s_i of world endowment for each factor.

---

[6]Antweiler and Trefler (2002) also allow for country-specific factor augmenting productivity differences, obtained from factor prices. However, lack of precise wage data leads them to uniformly adjust for all types of labor rather than for skilled and unskilled worker productivity separately. The fit of my model that focuses on *relative* levels of factor supply is therefore not affected by their adjustments.

$$\sum_{o\epsilon I-1} FCT_{i,o} - \sum_{i\epsilon I-1} FCT_{o,i} = V_i - s_i \sum_{i\epsilon I} V_i \quad (2)$$

This pure HOV prediction has received mixed support in the theory (albeit some when adjusting for factor augmenting technology, see Trefler (1995)). Research has, however, been more successful in showing that bilateral trade flows follow the direction implied by Hecksher Ohlin trade theory quite closely. This arguably weaker prediction receives strong support in several studies (see Debaere (2003) and Choi and Krishna (2004)) and it also has received a theoretical underpinning by Romalis (2004).

Romalis establishes that the predictions of HOV theory hold qualitatively in the context of Krugman's (1980) model of monopolistic competition and transport costs. The tests of the bilateral factor content of trade and the findings of Romalis are the starting point for the empirical section of this paper: rather than testing (2), I relate the factor content of bilateral trade (1) to the relative abundance of factors at home and abroad. The weakest test is whether the relative supply of skills at home and abroad affects the relative factor content of imports. Table 1 tests the following relation:

$$\frac{FCT_{i,o,skilled}}{FCT_{i,o,skilled} + FCT_{i,o,unskilled}} = \alpha + \beta_1 \frac{V_{i,skilled}}{V_{i,skilled} + V_{i,unskilled}} + \beta_2 \frac{V_{o,skilled}}{V_{o,skilled} + V_{o,unskilled}} + \varepsilon_{i,o} \quad (3)$$

Where $FCT_{i,o,skilled}$ and $FCT_{i,o,unskilled}$ measure the skilled and unskilled labor content of trade, while $V_{i,skilled}$ and $V_{o,unskilled}$ measure the abundance of these two factors in the importing and exporting nation.

Column (1) of Table 1 estimates equation (3) with β_2 restricted to 0, i.e. only considering the relative supply of skilled labor in the exporting country. The coefficient is significantly positive, implying that more skill abundant countries tend to export more skill intensive goods and hence have a larger relative skilled factor content of exports compared to the unskilled factor content of trade. The coefficient equals 0.051, implying that raising a country's fraction of skilled workers by 10 percentage points increases the skill intensity of its export by 0.51 percentage points.

Column (2) instead restricts β_1 to equal 0, i.e. it only estimates the effect of domestic skill supply on the composition of imports. Countries that are more skill abundant, on average, tend to import relatively fewer skill intensive goods and hence have a lower relative import skill labor content. The coefficient is equal to -0.036 implying that raising a country's fraction of skilled workers by 10 percentage points decreases the skill intensity of its imports by 0.36 percentage points. Column (3) confirms these patterns when both foreign's and home's skill abundance are included: countries that are skill abundant import less skill intensive goods and export more skill intensive goods. These patterns are again confirmed when using a different definition of the skill intensity of imports, namely the ratio of the population with at least some secondary education

in Columns (4) to (6).

Relative endowment differences have significant effects on the relative factor content of imports and exports. I next nest this finding in an otherwise standard gravity framework to predict the skill of trade and isolate its geographic component. The specifications in Table 2 relate the factor content of bilateral imports to geographical distance, country size (measured by population or factor abundance). With the Frankel and Romer (1999) identification strategy in mind, I do not include any information on the importing nation other than its population size in the regression.

I next present gravity-style estimations that relate importer information, exporter information, and bilateral distance to the bilateral factor content of trade:

$$FCT_{i,o,skilled} = EXP\left[\alpha + \gamma_1 Log\left(dist_{i,o}\right) + \gamma_2 Log\left(POP_i\right) + \gamma_3 Log\left(V_{o,skilled}\right) + \overline{\varepsilon}_{i,o}\right] \quad (4)$$

Table 2 describes the results from estimating these gravity-style equations Poisson specifications[7] of the form of Equation (4). In columns (1) to (4) the dependent variable is the skilled labor content of trade measured in number of workers with finished high school education. Column (1) estimates model (4) using trade and endowment data from 1992. The independent variables include distance, the logarithm of the population in the exporting and the importing country, and the relative skill abundance in the exporting nation. A country that has a 1% more skilled labor force (keeping the population constant) on average exports 3.25% more skilled labor content. As expected, distance between two nations decreases trade flows and therefore also the embodied factor content. Secondly, the size of the importing market, as captured by the population in the importing nation increases trade volume, but with an elasticity of less than 1, implying that bigger nations tend to trade less in percentage terms of their GDP.

In the remainder of Table 2, instead of looking at the exporter skill supply in relative terms, I add the logarithm of the total supply of skilled labor, again measured in the number of workers with finished high school education. The coefficient is estimated at 0.76, implying that a 1% higher supply of skilled labor in the exporting country is associated with a 0.76% higher skilled labor content of trade (the elasticity is smaller than 1 since larger countries trade less on average).

When constructing the measure of proximity to skills below, I run gravity equation such as the one presented in Column (2) separately for each of the five time periods. Against this backdrop, it is interesting to see whether the nature of how distance has shaped trade flows has changed of time. Column (3) repeats the specification of Column (2) for the year 1972 instead of 1992. The distance coefficient is again estimated at 0.655 and also the other coefficients remain remarkably stable throughout time. Thus, the over time variation in the measures constructed below derives from the over time variation of skill supply in different regions of the world rather than variation in how geography affects trade flows.

There may be other reasons in addition to the supply of skills that lead certain countries

---

[7] I use the estimation command suggested by Silva and Tenreyro (2006). The results presented below are robust to using alternative specifications of the gravity estimation such as the ones of Helpman et al. (2006).

to export more or less skilled labor, most notably the skill supply of countries neighboring the exporter (which could be termed "multilateral resistance to skilled labor " following Anderson and van Wincoop (2003)). Column (4) thus adds exporter fixed effects. Since the estimation is for 1992 only, the variable foreign supply of skilled workers drops out of the specification. The coefficient of distance and the coefficient of home's population remain relatively unchanged.

Specifications (5) and (6) use a different variable to measure the skill supply in Foreign. In (5), the skilled labor content of trade is measured by the number of workers with at least some secondary education in the exporting nation. The dependent variable in this specification is the logarithm of the supply of workers with at least some secondary education. In (6) the skilled labor content of trade is measured by the number of workers with at least some tertiary education and the dependent variable is the number of workers with at least some tertiary education in the exporting nation. Finally, in the last two specifications of Table 1, I document that the proposed methodology can also predict the capital and land content of trade.

In accordance with the results of David and Weinstein (2001), factor endowments correlate strongly and in the right order of magnitude (elasticities estimated below 1, but not by much) with the observed factor content of trade. I now predict equation (4) of Table 2 with exporter fixed effects to end up with a variable $GFCT\_skilled$, where $GFCT$ stands for the "Geographic Factor Content of Trade" and $skilled$ measures the number of worker with finished high school or equivalent. $GFCT\_skilled$ thus corresponds to a country's geographical proximity to skilled labor. For example, a value of 0.01 means that given the geographic location of this country, on average the skilled worker content of trade is equal to 0.01 per head of the population.

In similar fashion, I predict $GFCT\_unskilled$, the geographic element of the no-highschool workers content of trade, $GFCT\_PTA$ the geographic element of the "at least some primary education"-worker content of trade, $GFCT\_STA$ the geographic element of the "at least some secondary education"-workers content of trade, $GFCT\_NEA$ the geographic element of the no-education workers content of trade, $GFCT\_TTA$ the geographic element of "at least some tertiary"-workers content of trade, $GFCT\_KAP$ the geographic element of capital content of trade, $GFCT\_LND$ the geographic element of the land content of trade. It is noteworthy that for each of these variables, I run and predict a separate specification for each of the 5 time periods, hence resulting in time varying measures.

I standardize all resulting measures so that the coefficients below can easily be interpreted. I end up with estimates for 63 countries (of which 41 are non-OCED members) that are listed in Table 6 of Appendix C.

2.2   Imported Human Capital and Domestic Education

I next use the constructed measures of "geographic proximity to skilled labor" to identify whether trade affects human capital decisions. These variables are estimated for each of the 5 time periods separately, thus allowing to analyze the over time variation of the instrument.

The structure of Table 3 is the following. Columns (1) to (4) serve to highlight the methodology used to identify the causal effect of imported skills on domestic education. Column (5) then presents the main specification. To make sure that none of the results are driven by the underlying upward trends of both trade and education, all specifications include a trend.

Column (1) in Table 3 displays a random effects model with 41 non-OECD countries and 5 5-year intervals from 1972 to 1992. The only regressor is $GFCT\_skilled$, the geographic skill content of trade measured by workers with finished high school education or equivalent. The dependent variable is the logarithm of total average years of education in the workforce over 15 years of age. The coefficient is estimated at -0.08 and is statistically highly significant. It is also economically very large: a one standard deviation difference in geographic proximity to skilled labor is associated with a 8% difference in education levels.

A potential problem with the specification in Column (1) is that countries close to supply of skilled labor also tend to be geographically open to trade in general. Column (2) thus adds a country's general level of geographic openness to trade – taken from Frankel and Romer – to the estimation. While the effect of geographic openness on education itself is positive, the effect of proximity to skilled workers is negative, with the coefficient now even being estimated at -0.1.

A second potential problem is tackled in Columns (3) and (4): the geographic measure for trade constructed in the section above is collinear with other country-specific determinants of development such as institutional quality (see, in particular the critiques by Rodrick et al. (2004) and by Dollar and Kray (2003)). Column (3) thus adds settler mortality from Acemoglu et al. (2001) and legal origin dummies (from La Porta et al. (1998), coefficients not displayed) to control for the historical determinants of institutions. Addition of these controls does not seem to affect the coefficients by much, but there might be potentially other country-specific determinants of development that are collinear with $GFCT\_skilled$. To address all such concerns, Column (4) follows the methodology of Dollar and Kray (2003) and adds country-fixed effects. The specification thus does not rely on the cross-sectional information as in Frankel and Romer's original analysis, but rather, the time-series variation.

Dollar and Kray (2003) construct a time-varying version of the Frankel and Romer instrument for trade. To address the concern that the over time variation of $GFCT\_skilled$ might be collinear with the time-varying general openness to trade, I thus also include a time-varying measure of geographic openness to trade in addition to the time-varying measure of geographic proximity to skilled labor.

The resulting main specification in Column (5) thus includes a trend and fixed effects, and two time-varying measures of geographic openness (in general to trade and to importing skilled labor). Overall, Column 5 thus exploits variation in how some countries tend – compared to their relative openness to all goods – be relatively close to supply of skilled labor and how this relative proximity to skilled labor varies throughout time.

I find that the coefficients of proximity to skilled labor is statistically highly significant and is

also very large in economic terms: holding country, time, and general openness to trade constant, a one-standard deviation difference in geographic proximity to skilled labor is associated with a 12% difference in education levels. This is economically very sizeable and also comparable to the effect of geographic openness itself (positive coefficient 0.191, also this variable is standardized).

Columns (6) and (7) further investigate the time dimension of proximity to skills and domestic education: human capital decisions tend to be made at the beginning of one's life, and geographic proximity to skilled labor should thus have a slow but long-lasting effect on human capital levels. Column (6) adds the 5 year lag of proximity to skilled workers to the specification, which also affects the level of education, but to a weaker extent. Column (7) relates 5-year changes in $GFCT\_skilled$ to 5-year changes in a country's average education levels. The order of economic magnitude is comparable to the level regressions: a change of proximity to skills by one standard deviation is associated with a 10% change in the rate of skill accumulation.

Table 3 documents that being geographically close to countries with a high high school completion rate decreases overall education in the importing country. I next investigate which type of education is affected the most by such proximity and also, if different types of education react differently to different types of imported skills.

Columns (1) and (2) of Table 4 reproduce the main specification of Column 5 in Table 3 for two alternative dependent variables. Both estimations include country fixed effects, a trend, and time-varying measures of general trade openness as well as of proximity to workers with finished high school ($GFCT\_skilled$). In specification (1), the dependent variable is the logarithm of average years of *primary education* in the workforce. In specification (2), the dependent variable is the logarithm of average years of *higher (secondary plus tertiary) education* in the workforce. While the effect of $GFCT\_skilled$ is significant for both types of education, the coefficient is larger for advanced education: a one-standard deviation difference in proximity to skilled labor is associated with a 15% reduction of advanced education, but only a 10% reduction in primary education.

Columns (3) and (4) evaluate the flip side of the results presented above: does proximity to *unskilled labor* increase domestic education? The dependent variables are again the logarithm of primary (in Column (3)) and the logarithm of higher education (in Column (4)). Both primary education and higher education significantly increase if a country is closer to supply of unskilled labor. Again, I find that this relation is more pronounced for advanced education than for primary education.

Columns (5) and (6) estimate the response to proximity of *highly skilled workers*. A highly skilled worker is defined as having either at least some secondary or at least some tertiary education. Also for this independent variable, I find that both primary education and higher education are negatively affected by proximity to highly skilled workers, with the effect being stronger for higher education.

3 A Model of Heterogenous Workers

I next develop a model analyzing the welfare effects of trade-induced human capital accumulation. The framework of this paper draws on the insights of Findlay and Kierzkowski (1983), who propose a general equilibrium model of human capital accumulation in the presence of international trade. I depart from their model with two key assumptions. In my framework, countries are characterized by exogenously given differences of the efficiency of human capital (for empirical evidence see Caselli and Coleman (2005) and also Trefler (1995)).

A second departure from Findlay and Kierzkowski (1983) is that I assume that, while workers are homogenous in how well they can provide unskilled labor, they differ in how well they can supply skilled labor if they chose to get an education. In the resulting equilibrium of the economy, low type workers do not accumulate skills. Higher type workers do, and while there may exist a cut-off type that is indifferent between getting an education or not, all other skilled workers earn a surplus from education. Trade induced changes in relative wages affect this surplus in a way that favors already rich and developed nations, leading to divergence of welfare.[8]

3.1 Preferences, Production Relations and Demography

This section describes the economic environment. The model is formulated in continuous time, which is indexed by t ($t \geq 0$). The world economy consists of many small countries that are indexed by i. Each country i has mass 1 of identically and infinitely lived households. Each household is composed of a mass of heterogeneous and finitely lived workers. I describe the formation of skills below. Households make the education decisions for workers and have stable preferences over consumption that are additive, time separable, and exhibit a constant rate of time preference.

$$V(t,i) = \int_t^\infty U(C_{\tau,i}) e^{-\delta(\tau-t)} d\tau \tag{5}$$

I assume that U is strictly increasing, strictly concave and twice continuously differentiable, with $U'(0) = \infty$. Infinite marginal utility at $C_{\tau,i} = 0$ is assumed for convenience so that the economy is never on a path where investment is equal to zero for all times. A standard budget constraint applies, which restricts the net present cost of the path of consumption being at most as big as the net present value of future income. Let $Y_{i,t}$ denote a country's production. The budget constraint of the representative household is hence given by

$$\int_t^\infty C_{\tau,i} e^{-\int_t^\tau r_\nu d\nu} d\tau \leq \int_t^\infty Y_{i,\tau} e^{-\int_t^\tau r_\nu d\nu} d\tau + B_{i,t} \tag{6}$$

---

[8]This characteristic of the model is what makes human capital different from physical capital. Baldwin (1992) discusses the dynamic gains from trade when physical capital is accumulated endogenously. He concludes that in the absence of externalities, trade induced accumulation has no welfare consequences.

The interest rate r_t is not country specific, i.e. well developed global capital markets exist. $B_{t,i}$ denotes the net asset position of country i.[9]

Final output Y is defined over a constant elasticity of substitution (CES) aggregate of a skill intensive and a labor intensive good. Denoting the amount of the labor intensive intermediate good used in production by $X_{l,i}$ and the amount of the human capital intensive good by $X_{h,i}$, final output in country i is given by[10]

$$Y_i = \left(X_{l,i}^{\beta} + X_{h,i}^{\beta} \right)^{\frac{1}{\beta}} \tag{7}$$

The final good is produced competitively. The elasticity of substitution between the two intermediate goods is constant and equal to $(1-\beta)^{-1}$. Throughout the analysis, I assume that the intermediate goods are gross substitutes.

Assumption 1. $0 < \beta < 1$

Assumption 1 implies that price effects are not very strong so that in equilibrium, a human capital abundant economy is characterized by a low price of skill intensive goods but still larger total expenditures on skill intensive goods than in a labor abundant economy. Autor et al. (1998) have estimated the elasticity between skilled and unskilled labor directly. They conclude that it is unlikely to fall outside the interval $[1, 2]$, which in this model corresponds to $0 < \beta < 0.5$. I denote the prices of the two intermediate goods in country i by $p_{l,i}$ and $p_{h,i}$. Normalizing the price of the final good to unity implies $p_{h,i}^{-\frac{\beta}{1-\beta}} + p_{l,i}^{-\frac{\beta}{1-\beta}} = 1$, i.e. the relative price differs across countries when there is no international trade.

The two intermediate goods are produced from two factors, human capital and "raw" unskilled labor. Human capital H_i can be used to produce the skill intensive good using a linear transformation technology. Labor L_i can be used to produce the labor intensive good using a linear transformation technology. I sometimes refer to these two goods as the skill intensive sector and the labor intensive sector respectively. While raw labor can be used equally efficiently in all countries, I assume that the effectiveness of human capital depends on some exogenously given, country-specific parameter A_i that is stable over time.[11]

I denote the output of the skill intensive good in country i by $Y_{h,i}$ and the output of the labor intensive good by $Y_{l,i}$.

$$Y_{l,i} = L_i \quad \text{and} \quad Y_{h,i} = A_i H_i \tag{8}$$

The two intermediate goods are produced competitively. There are no factors of production other than human capital and labor. Equation (8) incorporates the simplification that production in

---

[9]This implies that final output can always be traded so that countries can borrow, lend, and repay to each other.

[10]For simplicity, (7) omits the distribution parameters normally present in the CES production function.

[11]These cross-country differences in A_i can be seen as stemming from differences in the institutional setup of a country, see Caselli and Coleman (2005). Appendix B endogenizes the level of technology.

each sector requires either only unskilled labor or only human capital. A generalization of the model at hand with both goods requiring both factors but at different intensities would not change the results as long as countries have similar enough factor supplies such that factor price equalization holds in the open economy equilibrium.

I now turn to the supply of skilled and unskilled labor. Each household consists of a mass of heterogeneous and finitely lived workers. Per household and unit of time, a mass of δ workers is born. Young workers are of type θ and can spend time educating themselves. If they choose to get an education, they enter the labor force after a fixed period of time T and start supplying one unit of unskilled labor and θ units of skilled labor. Workers that do not get an education supply one unit of unskilled labor from their moment of birth. For each type θ and at each moment of time, households decide whether the worker does get an education or not. Let $h(t, i, \theta)$ denote the education decision for a worker of type θ in country i at time t. $h(t, i, \theta)$ equals 1 if the worker gets an education and 0 otherwise. There is no cost of education other than time spent in school. Also, there is no utility from getting an education or working. After entering the labor force, all agents face a constant and age-independent rate of death δ. This convenient structure of the life cycle ensures that the size of a country's working population and the demographic composition are constant along any stationary equilibrium.

Types are distributed equally in all households and countries with a Pareto density function with shape parameter $(1 - \eta)^{-1}$ and scale parameter ηc.

$$F(\theta) = 1 - \left(\frac{\eta c}{\theta}\right)^{\frac{1}{1-\eta}} \tag{9}$$

The parameter restrictions $0 < \eta < 1$ and $0 < c$ as well as the lower bound of $\eta c \leq \theta$ apply. A lower η is associated with more heterogeneous workers. The scale parameter in (9) is chosen such that η does not affect the average type and it is always true that $E(\theta) = c$. With this formulation, a decrease of η is a mean preserving spread of the distribution of types.

Since all workers are perfectly substitutable the total supply of human capital is given by the sum over past education decisions adjusted for types, the probability of survival, and whether a worker is currently schooling or working.

$$H_{i,t} = \delta \int_{-\infty}^{t} e^{-(t-(T+\tau))\delta} \int_{\theta} f(\theta) \Upsilon_{t,i,\tau} h(t, i, \theta) \theta d\theta d\tau, \tag{10}$$

where $\Upsilon_{\tau,i}$ denotes the indicator function that equals 1 if a worker has left school and 0 otherwise. Since education is restricted to take place at the beginning of an individuals' life, $\Upsilon_{\tau,i}$ takes the value 1 whenever $\tau \leq t - T$. Similarly, the supply of labor takes into consideration that some

agents are currently in school.

$$L_{t,i} = \delta \int_{-\infty}^{t} e^{-\delta(t-\tau)} \int_{\theta} f(\theta) \left(1 - h(t,i,\theta)\right) d\theta d\tau$$

$$+\delta \int_{-\infty}^{t} e^{-(t-(T+\tau))\delta} \int_{\theta} f(\theta) \Upsilon_{t,i,\tau} h(t,i,\theta) d\theta d\tau \qquad (11)$$

Supply of services from labor L comes from two groups: unskilled workers and skilled workers who have finished their education.

4 Autarky Wage Patterns

This section establishes the equilibrium in a closed economy. Before solving for the stationary equilibrium path of the economy in autarky, I establish the instantaneous competitive equilibrium. Thereafter, I establish a stationary equilibrium and explain the origin of income and consumption differences in autarky.

Definition 1 *A feasible autarky allocation in country i given the supply of labor (11) and the supply of human capital (10), consists of functions $[h(t,i,\theta), Y_{i,t}, C_{t,i}]$ that satisfy (8) and (6) such the integral over (5) is finite and well defined. A resource constraint restricting input use in (7) to $X_{l,i} \leq Y_{l,i}$ and $X_{h,i} \leq Y_{h,i}$ applies.*

At each point in time t, there are perfectly competitive spot markets for the two intermediates and the final good. Non-satiation of the instantaneous utility together with the strictly positive marginal product of inputs in (7) ensures that all inequalities hold. I first establish the instantaneous equilibrium given factor supplies. For simplicity, I drop time subscripts t unless there is danger of confusion. I denote the wage of raw labor by $w_{l,i}$, the factor return of one unit of human capital by $w_{h,i}$ and the relative wage by $w_i \equiv \frac{w_{h,i}}{w_{l,i}}$. Profit maximization by competitive final goods producers (7) relates the relative price of intermediate goods to relative input use. Also, I denote the relative prices of the skill intensive good in country i by p_i.

$$p_i \equiv \frac{p_{h,i}}{p_{l,i}} = \left(\frac{Y_{h,i}}{Y_{l,i}}\right)^{-(1-\beta)} \qquad (12)$$

Intermediate goods are produced using a linear transformation technology and (12) also determines the relative wage.

$$w_i = A_i^{\beta} \left(\frac{H_i}{L_i}\right)^{-(1-\beta)} \qquad (13)$$

The relative wage is increasing in the efficiency of technology but decreasing in the relative abundance of human capital. Since the price of the final good is normalized to 1, the relative price p_i

alone pins down $p_{l,i}$ and $p_{h,i}$ and consequently also wages.

Each household chooses the education taking the actions of other households in the economy as given. A strategy for a household is a subset of each cohort of workers that are sent to the educational sector and the intertemporal consumption decision. I evaluate first the education decision $h(t, i, \theta)$ of each household. Since there exist perfect capital markets, each household maximizes the net present flow of labor income from each worker. Denote by $N(t, i, \theta, h)$ the net present value of the lifetime income that a worker of type θ born at t in country i receives when the education decision is $h(t, i, \theta)$. Income is discounted to the point of birth t of the respective worker and equal to

$$
N_{t,i}(\theta, h) = \begin{cases} \int\limits_{t}^{\infty} w_{l,\tau,i} e^{-\int_{t}^{\tau} \delta + r(\nu) d\nu} d\tau & \text{if } h(t, i, \theta) = 0 \\ \int\limits_{t+T}^{\infty} (\theta w_{h,\tau,i} + w_{l,\tau,i}) e^{+\delta T - \int_{t}^{\tau} \delta + r(\nu) d\nu} d\tau & \text{if } h(t, i, \theta) = 1 \end{cases} \tag{14}
$$

The effective cost of education is giving up the unskilled wage from time t to $t+T$. The benefit is the additional income equal to θ times the skilled wage from time $t+T$ on. Along any path of the economy, (14) leads to threshold for the worker type and the education decision of a household: if it is optimal for a household to choose $h(t, i, \theta) = 1$, then the same is true for any other type $\theta' > \theta$. Therefore, there exists a cutoff level $\overline{\theta}_{i,t}$ such that all types $\theta \geq \overline{\theta}_{i,t}$ get an education and all other types do not. The main sections of the paper are concerned with across-countries comparison of the aggregate gains from trade. I therefore define the aggregate net present income from the current cohort of workers $I_{t,i}$. Total income is equal to the integration of the maximal income (14) over types. This defines the discounted flow of income from the current generation of workers, which is of mass δ.

$$
I_{t,i} \equiv \delta \int_{\theta} f(\theta) \max_{h(t, i, \theta)} N_{t,i}(\theta, h) d\theta \tag{15}
$$

There is no aggregate uncertainty in this economy. Given (15) for past, present and future generations, the household has a separate consumption decision. Optimization of intertemporal utility (5) subject to (6) yields a familiar result for the slope of the consumption process.

Definition 2 *A competitive static equilibrium, given by the initial stock of human capital (10), labor (11) and A_i consists of a feasible allocation of functions for $[c(\tau, i), T(t, i), r(t), p(x_i)]$ such that (12) and (13) hold, $h(t, i, \theta)$ maximizes lifetime income for all cohorts (15) and the path of consumption maximizes (5) subject to (6).*

I next consider the existence and uniqueness of a stationary equilibrium (SE) in autarky. Let an "A" superscript denote expressions along such a stationary equilibrium, in which the relative price is constant and equal to p_i^A, the relative wage is a function of A_i and p_i and the interest rate is stable. Households choose a cutoff level $\overline{\theta}_i^A$ and, since there is no technological progress, output

and consumption are constant. Convergence to a stationary equilibrium is established easily because investment and intertemporal consumption decisions are independent. First, evaluate the cutoff condition (16) along any path of development. A single household has no influence on the relative wages or interest rates. Even if is optimal to school all types of workers, there is still a well defined and finite supply of unskilled and skilled labor for any path of wages and interest rates that leads to a finite net discounted value of income. Arbitrage considerations ensure a non-negative rate of interest at all moments of time. A nonzero interest rate combined with a positive rate of death δ implies that the discounted value of income is finite for any worker. Hence intertemporal income of a household is always defined. By standard arguments, time separable and concave preferences combined with a constant rate of time preference lead to a constant interest rate of $r = \rho$ along any path where income is stable. If $\rho > 0$, a unique and stable stationary equilibrium exists in which the choice of the cutoff point is a constant function of the interest rate and the autarky wages $w_{h,i}^A$ and $w_{l,i}^A$. Evaluating the entry condition (14) at the worker of type $\theta = \overline{\theta}_i^A$ who is indifferent between going to school or not, this cutoff level solves

$$w_{l,i}^A = e^{-\rho T} \left(\overline{\theta}_i^A w_{h,i}^A + w_{l,i}^A \right) \tag{16}$$

Given the optimal choice of $\overline{\theta}_i^A$, one can solve for the maximal net present value of income from the present cohort of workers, which if given by (15) in autarky. Along any path of the economy with constant wages and cutoff level $\overline{\theta}_i$, I denote the net present value of income from the current cohort of workers by $I\left(\overline{\theta}_i, w_{l,i}, w_{h,i} \right)$. Without assuming any specific distribution of types, it is always possible to express the net present income of a cohort of workers depending exclusively on the two wages. Evaluated at $\overline{\theta}_i^A$, the total income discounted to the point of birth of a generation of workers is equal to

$$I\left(\overline{\theta}_i^A, w_{l,i}, w_{h,i} \right) = \frac{\delta}{\rho + \delta} \left(1 + e^{-\rho T} \frac{w_{h,i}}{w_{l,i}} \int_{\overline{\theta}_i^A}^{\infty} f\left(\theta \right) \left(\theta - \overline{\theta}_i^A \right) d\theta \right) w_{l,i} \tag{17}$$

For any relative wage $w_i = \frac{w_{h,i}}{w_{l,i}}$, income is at least equal to $\frac{\delta}{\rho+\delta} w_{l,i}$. There are δ young workers who could start working right away and earn the unskilled wage forever, where the future is discounted at rate $\rho + \delta$ to account for the probability of death. Secondly, for any $w_{h,i} > 0$, there may exist high type agents that find it worthy to get an education. The marginal worker of type $\theta = \overline{\theta}_i^A$ just breaks even on his educational investment, but for all workers of higher type θ, the possibility to get educated increases their lifetime income. It is important to note that the aggregate surplus from having access to an education, which is represented by the second term in (17), is more than proportionally increasing in the relative wage w_i: if the relative wage increases, there are two margins in which net income from education is affected. The increased relative wage benefits all worker proportionally that would have chosen to get educated at lower wages. In addition, if the relative wage increases, the optimal cutoff level $\overline{\theta}_i^A$ decreases, hence benefiting

the additional entrants (weakly). An increase of the relative wage - given the unskilled wage - hence results in a more than proportional increase in the net income from education. In the case of no heterogeneity of workers (this corresponds to $\eta \to 1$ in the specific case of the Pareto distribution (9)) there is no surplus from education. In this case, the model becomes very similar to that of Findlay and Kierzkowski (1983) and all workers earn the unskilled wage (19). Intrinsic across-country differences in A_i hence do no longer matter because different workers earn different wages, but exclusively through general equilibrium effects that influence the unskilled wage.

I now solve for general equilibrium prices, wages and level of income (17) in the case of the Pareto distribution of types (9). In the autarky stationary equilibrium the only source of across-country variation is A_i. Solving the supply of labor (11) and human capital (10) for the constant cutoff $\overline{\theta}_i^A$, factor supply is given by $L_i^A = 1$ and

$$H_i^A = \lambda^{\frac{1}{\beta}} A_i^{\frac{\eta\beta}{1-\eta\beta}} \tag{18}$$

where $\lambda \equiv \eta^{\frac{\beta\eta}{1-\eta\beta}} \left(e^{\rho T} - 1\right)^{-\frac{\beta\eta}{1-\eta\beta}} c^{\frac{\beta}{1-\eta\beta}}$. In equilibrium, the higher a country's relative efficiency of human capital A_i, the more skill abundant is this country. With the supply of factors given, prices (12) and consequently wages (13) are determined uniquely. In autarky, skill abundant countries have a lower relative price of the skill intensive good, but still a higher relative wage.

The relative abundance of factors, technology and the normalization of the final good price to 1 relate the equilibrium unskilled wage $w_{l,i}^A$ to the level of domestic skill augmenting technology A_i.

$$w_{l,i}^A = \left(1 + \lambda A_i^{\frac{\beta}{1-\eta\beta}}\right)^{\frac{1-\beta}{\beta}} \tag{19}$$

A country that is characterized by a high A_i has a low autarky price of the skill intensive good. Because the normalization of the final good relates relative and absolute prices one to one, the price of the labor intensive good is high in these countries. Since each unit of raw labor can produce one unit of the unskilled good it thus receives a high wage. I denote stationary output by $Y\left(\overline{\theta}_i, w_{l,i}, w_{h,i}\right)$, which in autarky is equal to

$$Y\left(\overline{\theta}_i^A, w_{l,i}^A, w_{h,i}^A\right) = \left(1 + \lambda A_i^{\frac{\beta}{1-\eta\beta}}\right) w_{l,i}^A \tag{20}$$

In equilibrium, a country that is characterized by a high efficiency of human capital has a high level of net income (20), i.e. it is "rich". The stationary net present income (15) of young cohort of workers is equal to the total income from skilled labor plus the net income from human capital.

$$I\left(\overline{\theta}_i^A, w_{l,i}^A, w_{h,i}^A\right) = \frac{\delta}{\rho + \delta}\left(1 + e^{-\rho T}(1-\eta)\lambda A_i^{\frac{\beta}{1-\eta\beta}}\right) w_{l,i}^A \tag{21}$$

High efficiency countries have a high level of net income and are rich. Because of the convenient Pareto distribution of types, the *net* income from human capital is equal to a fraction $e^{-\rho T}(1-\eta)$ of the *total* income from skilled labor services.

How does the heterogeneity of workers influence the lifetime income of a cohort of workers? Consider first the case of homogenous types ($\eta \to 1$), in which all workers earn $w_{l,i}^A$. The model then becomes very similar to that of Findlay and Kierzkowski (1983). All workers earn the unskilled wage (19) and technology differences matter only through relative supply and price effects: a country with high A_i is characterized by a high supply of human capital and hence a lower price of the skill intensive good. A low price of the skill intensive good implies a high price of the labor intensive good and consequently a high unskilled wage. Consider now the case of a decrease in η, i.e. a mean preserving spread of the distribution of types. In autarky equilibrium a low η is associated with a large share of surplus as a fraction of total revenue of the skill intensive sector.[12]

More important than the effects η has on absolute levels of income and output is the impact it has on relative across-country differences. Nations intrinsically only differ with respect to their level of human capital augmenting technology A_i. The heterogeneity of workers guides how differences in technology translate into differences of income and factor abundance. If types are similar, small differences in human capital efficiency translate into large differences of relative factor abundance and income. If the degree of workers heterogeneity is large, differences in A_i translate into only moderate differences of factor endowment: the more spread the distribution of types is, the lower is the density of workers at any point along the distribution $f(\theta)$. For a given intrinsic difference in A_i and therefore in the relative demand for factors and in the cutoff point $\overline{\theta}_i$, the resulting international dispersion of relative factor supply is large if the distribution of workers is homogenous.

Cross-country differences are influenced by the elasticity of substitution between skill- and labor intensive intermediate goods. Consider first the case of β bigger than, but close to 0. In this case, price effects in (7) are offsetting differences in technology and countries have nearly identical factor supplies. Countries thus only differ in their level of technology and hence output.[13] A higher beta is associated with weaker price effects and thus increasingly pronounced across-country differences in autarky factor supply. In the case of $\beta = 1$ the production of the final good (7) is linear in inputs used, relative input prices are fixed and therefore international factor abundance levels are very different. The level of β also determines the size of gains from trade, which are derived in the next section.

---

[12]For given wages and therefore cutoff level $\overline{\theta}_i$, the supply of skilled workers (10) is lower if types are more heterogeneous. Although the expected value of the distribution of types is unaffected by η, the truncated expected value (that is the expected value given that the type is higher than $\overline{\theta}_i$) actually increases with η. This effect is captured in the value of λ.

[13]In the case of $\beta = 0$, (7) takes the Cobb Douglas shape with expenditure share of $1/2$ for each sector. As is well known, the factor augmenting productivity A_i is in this case equivalent to a Hick's neutral productivity level of $\sqrt{A_i}$.

5   Trade and the Evolution of Income and Welfare

Trade leads nations with a comparatively high level of human capital efficiency to specialize in skill intensive goods and leads to other nations providing unskilled labor services. In a dynamic context, the basic asymmetry of the model is that trade induces productive nations to specialize in a factor that can be accumulated, which increases the growth potential of the economy. Less productive nations specialize in 'raw' labor, a factor in fixed supply. Opening markets to trade therefore results in divergence of the world distribution of income.

A great deal of literature debates the gains from trade for poor nations. Young (1991) shows how trade can cause countries to specialize in industries with differential learning-by-doing potential and hence be on different dynamic learning paths. Countries with low initial experience in industrial production specialize in sectors with low learning potential and may thus loose from trade. Krugman and Venables (1995) show how, in the presence of increasing returns, initial patterns of specialization tend to reinforce themselves because new firms locate close to existing industry. Other contributions, not limited to, but including Matsuyama (1991) and the new economic geography literature originating from Krugman (1991), focus on similar mechanisms of increasing returns.

The model developed here differs substantially from the existing literature on the dynamic gains from trade because it does not focus on the evolution of location and productivity of different industries but rather on the endogenous formation of factor supplies. The notion that exchange - if it happens - must benefit all involved parties is an axiomatic insight of economic theory, and the same should be true for exchange between countries, international trade. But how are these gains from trade split up between nations at different stages of their economic development? This section establishes the gains from opening to trade. This is done in a partial equilibrium setting taking as given world prices. Global prices are derived in the next section. I focus on relative effects that occur to 'poor' and 'rich' countries. The structure of the present section is the following. First, as a benchmark model, I establish the gains from trade that would prevail in a world where education decisions are fixed at autarky levels. This is equivalent to welfare effects in a standard Heckscher Ohlin model of trade with factors of production in fixed supply. In this static setting, a country gains from trade because it is different from the rest of the world.

I show that the initial gains from trade are likely to lead to neutral gains from trade that favor neither developed nor developing countries and leave the relative dispersion of income unchanged. Dynamically, one has to distinguish between income divergence and divergence of welfare. I first describe the evolution of income. After opening markets, there is a phase of convergence of income that reflects the increased investment activity in richer countries and the decrease in education in other countries. After a period of time T the increased investment in human capital translates into again diverging income. I establish that the steady state of an open world is characterized by larger differences in human capital abundance and also larger output differences than in a world

of closed economies. I then turn to establish the evolution welfare. There are always additional efficiency gains that occur to countries because the education decision can adjust to international prices. However, because of the way in which trade affects the surplus from education, there can be dynamic divergence of welfare compared to the moment just after opening to trade. Finally, I develop conditions for when trade leads to absolute divergence of welfare compared to autarky and argue that these are likely to hold in reality.

Assume a small country i has a level of human capital efficiency of A_i and is in its autarky stationary equilibrium. At point in time τ^*, markets are unanticipatedly opened to trade with a large world that is characterized by A_w and a resulting relative price of the skill intensive good $p_w = \lambda^{-\frac{1-\beta}{\beta}} A_w^{-\frac{(1-\beta)}{1-\eta\beta}}$. A_w will be endogenized in the next section. Instantaneously after opening to trade, output of country i is given by autarky factor supplies (10) and (11), but valued at international prices.

$$
Y\left(\overline{\theta}_i^A, w_{l,w}, A_i p_w\right) = \left(1 + \lambda \left(\frac{A_i}{A_w}\right)^{\frac{1}{1-\eta\beta}} A_w^{\frac{\beta}{1-\eta\beta}}\right) \left(1 + \lambda A_w^{\frac{\beta}{1-\eta\beta}}\right)^{\frac{1-\beta}{\beta}} \tag{22}
$$

Opening to trade has two effects on income: it influences both relative wage w_i and the unskilled wage $w_{l,i}$. These two effects always work in opposite directions. If a country is more skill abundant than the rest of the world ($\frac{A_i}{A_w} > 1$), it benefits from trade because the relative wage w_i increases, but at the same time it looses from trade because the unskilled wage decreases. The opposite is true for a country j that is less skill abundant than the rest of the world.

It is important to point out that net effect always results in an increase of output. This can formally be shown by evaluating the first order condition of the ratio of (22) divided by (20) with respect to A_i. The minimum level of this ratio is equal to 1 and occurs at $A_i = A_w$. A country that happens to have autarky prices that are equal to the rest of the world is not affected by trade; all other countries strictly gain from trade.

Evaluating the second order condition of the above ratio establishes that countries that are more different from the rest of the world gain relatively more from trade. The intuition for this result follows from standard trade theory. Each country faces a concave frontier of how much it can supply of the two factors and because there are no market failures, the current supply is on and not inside this frontier. Statically, factor supply is fixed, but trade can change the relative price. At any relative price, the input constraint of final goods producers under trade passes through the current factor supply (8), is tangent to the concave factor supply frontier and hence encompasses the latter. Trade enables producers to a strictly larger set of input bundles, and since production isoquants are convex, output increases.

A question of interest is whether at the moment of trade, it is poor or rich nations that benefit relatively more from liberalization. A statement on convergence or divergence involves comparing income differences before and after opening to trade, i.e. four different levels of income. To establish the direction of relative gains from trade, I evaluate income differences for two small

economies, a country form the north (n) and a country from the south (s). I assume that the North is skill abundant compared to the rest of the world, so that that $A_n = (1 + \gamma) A_w$, where $\gamma > 0$. South is skill scarce and I assume that $A_s = (1 + \gamma)^{-1} A_w$. N and S are hence symmetrically different from the rest of the world. If for every pair of countries defined in this way there is divergence of output, I speak about uniform relative divergence.

Definition 3 (Uniform relative Di- and Convergence) *Let n and s be two small countries with $A_n = (1 + \gamma) A_w = (1 + \gamma)^2 A_s$. There is uniform relative divergence (convergence) of output if trade results in an increase (decrease) of relative income differentials for every $\gamma > 0$ and for every A_w.*

At the moment, statements of convergence or divergence will be made for country pairs. If, for all of possible such pairs, opening to trade differences in output and net present income are increased, one can make statements of the world distribution of income.

The appealing feature of the definition at hand is that it helps to establish for which range of world prices there will be divergence when opening to trade. The following lemma establishes instantaneous effects from trade.

Lemma 1 (Static Output Effects of Trade) *Consider the moment of opening to trade τ^*. There is uniform relative convergence (divergence) of output if the global size of the labor intensive sector is smaller (bigger) than the human capital intensive one.*

Proof. The Appendix establishes that

$$
\frac{Y\left(\overline{\theta}_n^A, w_{l,w}, A_n p_w\right) \Big/ Y\left(\overline{\theta}_s^A, w_{l,w}, A_s p_w\right)}{Y\left(\overline{\theta}_n^A, w_{l,n}^A, w_{h,n}^A\right) \Big/ Y\left(\overline{\theta}_s^A, w_{l,s}^A, w_{h,s}^A\right)} \left\{ \begin{array}{l} \geq 1 \text{ if } \lambda A_w^{\frac{\beta}{1-\eta\beta}} \leq 1 \\ < 1 \text{ if } \lambda A_w^{\frac{\beta}{1-\eta\beta}} > 1 \end{array} \right.
$$

It is also true that if $\lambda A_w^{\frac{\beta}{1-\eta\beta}} > 1$, the skill intensive sector is larger in terms of output and revenue than the labor intensive sector. ∎

If the skill intensive sector is large there is divergence, i.e. poor nations gain more from trade if their sector of specialization is relatively unimportant. This result seems striking at first sight, but thinking in terms of wages offers a good intuition. If $\lambda A_w^{\frac{\beta}{1-\eta\beta}} > 1$ the gains for unskilled labor are relatively large because labor is a globally scarce factor. Poor countries that export labor hence benefit more from trade than do rich countries.

Mankiw et al. (1992) estimate that the global expenditure share of the human capital is about as big as the one on pure labor services. A similar comparison can be made from the calculations of Hall and Jones (1999): estimates suggest that the two sectors are of about the same size. Hence, trade is in a static sense neither likely to favor poor nor rich nations and results in uniform gains from trade.

How is the path of income affected after opening to trade? Throughout the following analysis, I denote open economy expressions with an "O" superscript. The new optimal cutoff level for the education decision is hence denoted by $\overline{\theta}_i^O$ and solves

$$w_{l,w} = e^{-\rho T} \left(\overline{\theta}_i^O A_i p_{h,w} + w_{l,w} \right) \tag{23}$$

In the period from τ^* to $\tau^* + T$, any country n with $\frac{A_n}{A_w} > 1$ has a level of education investment that is larger than in autarky. During this period of time, the increased rate of schooling decreases the level of output in these countries: the supply of human capital is still fixed at autarky levels because skilled workers born before τ^* enter the labor market.

At the same time, an increased number of young workers chooses to get an education, leading to a temporary decrease of L_i and consequently output. At point in time τ^*, the rate of change of income is equal to equal to

$$\frac{\partial Y_i}{\partial t} \mid_{t=\tau^*} = \delta w_{l,w} \left(F\left(\overline{\theta}_i^O \right) - F\left(\overline{\theta}_i^A \right) \right) \tag{24}$$

Because the supply of skilled labor lags school enrollment rates by a period of time T, (37) is positive for a poor country with $\frac{A_i}{A_w} < 1$: in these economies, investment decreases instantaneously at τ^*, leading to a temporary 'overshooting' of output[14]. Only after point in time $\tau^* + T$ does the increased investment in human capital start to pay of as workers that started their schooling at τ^* enter the skilled labor force. After this point in time, there is divergence of output. The resulting long term level of output is given by

$$Y\left(\overline{\theta}_i^O, w_{l,w}, A_i p_w \right) = \left(1 + \lambda \left(\frac{A_i}{A_w} \right)^{\frac{1}{1-\eta}} A_w^{\frac{\beta}{1-\eta\beta}} \right) \left(1 + \lambda A_w^{\frac{\beta}{1-\eta\beta}} \right)^{\frac{1-\beta}{\beta}} \tag{25}$$

For any country n with $\frac{A_n}{A_w} > 1$ the long term level of output is necessarily bigger than the one prevailing at the moment of opening to trade. This reflects the increased investment activity compared to autarky. Similarly, the long term level of output under trade for any country s with $\frac{A_s}{A_w} < 1$ is necessarily smaller than the one prevailing just after autarky. The following proposition summarizes trade-induced changes of output after opening to trade.

Proposition 2 (Trade and the Dynamics of Income) *Let n and s be two small countries with $A_n = (1+\gamma) A_w = (1+\gamma)^2 A_s$. There is uniform relative divergence of output comparing the output just after opening to trade (22) to the one in the stationary equilibrium under free trade (25). There is also uniform relative divergence of output comparing the output in autarky stationary equilibrium (20) to the stationary equilibrium under free trade (25).*

---

[14]Depending on the rate of death δ and the time required for education T this effect can be very pronounced, and even lead to temporary reversals of income levels of rich and poor nations.

Proof. see Appendix ∎

The results of diverging output after opening to trade are straightforward. Trade increases investment rates in rich countries while it decreases them in poor countries. Naturally, an open world is characterized by a more stratified distribution of incomes.
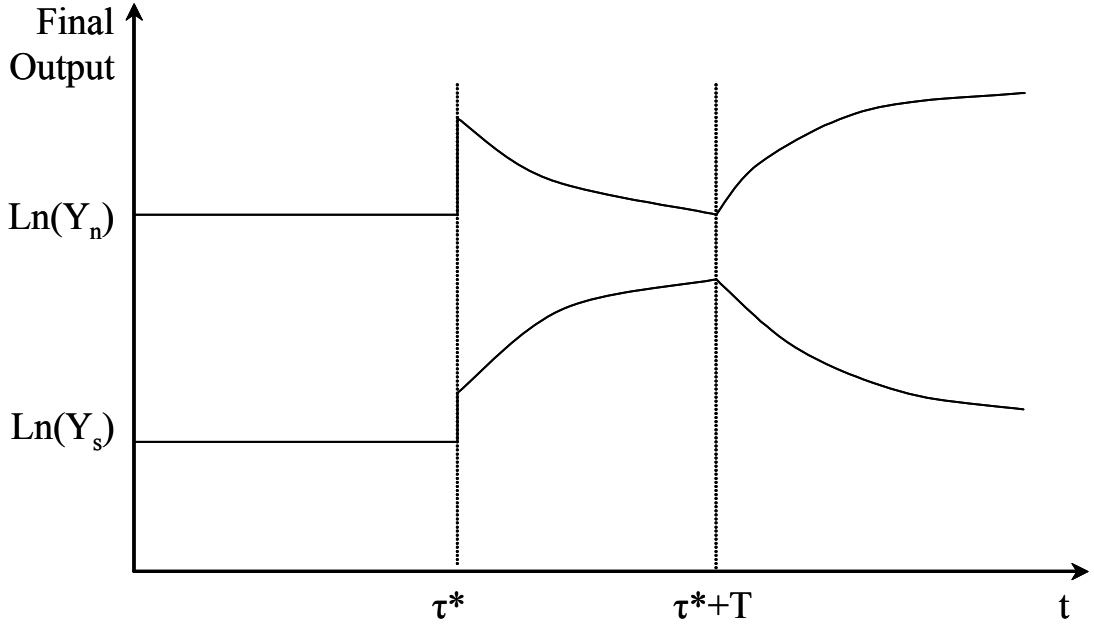

Figure 1

Figure 1 displays the path of output for two countries n and s as they have been defined previously. The path of outcome displays initial convergence followed by more pronounced divergence. What does the preceding analysis imply for welfare considerations? Because international capital markets exist, at each moment of time, each household simply consumes a fraction ρ of its complete net present value of future flows of income. Therefore, changes in welfare are equivalent to changes in the net present value of income from all cohorts of income. The comparison is simple for workers that have made their education decision before τ^*. Since their education decision is sunk, the increase of output due to trade is equivalent to the increase of net present income for this group of workers.

For young workers, there are two questions of interest. The first is whether they gain from trade and the second is whether they gain more than they would have if the education choice had not adjusted. First evaluate the net present value of income for cohorts of workers born at or after τ^* if the cutoff point had not changed from its autarky level $\overline{\theta}_i^A$.

$$ I\left(\overline{\theta}_i^A, w_{l,w}, A_i p_w\right) = \frac{\delta}{\rho+\delta}\left(1 + \left(\left(\frac{A_i}{A_w}\right)^{\frac{1}{1-\eta\beta}} - \eta\left(\frac{A_i}{A_w}\right)^{\frac{\beta}{1-\eta\beta}}\right)\lambda e^{-\rho T} A_w^{\frac{\beta}{1-\eta\beta}}\right) w_{l,w} \qquad (26) $$

Compare this to the level of net present income that the same cohort of workers get from adjusting

to the new optimal cutoff level $\overline{\theta}_i^T$.

$$I\left(\overline{\theta}_i^O, w_{l,w}, A_i p_w\right) = \frac{\delta}{\rho + \delta}\left(1 + (1-\eta)\left(\frac{A_i}{A_w}\right)^{\frac{1}{1-\eta}}\lambda e^{-\rho T}A_w^{\frac{\beta}{1-\eta\beta}}\right)w_{l,w} \tag{27}$$

(26) is the also net present value that a worker born just before τ^* gets.

Lemma 3 (Gains From Trade) *For all A_i and any A_w, there are gains from trade also when the cutoff remains at $\overline{\theta}_i^A$. There are additional gains from trade when $\overline{\theta}_i$ adjusts optimally.*

Proof. Compare (21), (26) and (27). It is easily established that

$$I\left(\overline{\theta}_i^O, w_{l,w}, A_i p_w\right) \geq I\left(\overline{\theta}_i^A, w_{l,w}, A_i p_w\right) \geq I\left(\overline{\theta}_i^A, w_{l,i}^A, w_{h,i}^A\right)$$

With equality if $A_i = A_w$ ∎

What happens to relative levels? The following proposition establishes whether there is divergence of net present income.

Proposition 4 (Post Opening Divergence) *Let n and s be two small countries with $A_n = (1+\gamma)A_w = (1+\gamma)^2 A_s$. It is always the case that comparing $I\left(\overline{\theta}_i^O, w_{l,w}, A_i p_w\right)$ to $I\left(\overline{\theta}_i^A, w_{l,w}, A_i p_w\right)$, there is uniform relative divergence. There is uniform relative divergence of $I\left(\overline{\theta}_i^O, w_{l,w}, A_i p_w\right)$ and $I\left(\overline{\theta}_i^A, w_{l,i}^A, w_{h,i}^A\right)$ iff*

$$e^{-\rho T} - 1 + \eta e^{-\rho T}\lambda A_w^{\frac{\beta}{1-\eta\beta}} > 0 \tag{28}$$

Evaluate the ratio of (27) to (26) for two countries N and S.

$$\frac{I\left(\overline{\theta}_n^O, w_{l,w}, A_n p_w\right)\Big/I\left(\overline{\theta}_s^O, w_{l,w}, A_s p_w\right)}{I\left(\overline{\theta}_n^A, w_{l,w}, A_n p_w\right)\Big/I\left(\overline{\theta}_s^A, w_{l,w}, A_s p_w\right)}$$

If $\gamma = 0$, this ratio equal 1. For any $\gamma > 0$, this ratio can be shown to be bigger 1. The second claim involves a similar comparison of (27) to (21). The equivalent ratio can shown to be bigger 1 for any $\gamma > 0$ if (28) holds.

The preceding proposition establishes whether the net present income of young workers diverges when opening to trade. The household receives additional income from old cohorts of workers that were born before τ^*. To establish whether the total net present income of the economy diverges, one has to evaluate the total relative increase in consumption, which is a combination of contributions from generations born before τ^* and from younger cohorts born thereafter. The total net present value of all future income of country i is given by two flows of income. First, there is a flow of $Y\left(\overline{\theta}_i^A, w_{l,w}, A_i p_w\right)$ from old cohorts or workers $\tau^* + T$, the size

of old cohorts stays constant at 1 but it decreases at rate δ thereafter. In addition, starting from τ^*, each moment of time a new cohort of workers of mass δ is born, receiving a net income of $I\left(\overline{\theta}_i^O, w_{l,w}, A_i p_w\right)$. Consumption smoothing implies that the household consumes a fraction ρ of its net wealth.

The new level of consumption after opening markets to trade is hence given by

$$C_i^T = \left(\left(1 - e^{-\rho T}\right) + \rho\left(\rho + \delta\right)^{-1} e^{-\rho T}\right) Y\left(\overline{\theta}_i^O, w_{l,w}, A_i p_w\right) + I\left(\overline{\theta}_i^O, w_{l,w}, A_i p_w\right) \qquad (29)$$

When is consumption, and therefore also welfare, likely to diverge?

Proposition 5 (Trade and Divergence of Welfare) *Let n and s be two small countries with $A_n = (1+\gamma) A_w = (1+\gamma)^2 A_s$. Opening to trade results in uniform divergence of welfare iff*

$$(1 - \beta) e^{-\rho T} - 1 + (1 - \beta) \eta e^{-\rho T} \lambda A_w^{\frac{\beta}{1-\eta\beta}} > 0 \qquad (30)$$

In autarky, households would consume (20). Again evaluating whether the gains from trade are bigger for a skill abundant country N than for a skill scarce country S, this is true for any $\gamma > 0$ if (30) holds.

How likely are is trade to lead to divergence under realistic parameter values? Consider first the conditions for post opening divergence of net present income (28). If the duration of education is sufficiently short or ρ approaches 0, there is always divergence. This result is straightforward: as $e^{-\rho T}$ goes to 1, workers do not have to invest much in order to become skilled. Any human capital accumulation that is induced by trade hence leads to large net gains for human capital abundant countries. If $e^{-\rho T}$ is is substantially below one, there is a significant cost of education. In this case, rich countries are likely to gain more from trade than poor nations if the global skill intensive sector is large compared to the labor intensive sector and if the heterogeneity of workers is small.

Why does worker heterogeneity have such an effect on the impact of trade liberalization? The same mechanism that controlled how different countries are in autarky influences how sensitive the supply of skilled labor is to changes in the relative wage induced by trade. Consider a developed country ($A_i > A_w$). If workers are heterogeneous, for a given change in the wage only a moderate number of additional workers enters the skilled sector. The increase in net income (i.e. in surplus) is only moderate, as well. In contrast, if workers are homogenous, a small increase in the wage induces a sizable entry in the skilled labor supply and consequently a larger increase in the surplus from education.[15]

---

[15] An interesting benchmark is when all workers are identical. In this case trade induces complete specialization and the gains from trade are the following. Workers in poor nations receive the global unskilled wage, while workers in rich nations receive A_i / A_w times the global unskilled wage. Because identical workers earn the unskilled wage, the gains from trade are fundamentally different and depend again only on wage and price effects of trade. Due to

The condition for total divergence of welfare is similar to the one for post opening divergence. Different countries are more likely to diverge if the time of schooling is short, the human capital intensive sector is relatively important and if workers are more homogenous. In addition, the elasticity of substitution now guides relative divergence. Since the skill supply reacts only slowly to changed demand conditions, there is less likely to be divergence. It is again noteworthy that empirical estimates of beta are small (see Autor et al. (1998)) so that conditions (28) and (30) are similar.

6   General Equilibrium and The Skill Bias of Trade

The last part of the model evaluates the general equilibrium response of simultaneously opening many countries to trade. The results of this section are related to a growing literature on the skill bias of global trade. The increased exposure to international trade seems to have resulted in both a pervasive increase in the skill premium while resulting in a decrease in the price of skill intensive goods. One group of papers explaining such diversion, including Dinopolous and Segerstrom (1999) and Gancia and Epifani (2005), argues that the skill intensive sector is more sensitive to scale. Trade increases the market size for an average firm and hence leads to a relative expansion of the skill intensive sector. A second class of models builds on the directed technical change literature, with contributions by Acemoglu and Zilibotti (2001), Acemoglu (2003), and Gancia (2004). Here, it is a combination of unequal protection of intellectual property rights and differential factor endowments that creates technical change biased towards skilled workers. By increasing the market size for skill complementary technologies in those countries that have good intellectual property rights protection, trade increases the skill bias of global technology.

The current paper presents a new channel for why trade is skill biased and leads to a global expansion of the skill intensive sector. The mechanism does not rely on how trade influences technology, but on how trade influences the international location of human capital. Trade equates goods prices across the world, and the dynamic response of education decisions tends to concentrate human capital in countries that can use skills efficiently. With the average skilled worker working in a country with a higher level of human capital augmenting technology, the output of skill intensive goods increases. This results in a decrease of the price of skill intensive goods. The expansion of the skill intensive sector takes place slowly as new cohorts enter the labor force.

Despite the decrease in the price of the skill intensive good, I show that an open economy is skill biased. This is a consequence of two related mechanisms. At the moment of opening to trade, the skill premium increases in human capital abundant countries, while it decreases in skill scarce countries. The arithmetic average of the skill premium - weighted by relative supply - hence increases with trade. Dynamically, there exists another effect leading to further skill bias.

---

this, Lemma 1 (Static Gains From Trade) also describes conditions under which there is con- and divergence in the case of homogenous workers.

The supply of human capital decreases in countries that are skill scarce and increases elsewhere, resulting in a further increase in the arithmetic average of the skill premium. The results of the model in general equilibrium hence explain why a globalizing world is characterized by both a decreasing price of the skill intensive good while at the same time resulting in a pervasive increase in the skill premium.

I order all countries i by their relative human capital effectiveness A_i. I assume that this measure is distributed with probability density function $g(A_i)$. This distribution might also include large countries, and hence the following analysis also encompasses the typical two-country North and South case. I assume that countries are not too different, so that there exists no country that would only have skilled workers in equilibrium.[16] A global competitive equilibrium follows the definition of equilibrium in a closed economy. The global resource constraint restricts total input use to be at most as big as global output of the two intermediate goods.

$$\int_i X_{l,i}\, di \le \int_i Y_{l,i}\, di \quad \text{and} \quad \int_i X_{h,i}\, di \le \int_i Y_{h,i}\, di \tag{31}$$

At the moment of opening to trade, global relative supply of factors is given by steady state autarky levels.

$$\frac{Y_{h,w}}{Y_{l,w}}\Big|_{t=\tau^*} = \lambda^{\frac{1}{\beta}} \int_{A_i} g(A_i)(A_i)^{\frac{1}{1-\eta\beta}}\, dA_i \tag{32}$$

I denote the average world level of human capital efficiency at the moment of opening to trade by A_w^A.

$$A_w^A \equiv \left(\int_{A_i} g(A_i)(A_i)^{\frac{1}{1-\eta\beta}}\, dA_i \right)^{1-\eta\beta} \tag{33}$$

Instantaneously after τ^*, countries with $A_i > A_w^A$ accumulate further human capital, while other nations disaccumulate. In a stationary equilibrium, each country chooses a level of human capital dependent on its level of A_i and on global prices $H_i^O = \lambda^{\frac{2-\beta}{\beta}} A_i^{\frac{\eta}{1-\eta}} p_w^O$, resulting in a total level of global output of

$$\frac{Y_{h,w}^O}{Y_{l,w}^O} = \lambda^{\frac{1}{\beta}} \left(\int_{A_i} g(A_i)(A_i)^{\frac{1}{1-\eta}}\, dA_i \right)^{\frac{1-\eta}{1-\eta\beta}} \tag{34}$$

Similarly to the definition of the average world level of human capital efficiency at the moment of opening to trade A_w^A, I denote the average long run global level of human capital efficiency in an open world by A_w^O.

$$A_w^O \equiv \left(\int_{A_i} g(A_i)(A_i)^{\frac{1}{1-\eta}}\, dA_i \right)^{1-\eta} \tag{35}$$

What is the difference between (33) and (35)? The key mechanism is that in autarky, the general equilibrium response of prices dampens differences in the supply of human capital: a nation that is

---

[16] In the long run equilibrium, this restriction is equivalent to $A_{MAX} < \eta c \left(e^{\rho T} - 1 \right) p_w^{-1}$.

characterized by a low A_i has a high price of the skill intensive good, thereby increasing demand. In an open economy, all countries face the same price and across-country differences in the supply of human capital are thus more pronounced. The next proposition establishes the net effect of this concentration of skills.

Proposition 6 (Expansion of the Skill Intensive Sector) *The stationary equilibrium under trade is characterized by a larger world production of skill intensive goods than in autarky.*

Proof. The dynamic relative supply of skill intensive goods (34) is larger than the static one (32) if the following inequality holds.

$$\left(\int_{A_i} g\left(A_i\right)\left(A_i\right)^{\frac{1}{1-\eta}} dA_i \right)^{1-\eta} > \left(\int_{A_i} g\left(A_i\right)\left(A_i\right)^{\frac{1}{1-\eta\beta}} dA_i \right)^{1-\eta\beta}$$

By Assumption 1 $\beta > 1$ and due to this and the general means inequality, this is always true. ∎

Trade, to a first order, "shifts" skilled workers from low A to high A countries. While trade also reduces skill abundance and the supply of the skill intensive good in some nations, it raises the supply in exactly those countries that can use them very efficiently. This concentration results in an expansion of the skill intensive sector.

A higher relative output implies a lower relative price of the skill intensive good, and one might suspect that trade therefore lowers the average skill premium. Interestingly, the opposite is the case.

In the context of the present model, skill bias is not easily established, since some countries may see their skill premium increase with trade, but in other countries there may be a decrease of the relative skilled wage. I therefore define skill bias in an average sense.

Definition 4 (Pervasive Skill Bias) *Trade is pervasively skill biased if the arithmetic average of the relative wage of human capital increases with trade.*

There are two questions of interest. First, is there pervasive skill bias at the moment of opening to trade? Second, is there additional skill bias along the dynamic path of the global economy? The following proposition answers both of these questions.

Proposition 7 (The Skill Bias of Trade) *There is pervasive skill bias at τ^*. The dynamic response of educational investment results in further skill bias.*

Proof. Compare the arithmetic average of the skill premium before, at the moment of and in the long run after trade liberalization. It is both true that

$$\int_{A_i} g\left(A_i\right) H_i^A A_i p_w \left(\frac{Y_{h,w}}{Y_{l,w}} \Big|_{t=\tau^*} \right) dA_i > \int_{A_i} g\left(A_i\right) H_i^A w_i^A dA_i$$

28

and

$$\int_{A_i} g\left(A_i\right) H_i^O A_i p_w^O dA_i > \int_{A_i} g\left(A_i\right) H_i^A A_i p_w \left(\frac{Y_{h,w}}{Y_{l,w}}\mid_{t=\tau^*}\right) dA_i$$

These two inequalities are satisfied by the general means inequality. ∎

The same mechanism that is responsible for the output increase of the skill intensive sector is responsible for the skill bias of trade. Consider first the moment of opening to trade. When goods prices are equalized, the wage increases in skill abundant countries, while it decreases in skill scarce countries. Since all countries have an equal endowment of unskilled labor, this channel is not present for unskilled sector. Additionally, the dynamic response of human capital amplifies the initial skill bias. Trade induces skill accumulation in high wage countries and de accumulation elsewhere. The arithmetic average of the wage hence increases further. This result is related to Dinopolous and Segerstrom (1999) and especially to Gancia and Epifani (2005): while these authors argue that the skill intensive sector is more sensitive to scale, here it is the fact that the factor used intensively in one industry can be accumulated and this, on the aggregate, leads to the industry to having a higher growth potential.

What is the path of globalization when many nations simultaneously open their markets to trade? This section establishes the path of global development. The main insights are very similar to that of Section 5 evaluated at A_w^O (see Equation (35)). Also, there may exist a group of intermediately developed countries that starts the process of globalization as exporters of the skill intensive good and successively become importers of the latter. This results stems from the expansion of the skill intensive sector and the resulting decline of skill intensive goods prices caused by trade.

At the moment of opening to trade, world prices are given by static world supply (32). Lemma 1 (Static Output Effects of Trade) describes the evolution of the world income distribution at the moment of trade, which converges if at the moment of opening to trade, the size of the world skill intensive sector is larger than that of the unskilled sector. The long run distribution of income is given by Proposition 2 (Trade and the Dynamics of Income) and the long term level of world average technology (A_w^O), which is pinned down by (35). That is, there is long term divergence of the world distribution of income around A_w^O.

What happens to investment and the path of income after τ^*? Each household in each country considers the same evolution of goods prices and the education decision leads to an optimal cutoff level that solves (for any $t \geq \tau^*$)

$$\int_{t+T}^{\infty} \left(\overline{\theta}_{i,t} A_i p_{h,\tau,w} + p_{l,\tau,w}\right) e^{+\delta T - \int_t^\tau \delta + r(\nu)d\nu} d\tau = \int_t^\infty p_{l,\tau,w} e^{-\int_t^\tau \delta + r(\nu)d\nu} d\tau \qquad (36)$$

Because all countries evaluate the same evolution of prices, it is easy to make *relative* statements about the cutoff level $\overline{\theta}_{i,t}$. Define the level of technology for which the dynamic path of wages

(36) evaluated at $t \geq \tau^*$ leads to exactly the same cutoff level as in autarky by A_t^D. Comparing (36) to (33) and (34), for any $t \geq \tau^*$, $A_{t,w}^D$ satisfies

$$A_w^A < A_{\tau^*,w}^D \leq A_w^O$$

After opening markets to trade, all countries with $A_i < A_{t,w}^D$ decrease their educational investment while others increase their level of investment. There is thus instantaneous convergence of income around $A_{t,w}^D$. How does the distribution of world income evolve thereafter? First evaluate the evolution of relative output for countries that are more technologically advanced than the rest of the world in long term equilibrium A_w^O. At any point in time $t > \tau^*$ these countries invest more in skills than in autarky. Thus, again the GDP of these countries initially decreases until period $\tau^* + T$ and then increases. The opposite is true for all countries with $A_i < A_{\tau^*,w}^D$. Along any point in time $t > \tau^*$ these countries invest less in skills than in autarky. The dynamics for the countries with $A_{\tau^*,w}^D < A_i < A_w^O$ are more interesting. This group starts the process of globalization being an exporter of the skill intensive good but successively becomes an importer of the latter. That is, as $A_{t,w}^D$ converges to A_w^O, a larger and larger fraction has lower investment in education than in autarky.

What are the welfare consequences of globalizing markets? Consider first countries that do not change their pattern of specialization i.e. all $A_{\tau^*,w}^D < A_i < A_w^O$. Proposition 5 (Trade and the Divergence of Welfare) establishes conditions under which welfare diverges for a given *constant* level of world prices. In fact, the world price of skill intensive goods is higher than in the long run equilibrium with A_w^O. This creates additional temporary gains for exporters of skill intensive goods: if (30) holds for $A_w = A_w^O$, there is divergence around A_w^O. In fact, divergence is more likely than if prices would instantaneously jump to their long term levels. Consider now this group of countries that has $A_{\tau^*,w}^D < A_i < A_w^O$. Some of these countries might experience smaller dynamic than static gains from trade. For example consider – if it exists – a country with $A_i = A_w^O$. This country starts as an exporter of the skill intensive sector but does not trade in the long run. By Lemma 1 (Static Gains From Trade), this nations gains statically from trade, but it does not gain from trade in the long run. Putting things together, globalization results in long term divergence of income around A_w^O, the long term average level of technology.

7   Conclusion

Recent contributions to the literature of economic growth have argued that factor accumulation is a key ingredient for long term economic success. Countries that have sustained high rates of growth did so because of their high levels of savings and investment in human capital (see Young (1995) and Mankiw et al. (1992)). Other nations stagnated precisely because their institutional setups hindered private savings and investment (see for example Hall and Jones (1999)).

To evaluate whether trade has sizeable and first order effects on economic performance, it is therefore essential to show how exposure to international prices influences factor accumulation. Indeed, one of the most fundamental insights of the theory of international trade is Samuelson's (1948) factor price equalization theorem suggest that when some factors, such as physical and human capital, are in variable supply, trade thereby re-enforces initial patters of specialization.

However, being a net supplier of human capital that can be accumulated increases the growth potential of the economy, while specialization in labor intensive sectors means specialization in a factor in fixed supply. In addition to showing how trade can result in divergence of income, I evaluate how trade affects relative welfare differentials. The dynamic response of the economy that introduces the asymmetry between nations in the model. This result stems from the two margins in which the relative wage influences the surplus from education: a higher relative wage increases the income for all workers that already would have chosen schooling at lower wages. In addition, an increase in the relative wage induces more entry into the skilled labor force. In total, the surplus from education responds more than proportionally to changes in the relative wage. Skill scarce nations, in contrast, have their comparative advantage in a factor that is in fixed supply and cannot be accumulated.

The key insight of the mechanism at work is that while all countries gain from trade, it is already developed nations that gain proportionally the most from trade. Trade hence might result in dynamic divergence of welfare.

References

[1] Acemoglu, D. (2003) "Patterns of Skill Premia", The Review of Economic Studies, 70(2): 199-230.

[2] Acemoglu, D., Johnson, S. and Robinson J.A. (2005) "Institutions as the Fundamental Cause of Long-Run Growth", Handbook of Economic Growth, forthcoming

[3] Acemoglu, D. and Ventura, J. (2002) "The World Income Distribution", The Quarterly Journal of Economics, 117(1): 659-694.

[4] Acemoglu, D. and Zilibotti, F. (2001) "Productivity Differences", The Quarterly Journal of Economics, 116(1): 563-606.

[5] Antweiler, W and Trefler, D (2002) "Increasing Returns and All That: A View from Trade", The American Economic Review, 92(1)), pp. 93-119.

[6] Auer, Raphael and Fischer, Andreas M., (2010). "The effect of low-wage import competition on U.S. inflationary pressure," Journal of Monetary Economics, Elsevier, vol. 57(4), pages 491-503, May.

[7] Auer, Raphael, Kathrin Degen, and Andreas M. Fischer (2010) "The Effect of Chinese Exports on European Producer Prices" mimeo, Princeton University

[8] Autor, D.H., L.F. Katz, and A.B. Krueger (1998) "Computing Inequality: Have Computers Changed the Labor Market?", The Quarterly Journal of Economics, 113(4): 1169-1213.

[9] Barro, R. and Lee, J. W.(1996) "International Measures of Schooling Years and Schooling Quality", The American Economic Review P&P, 86(2), 218-223.

[10] Baldwin, R.E. (1992) "Measurable Dynamic Gains from Trade", The Journal of Political Economy, 100(1): 162-174

[11] Bernard, A. B., Jensen, J. B., Schott, P. K., (2006). Survival of the best fit: Exposure to low-wage countries and the (uneven) growth of US manufacturing plants, Journal of International Economics 68(1), 219-237.

[12] Caselli, F. and Coleman J. (2006) "The World Technology Frontier", The American Economic Review, 2006

[13] Choi, Yong-Seok and Krishna, Pravin (2004) "The Factor Content of Bilateral Trade: An Empirical Test", The Journal of Political Economy, 112(4): 887-914.

[14] Davis, D. R. and Weinstein, D.E. (2001) "An Account of Global Factor Trade", The American Economic Review, 91(5): 1423-1453.

[15] Debaere, Peter (2003) "Relative Factor Abundance and Trade", The Journal of Political Economy, 111(3): 589-610

[16] Dinopoulos, E and P. Segerstrom (1999) "A Schumpeterian Model of Protection and Relative Wages", The American Economic Review, 89(3): 450-472.

[17] Devarajan, S. and Rodrick, D "Trade Liberalization in Developing Countries: Do Imperfect Competition and Scale Economies Matter?", American Economic Review, Papers & Proceedings 79(2), May 1989.

[18] Dollar, David and Kraay, Aart, (2003). "Institutions, trade, and growth," Journal of Monetary Economics, Elsevier, vol. 50(1), pages 133-162, January.

[19] Epifani, P. and Gancia, G. (2005) "Increasing Returns, Imperfect Competition and Factor Prices", mimeo, CREI.

[20] Feenstra, Robert C., Robert E. Lipsey and Harry P. Bowen (1997) "World Trade Flows, 1970-1992, with Production and Tariff Data," NBER Working Paper 5910.

[21] Findlay, R. and Kierzkowski, H (1983) "International Trade and Human Capital: A Simple General Equilibrium Model", The Journal of Political Economy, 91(6): 957-978.

[22] Frankel, A. Frankel and David Romer (1999). "Does Trade Cause Growth?," American Economic Review, American Economic Association, vol. 89(3), pages 379-399, June

[23] Galor, O. and Mountford, A. (2006) "Trade and the Great Divergence: The Family Connection". American Economic Review 96, May 2006, 229-303.

[24] Gancia, G. (2005) "Globalization, Divergence and Stagnation", mimeo, CREI.

[25] Hausmann, R., J. Hwangand D. Rodrick "What You Export Matters", Journal of Economic Growth, volume 12, no. 1, March, 2007.

[26] E.Helpman, and O.Itskhoki, "Labor market rigidities, trade and unemployment", The Review of Economic Studies. 77: 1100-1137, 2010.

[27] E.Helpman, O.Itskhoki, and S. Redding, "Unequal effects of trade on workers with different abilities", Journal of the European Economic Association (Papers and Proceedings) 8 (Issue 2-3): 421-433, 2010.

[28] E.Helpman, O.Itskhoki, and S. Redding, "Inequality and unemployment in a global economy", Econometrica, 78: 1239-1283, 2010.

[29] Elhanan Helpman & Marc Melitz & Yona Rubinstein, 2008. "Estimating Trade Flows: Trading Partners and Trading Volumes," The Quarterly Journal of Economics, MIT Press, vol. 123(2), pages 441-487, 05

[30] Anthony Kiszewski, Andrew Mellinger, Andrew Spielman, Pia Malaney, Sachs Jeffrey, and Sonia Ehrlich Sachs (2004)."A Global Index of the Stability of Malaria Transmission" American Journal of Tropical Medicine and Hygiene, 70(5), pp. 486-498

[31] Krugman, P. (1980) "Scale Economies, Product Differentiation, and the Pattern of Trade", The American Economic Review, 70(5): 950-959.

[32] Krugman, P. (1991) "Increasing Returns and Economic Geography", The Journal of Political Economy, 99(3): 483-499.

[33] Krugman, P. (2008) "Trade and Wages, Reconsidered" Paul Krugman, February 2008. Presented at the 2008 Spring Meeting of the Brookings Panel on Economic Activity.

[34] Krugman, P. and Venables, A.J (1995) "Globalization and the Inequality of Nations", The Quarterly Journal of Economics, 110(4): 857-880.

[35] La Porta, Rafael; Florencio Lopez-de-Silanes, Andrei Shleifer and Robert W. Vishny. 1998. "Law and Finance," *The Journal of Political Economy*, 106(6), pp. 1113-1155.

[36] Mankiw, N.G, Romer, D and Weil, D "A Contribution to the Empirics of Economic Growth", The Quarterly Journal of Economics, 107(2): 407-437.

[37] Matsuyama, K. (1991) "Increasing Returns, Industrialization, and Indeterminacy of Equilibrium", The Quarterly Journal of Economics, 106(2):617-650.

[38] Ohlin, B. (1933) "Interregional and International Trade", Harvard University Press, Cambridge.

[39] Rodrik, Dani, Arvind Subramanian & Francesco Trebbi, 2004. "Institutions Rule: The Primacy of Institutions Over Geography and Integration in Economic Development," Journal of Economic Growth, Springer, vol. 9(2), pages 131-165, 06.

[40] Romalis, J. (2004) "Factor Proportions and the Structure of Commodity Trade", The American Economic Review, 94(1): (67-97).

[41] Samuelson, Paul A. (2004) "Where Ricardo and Mill Rebut and Confirm Arguments of Mainstream Economists Supporting Globalization", Journal of Economic Perspectives, Volume 18 (3), pp 135–146.

[42] Stiglitz, J.E. (1970) "Factor Price Equalization in a Dynamic Economy", The Journal of Political Economy, 78(3): 456-488.

[43] Stolper, W. and Samuelson, P. (1941), "Protection and real wages", The Review of Economic Studies.

[44] Tenreyro, Silvana and J.M.C. Santos Silva. (2006) "The Log of Gravity" The Review of Economics and Statistics, November 2006, Vol. 88, No. 4: 641-658.

[45] Trefler, D (1995) "The Case of the Missing Trade and Other Mysteries", The American Economic Review, 85(5), pp. 1029-1046.

[46] Trefler, D (2002) "The Case of the Missing Trade and Other Mysteries: Reply", The American Economic Review, 92(1), pp. 405-410.

[47] Vanek, Jaroslav (1968), "The Factor-Proportions Theory: The N-Factor Case", Kyklos, 21(4): 749-756.

[48] Ventura, J. (1997) "Growth and Interdependence", The Quarterly Journal of Economics, 112(1): 57-84.

[49] Young, A. (1991) "Learning by Doing and the Dynamic Effects of International Trade", The Quarterly Journal of Economics, 106(2): 369-405.

[50] Young, A. (1995) "The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience", The Quarterly Journal of Economics, 110(3): 641-680.

8 Appendix A

Proof. Of Lemma 1 (Static Output Effects of Trade)

Evaluate autarky output (20) to output at τ^* (22) for two countries $A_n = (1 + \gamma) A_w = (1 + \gamma)^2 A_s$. The pre opening ratio of output is equal to

$$
Y\left(\overline{\theta}_n^A, w_{l,w}, A_n p_w\right) \Big/ Y\left(\overline{\theta}_s^A, w_{l,w}, A_s p_w\right) = \frac{\left(1 + \lambda \left(\frac{A_i}{A_w}\right)^{\frac{1}{1-\eta\beta}} A_w^{\frac{\beta}{1-\eta\beta}}\right)}{\left(1 + \lambda \left(\frac{A_i}{A_w}\right)^{-\frac{1}{1-\eta\beta}} A_w^{\frac{\beta}{1-\eta\beta}}\right)}
$$

The post opening ratio of output is equal to

$$
Y\left(\overline{\theta}_n^A, w_{l,w}, A_n p_w\right) \Big/ Y\left(\overline{\theta}_s^A, w_{l,w}, A_s p_w\right) = \frac{\left(1 + \lambda A_n^{\frac{\beta}{1-\eta\beta}}\right)^{\frac{1}{\beta}}}{\left(1 + \lambda A_s^{\frac{\beta}{1-\eta\beta}}\right)^{\frac{1}{\beta}}}
$$

When is there absolute divergence? The relative level of output has a form of has a form of $\left(\frac{z^k x + 1}{z^{-k} x + 1}\right)^{\frac{1}{k}}$, where $z = 1 + \gamma$. The autarky level of k is higher than under autarky. If

$$
\frac{\partial}{\partial k}\left(\frac{z^k x + 1}{z^{-k} x + 1}\right)^{\frac{1}{k}} > 0
$$

holds, there is divergence. First note that when $x = 1$, $\left(\frac{z^k x + 1}{z^{-k} x + 1}\right)^{\frac{1}{k}} = z$. If $x < 1$, $\left(\frac{z^k x + 1}{z^{-k} x + 1}\right)^{\frac{1}{k}} < z$. Rewriting this expression

$$
\frac{\partial}{\partial k} \exp\left[\frac{1}{k} \log\left(z^k x + 1\right) - \frac{1}{k} \log\left(z^{-k} x + 1\right)\right]
$$

Where the inner exponents need to be rewritten in log-exponential form, too. This can be shown to be

$$
\left(\frac{z^k x + 1}{z^{-k} x + 1}\right)^{\frac{1}{k}} \left(\frac{\partial}{\partial k}\left(\frac{1}{k} \log\left(z^k x + 1\right)\right) - \frac{\partial}{\partial k}\left(\frac{1}{k} \log\left(z^{-k} x + 1\right)\right)\right)
$$

Omitting terms that are positive it remains to be shown that

$$\frac{\partial}{\partial k}\left(\frac{1}{k}\log\left(z^k x + 1\right)\right) - \frac{\partial}{\partial k}\left(\frac{1}{k}\log\left(z^{-k} x + 1\right)\right) > 0$$

Putting things together, multiplying by k^2 this is true, if

$$\log\left(z\right)\left[\frac{z^k x}{(z^k x + 1)} + \frac{z^{-k} x}{(z^{-k} x + 1)}\right] - \log\left(\frac{z^k x + 1}{z^{-k} x + 1}\right)^{\frac{1}{k}} > 0 \tag{37}$$

Recalling that when $x = 1$, $\log\left(\frac{z^k x + 1}{z^{-k} x + 1}\right)^{\frac{1}{k}} = \log(z)$ so (37) is equal to 0. In addition, (37) takes the value 0 if $x \to \infty$ and if $x = 0$. Evaluating the slope of (37) with respect to x, it can be shown that at levels of x just below 1,(37) is decreasing, implying that (37) is bigger 0 for any $1 > x > 0$. In addition, it can be shown there exist at most 3 levels of x where (37) equals 0. Hence, (**??**) is increasing in k whenever $1 > x > 0$. ∎

Proof. of Proposition 2 (Trade and The Dynamics of Income)

To establish the two claims of the proposition, compare the relative ratio of output for two countries N and S in autarky (20), just after opening to trade (22) and in the stationary equilibrium with trade (25). It is both true that for any $\gamma > 0$, the following inequalities hold.

$$\frac{Y\left(\overline{\theta}_n^O, w_{l,w}, A_n p_w\right)}{Y\left(\overline{\theta}_s^O, w_{l,w}, A_s p_w\right)} \Bigg/ \frac{Y\left(\overline{\theta}_n^A, w_{l,w}, A_n p_w\right)}{Y\left(\overline{\theta}_s^A, w_{l,w}, A_s p_w\right)} \tag{38}$$

First note that if $\gamma = 0$, this ratio is equal to 1. Now evaluate the first and second derivative of (38) with respect to γ. The first derivative is positive at $\gamma = 0$, while the second derivative is positive for any γ. Hence, for any $\gamma > 0$ (38) takes a value larger than 1. A proof along the same lines establishes that for any $\gamma > 0$ comparing (20) to (25) result in dynamic divergence, i.e.

$$\frac{Y\left(\overline{\theta}_n^O, w_{l,w}, A_n p_w\right)}{Y\left(\overline{\theta}_s^O, w_{l,w}, A_s p_w\right)} > \frac{Y\left(\overline{\theta}_n^A, w_{l,n}^A, w_{h,n}^A\right)}{Y\left(\overline{\theta}_s^A, w_{l,s}^A, w_{h,s}^A\right)}$$

∎

9 Appendix B: Endogenous Technology

The previous results have been derived under the assumption of exogenous technology differences. This section endogenizes technology in a two sector model of endogenous growth. It is established that all results are amplified.

Assume that the production of intermediate goods is modified alla Romer (1990) in the two sector version of Acemoglu (1998). Technology is local and in each country, the production function combines factor specific differentiated input goods and the respective factor. Each of these input goods is produced using a linear transformation of the respective intermediate good[17]. I denote the amount of each input good used in the labor intensive sector by $i_{L,i}$ and the one used for production of the skill intensive good by $i_{H,i}$. The net output of each intermediated (denoted by $\widetilde{Y}_{j,i}$ for $j\epsilon\left[L,H\right]$) given by

$$\widetilde{Y}_{L,i} = \left(\int_0^{N_{L,i}} i_{L,i}^{\gamma}di\right)L_i^{1-\gamma} - \int_0^{N_{L,i}} i_{L,i}di - R_{L,i} \tag{A1}$$

$$\widetilde{Y}_{H,i} = \left(\int_0^{N_H} i_{H,i}^{\gamma}di\right)H_i^{1-\gamma} - \int_0^{N_{H,i}} i_{H,i}di - R_{H,i} \tag{A2}$$

$(1 < \gamma < 1)$ Where $R_{L,i}$ and $R_{H,i}$ are the flows of R&D expenditures that are used to invent new blueprints in each sector.[18] I assume that innovation in sector j uses only the respective intermediate good as input to produce new innovations. Furthermore, as in Jones(1995) , innovation becomes more difficult as the current level of innovation is higher. Denoting the flow-cost of innovation in terms of the respective intermediate goods in sector j and country i by $\vartheta\left(N_{j,i}\right)$, such that the absolute cost is $P_{j,i}\vartheta\left(N_{j,i}\right)$

$$\vartheta\left(N_{j,i}\right) = N_{j,i}^{\mu}$$

with $\mu > 0$, innovation in each country essentially runs into decreasing returns. I now characterize countries not by their intrinsic difference in technology, but by their difference in their educational sector. That is, some countries are essentially better at educating their workforce. The demographic structure is essentially unchanged, except that in country i, a skilled worker of type θ now supplies $s_i\theta$ units of skilled labor if she chooses to get educated. s_i is the country specific efficiency of the educational system that is given exogenously. Models of endogenous investments in technology that are financed with profits from monopolistic competition features two related market failures: because each input good monopolist cannot prices discriminate, it charges a constant markup prices hence producing a suboptimal amount. For given levels of technology, the production of a country is thus suboptimal. More importantly, the same lack of ability to price discriminate also leads to the monopolist not capturing the full social surplus from her invention. There is thus also suboptimal entry into the input producing sector, with important dynamic consequences for technology, output and welfare. Because innovators face a

---

[17] To be sure: there are now two sorts of input goods used two produce two intermediate goods used to produce the final good.

[18] Epifani and Gancia show in one section how trade can lead to skill bias when the elasticity of substitution $(1-\gamma)^{-1}$ between varieties is larger in the skill intensive sector that nin the labor intensive one.

constant demand elasticity, they charge a price of $1/\gamma$ times their marginal costs. Each innovator in the L sector hence sells $i_{L,i} = \gamma^2 L_i$ units while a firm in the H sector sells $i_{H,i} = \gamma^2 H_i$. Free entry into the market for input goods hence implies that

$$N_{L,i} = \left((1-\gamma)\,\gamma^2 L_i\right)^{\frac{1}{\mu}} \quad \text{and} \quad N_{H,i} = \left((1-\gamma)\,\gamma^2 H_i\right)^{\frac{1}{\mu}}$$

The net output in each sector is hence given by

$$
\begin{align}
\widetilde{Y}_{L,i} &= \left((1-\gamma)\,\gamma^2\right)^{\frac{1}{\mu}} \gamma^{2\gamma} L_i^{\frac{1+\mu}{\mu}} - \int_0^{N_{L,i}} i_{L,i}\,di - R_{L,i} \tag{A1} \\
\widetilde{Y}_{H,i} &= \left(\int_0^{N_H} i_{H,i}^{\gamma}\,di\right) H_i^{1-\gamma} - \int_0^{N_{H,i}} i_{H,i}\,di - R_{H,i} \tag{A2}
\end{align}
$$

and the relative wage is given by

$$w_i = \left(\frac{N_{H,i}}{N_{L,i}}\right)^{\beta} \left(\frac{H_i}{L_i}\right)^{-(1-\beta)} = \left(\frac{H_i}{L_i}\right)^{\frac{\beta}{\mu}-(1-\beta)}$$

Because relative technology is increasing in factor abundance, the relative wage may now be increasing in the supply of skilled labor. The steady state education supply in each country is a function of the wage and the domestic schooling technology s_i.

$$\frac{H_i}{L_i} = (\eta c)^{\frac{1}{1-\eta}}\,\eta\,\left(e^{\rho T}-1\right)^{-\frac{1}{1-\eta}}\,w_i^{\frac{\eta}{1-\eta}}\,s_i^{\frac{1}{1-\eta}}$$

s_i matters more than proportional, because it influences both the cutoff and the average level of education per skilled worker.

$$\left(\frac{H_i}{L_i}\right)^{1-\beta\eta\frac{1+\mu}{\mu}} = (\eta c)^{\eta}\,\eta^{1-\eta}\,\left(e^{\rho T}-1\right)^{-1}\,s_i$$

An non explosive equilibrium closed economy requires that $\beta\eta\frac{1+\mu}{\mu} < 1$, and the condition $\eta\frac{1+\mu}{\mu} < 1$ is required for a non-explosive open equilibrium. Otherwise, the result of the model with endogenous education and an intrinsic difference in the efficiency in the educational system is equivalent to the model with fixed technology, except that because also technology adjusts, countries tend to be more dissimilar.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable:			Relative Skilled Labor Content of Imports measured by			
				(4)-(6): Workers with at Least Some Secondary Education / all Labor		
	(1)-(3): Workers with High School Equivalent / all Labor					
Foreign Skill Supply I	0.051 [0.005]***		0.047 [0.005]***			
Home Skill Supply I		-0.036 [0.006]***	-0.031 [0.005]***			
Foreign Skill Supply II				0.116 [0.009]***		0.109 [0.009]***
Home Skill Supply II					-0.071 [0.014]***	-0.058 [0.013]***
Observations	3055	3055	3055	3055	3055	3055
R-squared	0.07	0.04	0.1	0.08	0.03	0.1

Notes for Table 1: In all specifications, the sample includes 3055 country-pair observations for the year 1992. In all specifications, the dependent variable is the relative skill intensity of imports measured as the ratio of the skilled labor content of imports divided by the total (skilled plus unskilled) labor content of imports. In Columns 1 to 3, "skilled labor" is equal to the share of workers who finished high school (or equivalent). In Columns 4 to 6, "skilled labor" is equal to the share of workers with at least some secondary or tertiary education. In Columns 1 and 4, the independent variables is the share of skilled workers in the exporting country. In Columns 2 and 5, the independent variables is the share of skilled workers in the importing country. In Columns 3 and 6, the share of skilled workers in both the importing and the exporting country is added. Robust standard errors in parentheses, observations clustered within importing nation; * significant at 10%; ** significant at 5%; *** significant at 1%

Table 2 - Gravity Estimation of the Factor Content of Bilateral Imports (Poisson Estimates)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent Variable:				Import Factor Content of Bileratal Imports for the Following Factor:				
	Workers w. Finished High School or Equivalent				w. sec. Schooling	w Tert. Schooling	Capital	Land
Year Analyzed:	1992	1992	1972	1992	(1992)	1992	1992	1992
Fraction of Workers w. high School in For	3.251 [0.309]***							
Ln Foreign Supply of Workers w. High School		0.76 [0.042]***	0.754 [0.037]***					
Ln Foreign Supply of Workers w sec. Schooling					0.782 [0.053]***			
Ln Foreign Supply of Workers w. tert. Schooling						0.733 [0.042]***		
Ln Foreign Supply of Capital							0.828 [0.045]***	
Ln Foreign Supply of Land								0.428 [0.068]***
Ln Population Foreign	0.599 [0.053]***							
Ln Population Home	-1.15 [0.055]***	-1.121 [0.057]***	-1.176 [0.060]***	-1.058 [0.045]***	-1.099 [0.062]***	-1.115 [0.054]***	-1.048 [0.046]***	-1.295 [0.069]***
Log Distance	0.66 [0.058]***	0.655 [0.059]***	0.665 [0.068]***	0.663 [0.054]***	0.651 [0.063]***	0.649 [0.056]***	0.682 [0.057]***	0.723 [0.059]***
Exporter Fixed Effects				y				
Observations	3723	3723	3723	3723	3723	3723	3723	3723

Notes: Table 2 presents gravity estimations that relate importer information, exporter information, and bilateral distance to the bilateral factor content of trade. In (1) to (4) the dependent variable is the skilled labor content of trade measured in the number of workers with finished high school education. In (5), the skilled labor content of trade is measured by the number of workers with at least some secondary education. In (6) the skilled labor content of trade is measured by the number of workers with at least some tertiary education. In (7), the dependent variable is the physical capital content of trade and in (8) the Land Content of imports. In (1) the fraction of workers in the population with finished high school education is added as independent variable. In (2) to (8), the independent variables include the supply of the respective factor (see dependent variable) in the exporting country. The sample includes all bilateral import flows (including 0s) for 1992 (72 in Column 3). Robust standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 3 - Geographic Proximity to Skills and Domestic Education (RE or FE Panel Regressions Spanning 5 5-Year Intervals from 72-92)

Dependent Variable:	(1) Raw Panel Correlation	(2) Adding Geog. Openess	(3) Adding Controls for Institutions	(4) Adding Fixed Effects (FE)	(5) FE & time varying Geog. Openess	(6) Lagged Prox-imity to Skills	(7) 5 Year Changes on Changes
	(1)-(6): Ln Avg. Years of Education in the Workforce						
Geog. Proximity to Skilled Workers	-0.08 [0.024]***	-0.10 [0.024]***	-0.11 [0.037]***	-0.10 [0.024]***	-0.12 [0.024]***		
Lag 1 of Proximity to Skilled Workers						-0.07 [0.030]**	
Ch. of Proximity to Skilled Workers							-0.10 [0.032]***
Frankel Romer Geog. Openess		0.01 [0.004]***					
Dollar & Kray Geog. Openess					0.191 [0.063]***	0.104 [0.065]	
Ch. Dollar & Kray Geog. Openess							0.126 [0.066]*
Settler Mortality			-0.241 [0.099]**				
Trend	0.13 [0.007]***	0.14 [0.006]***	0.13 [0.008]***	0.14 [0.006]***	0.10 [0.014]***	0.11 [0.016]***	-0.01 [0.008]
Legal Org. dummies			y				
Country Fixed Effects				y	y	y	
Groups	204	204	159	204	204	164	163
Observations	41	41	32	41	41	41	41

Notes: Table 3 presents Panel Estimations relating the constructed measure of "Geographic Proximity to Skilled Labor" to levels (dependent variable in Columns (1) to (6)) and changes (dep. var. in Column (7)) of the average years of education in the workforce. In (4), a country-specific and time-invariant variable "Geographic Openness" from Frankel and Romer (1999) is added as invariant variable. In (5), settler mortality from Acemoglu et al. (2001) and legal origin dummies are added. (5) and (6) add a time-varying variable of geographic openness constructed following Dollar and Kray (2003). The same variable once differenced is used in the random effects specifications of (7). Robust standard errors in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%

	(1)	(2)	(3)	(4)	(5)	(6)
	Response of Primary vs. Higher Education to Skilled Labor Import		Response of Primary vs. Higher Education to Unskilled Labor		Response to Highly Skilled Labor	
	Dependent Variable is the Logarithm in the Years (Average Population) of					
	Primary Educ	Higher Educ	Primary Educ	Higher Educ	Primary Educ	Higher Educ
Geog. Proximity to Skilled Workers	**-0.10** [0.024]***	**-0.15** [0.048]***				
Geog. Proximity to Unskilled Workers			**0.07** [0.036]**	**0.18** [0.068]***		
Geog. Proximity to Highly Skilled Workers					**-0.088** [0.022]***	**-0.119** [0.043]***
Dollar & Kray Geog. Openess	0.16 [0.064]**	0.10 [0.126]	0.10 [0.066]	0.00 [0.126]	0.15 [0.064]**	0.09 [0.127]
Trend	0.08 [0.014]***	0.22 [0.028]***	0.08 [0.015]***	0.23 [0.029]***	0.08 [0.014]***	0.22 [0.028]***
Country Fixed Effects	y	y	y	y	y	y
Groups	204	204	204	204	204	204
Observations	41	41	41	41	41	41
Within R2	0.65	0.7	0.62	0.7	0.65	0.7

Notes: Table 4 analyses whether different types of education react differently to various measures of geographic proximity to skilled or unskilled labor. In specifications (1), (3), and (5), the dependent variable is the logarithm of average years of primary education in the average workforce. In specifications (2), (4), and (6), the dependent variable is the logarithm of average years of secondary and tertiary education in the average workforce. In (1) and (2), the independent variable is the geographic proximity to skilled (w. finished high school) labor. (3) and (4) add the geographic proximity to unskilled labor (measure: no schooling). (5) and (6), add the geographic proximity to highly skilled labor (at least some tertiary education).

COUNTRY	CODE	Actl FCT HK1/POP	Pred. FCT HK1/POP	Actual FCT HK2/POP	Pred. FCT HK2/POP
Argentina	ARG	0.0033684	0.0013843	0.0076796	0.0019838
Australia	AUS	0.0156595	0.0012524	0.0353459	0.0015204
Austria	AUT	0.050929	0.0079536	0.1049795	0.0102248
Belgium	BEL	0.0995534	0.0242058	0.2002868	0.0319474
Bangladesh	BGD	0.0001472	0.0006098	0.0002498	0.0005991
Bolivia	BOL	0.0013662	0.0021585	0.0029329	0.0025738
Brazil	BRA	0.000902	0.0008657	0.0020244	0.0008593
Canada	CAN	0.0340874	0.0126008	0.0768641	0.0038954
Chile	CHL	0.0048128	0.0014096	0.0107315	0.0014921
Cameroon	CMR	0.0005447	0.0013528	0.0011327	0.0013688
Colombia	COL	0.001603	0.0017553	0.0035777	0.0013072
Costa Rica	CRI	0.0062644	0.0044054	0.0112671	0.003127
Germany	DEU	0.0371908	0.0078331	0.0737739	0.0086087
Dominican Republi	DOM	0.0045665	0.003405	0.0070124	0.0020678
Ecuador	ECU	0.0018717	0.0026027	0.0043515	0.0027665
Egypt	EGY	0.0011397	0.0018414	0.0022832	0.0026529
Spain	ESP	0.0189396	0.0034027	0.0393566	0.0041596
Ethiopia	ETH	0.0001348	0.0007075	0.0002709	0.0007102
Finland	FIN	0.0280207	0.0080966	0.0606272	0.010228
France	FRA	0.0338046	0.009455	0.0704005	0.0108103
UK	GBR	0.0299144	0.008869	0.0627145	0.010267
Ghana	GHA	0.0004863	0.0013363	0.0010198	0.0012835
Greece	GRC	0.0156624	0.0036018	0.0312232	0.004544
Guatemala	GTM	0.0018572	0.0038483	0.0035795	0.0024711
Honduras	HND	0.0018829	0.0052114	0.0032362	0.005305
India	IND	0.0001068	0.0005961	0.0002446	0.0008205
Ireland	IRL	0.051388	0.0105353	0.1065766	0.0140363
Iceland	ISL	0.0439459	0.0118418	0.0901199	0.0150537
Israel	ISR	0.0212666	0.0031558	0.047085	0.0046584
Italy	ITA	0.0230816	0.0040044	0.0474788	0.0052702
Jamaica	JAM	0.005729	0.0080753	0.0099525	0.0042925
Japan	JPN	0.0109529	0.0020878	0.0206181	0.0019955
Korea, Rep.	KOR	0.0106769	0.0026641	0.0241156	0.0020616
Sri Lanka	LKA	0.0010173	0.0009491	0.001901	0.0009943
Morocco	MAR	0.0019483	0.0027749	0.0038536	0.0037612
Madagascar	MDG	0.0001902	0.0007833	0.00041	0.000801
Mexico	MEX	0.0053249	0.0031339	0.0115914	0.0013737
Malawi	MWI	0.0001881	0.0009287	0.000401	0.0009002
Malaysia	MYS	0.0108268	0.0012462	0.0263758	0.0014133
Nigeria	NGA	0.0004729	0.0008495	0.0010941	0.000735
Netherlands	NLD	0.0735976	0.0164973	0.147273	0.0210376
Norway	NOR	0.0476122	0.0098605	0.1006144	0.0124308
New Zealand	NZL	0.0170064	0.001469	0.038523	0.0013423
Pakistan	PAK	0.0003959	0.003445	0.0008485	0.0051765
Panama	PAN	0.0385122	0.0055632	0.0857173	0.0059807
Peru	PER	0.0009234	0.0013595	0.0018967	0.001142
Philippines	PHL	0.0012117	0.0014731	0.0026486	0.0017009
Papua New Guine	PNG	0.0017484	0.001458	0.0037988	0.0010718
Portugal	PRT	0.0258084	0.0062916	0.0508878	0.0090776
El Salvador	SLV	0.0019679	0.0051129	0.0039094	0.0037858
Suriname	SUR	0.0059145	0.0047717	0.0126213	0.0047342
Sweden	SWE	0.0411911	0.0076858	0.0865051	0.0099012
Syrian	SYR	0.0010638	0.0013792	0.0022904	0.0019241
Thailand	THA	0.0045238	0.0026697	0.0105152	0.0037086
Tunisia	TUN	0.0059709	0.004736	0.0111689	0.006899
Turkey	TUR	0.002042	0.0019111	0.004691	0.002062
Tanzania	TZA	0.0002024	0.000708	0.0004511	0.0006767
Uruguay	URY	0.0051781	0.0057908	0.0110467	0.0093274
US	USA	0.0148143	0.0016287	0.0313321	0.0016086
Venezuela,	VEN	0.0044967	0.0022322	0.0101182	0.0018017
South Africa	ZAF	0.0026293	0.0005744	0.005827	0.0005227
Zambia	ZMB	0.0004482	0.0007637	0.0008866	0.0007648
Zimbabwe	ZWE	0.0006618	0.0010386	0.0013359	0.0010024

Swiss National Bank Working Papers published since 2004:

2004-1   Samuel Reynard: Financial Market Participation and the Apparent Instability of Money Demand

2004-2   Urs W. Birchler and Diana Hancock: What Does the Yield on Subordinated Bank Debt Measure?

2005-1   Hasan Bakhshi, Hashmat Khan and Barbara Rudolf: The Phillips curve under state-dependent pricing

2005-2   Andreas M. Fischer: On the Inadequacy of Newswire Reports for Empirical Research on Foreign Exchange Interventions

2006-1   Andreas M. Fischer: Measuring Income Elasticity for Swiss Money Demand: What do the Cantons say about Financial Innovation?

2006-2   Charlotte Christiansen and Angelo Ranaldo: Realized Bond-Stock Correlation: Macroeconomic Announcement Effects

2006-3   Martin Brown and Christian Zehnder: Credit Reporting, Relationship Banking, and Loan Repayment

2006-4   Hansjörg Lehmann and Michael Manz: The Exposure of Swiss Banks to Macroeconomic Shocks – an Empirical Investigation

2006-5   Katrin Assenmacher-Wesche and Stefan Gerlach: Money Growth, Output Gaps and Inflation at Low and High Frequency: Spectral Estimates for Switzerland

2006-6   Marlene Amstad and Andreas M. Fischer: Time-Varying Pass-Through from Import Prices to Consumer Prices: Evidence from an Event Study with Real-Time Data

2006-7   Samuel Reynard: Money and the Great Disinflation

2006-8   Urs W. Birchler and Matteo Facchinetti: Can bank supervisors rely on market data? A critical assessment from a Swiss perspective

2006-9   Petra Gerlach-Kristen: A Two-Pillar Phillips Curve for Switzerland

2006-10 Kevin J. Fox and Mathias Zurlinden: On Understanding Sources of Growth and Output Gaps for Switzerland

2006-11 Angelo Ranaldo: Intraday Market Dynamics Around Public Information Arrivals

2007-1   Andreas M. Fischer, Gulzina Isakova and Ulan Termechikov: Do FX traders in Bishkek have similar perceptions to their London colleagues? Survey evidence of market practitioners' views

2008-18 Raphael Auer and Andreas M. Fischer: The Effect of Low-Wage Import Competition on U.S. Inflationary Pressure

2008-19 Christian Beer, Steven Ongena and Marcel Peter: Borrowing in Foreign Currency: Austrian Households as Carry Traders

2009-1 Thomas Bolli and Mathias Zurlinden: Measurement of labor quality growth caused by unobservable characteristics

2009-2 Martin Brown, Steven Ongena and Pinar Yeşin: Foreign Currency Borrowing by Small Firms

2009-3 Matteo Bonato, Massimiliano Caporin and Angelo Ranaldo: Forecasting realized (co)variances with a block structure Wishart autoregressive model

2009-4 Paul Söderlind: Inflation Risk Premia and Survey Evidence on Macroeconomic Uncertainty

2009-5 Christian Hott: Explaining House Price Fluctuations

2009-6 Sarah M. Lein and Eva Köberl: Capacity Utilisation, Constraints and Price Adjustments under the Microscope

2009-7 Philipp Haene and Andy Sturm: Optimal Central Counterparty Risk Management

2009-8 Christian Hott: Banks and Real Estate Prices

2009-9 Terhi Jokipii and Alistair Milne: Bank Capital Buffer and Risk Adjustment Decisions

2009-10 Philip Sauré: Bounded Love of Variety and Patterns of Trade

2009-11 Nicole Allenspach: Banking and Transparency: Is More Information Always Better?

2009-12 Philip Sauré and Hosny Zoabi: Effects of Trade on Female Labor Force Participation

2009-13 Barbara Rudolf and Mathias Zurlinden: Productivity and economic growth in Switzerland 1991-2005

2009-14 Sébastien Kraenzlin and Martin Schlegel: Bidding Behavior in the SNB's Repo Auctions

2009-15 Martin Schlegel and Sébastien Kraenzlin: Demand for Reserves and the Central Bank's Management of Interest Rates

2009-16 Carlos Lenz and Marcel Savioz: Monetary determinants of the Swiss franc