International Capital Market Integration, Educational Choice and Economic Growth*

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Abstract

This paper examines the impact of capital market integration (CMI) on higher education and economic growth. We take into account that participation in higher education is non-compulsory and depends on individual choice. Integration increases (decreases) the incentives to participate in higher education in capital-importing (-exporting) economies, all other things equal. Increased participation in higher education enhances productivity progress and is accompanied by rising wage inequality. From a national policy point of view, education expenditure should increase after integration of similar economies. Using foreign direct investment (FDI) as a measure for capital flows, we present empirical evidence which largely confirms our main hypothesis: An increase in net capital inflows in response to CMI raises participation in higher education and thereby fosters economic growth. We apply a structural estimation approach to fully track the endogenous mechanisms of the model.

Key words: Capital Mobility; Capital-Skill Complementarity; Educational Choice; Education Policy; Economic Growth; Wage Income Inequality.

JEL classification: F20, H52, J24, O10.

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1 Introduction

Capital markets have become increasingly integrated in the last decades. For instance, the average annual growth rate of foreign direct investment (FDI) inflows in the world has been about 25 percent in the period 1986-90, 20 percent in 1991-95 and almost 32 percent in 1996-99 (Markusen, 2002, Tab. 1.1).[1] Unsurprisingly in light of such evidence, a large literature on the consequences of increased capital mobility has developed.

This paper contributes to this literature by linking capital market integration (CMI) to higher education and growth. Examining the link between CMI and higher education is motivated by two facts. First, participation in higher education is non-compulsory and depends on individual educational choice. Second, there is strong empirical support for the hypothesis that physical and human capital are strongly complementary production factors (Goldin and Katz, 1998, Krusell, Ohanian, Ríos-Rull and Violante, 2000). We argue that, therefore, capital inflows increase individual incentives to acquire higher education by raising the relative marginal productivity of skilled to low-skilled labor. In turn, the supply of skilled labor is an important determinant of capital allocation (UNCTAD, 1996, 2002).[2] The link to economic growth is motivated by the literature on the positive role of human capital formation for productivity progress (see Glaeser, La Porta, Lopez-de-Silanes and Shleifer, 2004, for recent evidence). Taken together, capital-skill complementarity and non-compulsory higher education as determinant of productivity growth suggest the following hypothesis we attempt to advance in this paper. CMI increases the incentives to participate in higher education and raises both educational attainment and economic growth in countries which experience a (net) inflow of capital after integration, all other things being equal. By contrast, the share of skilled labor and therefore growth is reduced in economies in which integration causes a capital outflow. This suggests that the impact of CMI on economic growth

[1] In these three time periods, FDI stocks have grown on average by 18.2 percent, 9.4 percent and 16.2 percent, respectively. Moreover, the measure on international investment barriers, which we use to instrument capital flows in our empirical analysis, has declined dramatically over the last decades.

[2] In particular, tertiary education is found to be "an inducement for FDI" (UNCTAD, 2002, p. 36).

through increased participation in higher education depends on the initial conditions which affect the marginal productivity of capital and the pattern of capital flows.[3] By using data for the period 1960-2000 from 87 countries, we present empirical evidence which largely supports the main hypothesis derived from our theoretical model: All other things being equal, an increase in net capital inflows in response to CMI raises participation in higher education and thereby promotes economic growth.[4]

While participation in higher education is determined by individual choice, the output of schooling also depends on the amount of financial resources invested into the education system. The bulk of educational spending in secondary education and in many countries, Continental Europe for instance, also in tertiary education, typically comes from the public sector. This points to a prominent role of public education policy under integrated international capital markets. Therefore, we address the question how governments should react to changes in the demand for education caused by CMI. According to our analysis, public education expenditure (financed by a wage tax) raises the share of skilled labor in an integrated economy primarily through attracting foreign capital investment. This implies, from a national point of view, that education expenditure of an economy should be increased after integration with similar economies. Moreover, our analysis suggests that, under optimal adjustment of education policy, educational attainment typically rises after CMI. However, this is not generally true. If unfavorable initial conditions induce large capital outflows after integration, it may not be optimal to raise education expenditure to a point which fully offsets the negative effect of CMI on the individual incentives to participate in higher education.

[3]For instance, as argued by Lucas (1990), capital may flow from capital-poor to capital-rich economies when the latter have significantly higher stocks of initial human capital and higher total factor productivity.

[4]Our empirical analysis uses FDI as measure of capital flows. In line with our findings, empirical evidence suggests that FDI inflows typically have significant positive effects on economic growth (Alfaro, Chanda, Kalemli-Ozcan and Sayek, 2004; Khawar, 2005). According to our analysis, these positive effects come from the impact of investment flows on human capital formation. In their seminal contribution on capital mobility and growth, Barro, Mankiw and Sala-i-Martin (1995) present a neoclassical growth model with two capital goods and an international credit market. They show that, when only one of the two cumulated goods can serve as collateral for borrowing on the world market (capturing partial mobility of capital), the model can account for observed patterns of convergence of per capita income growth rates. Smulders (2004) considers the role of capital mobility on convergence in a framework with monopolistic competition and R&D-based growth.

This analysis is related to the literature on the link between education policy and capital mobility. Gradstein and Justman (1995) and Viaene and Zilcha (2002a) argue that CMI typically gives rise to overprovision of public education in a policy game among two identical countries, calling for policy coordination. Our results suggest a similar conclusion. However, we do not analyze the non-cooperative policy game or optimal education policy from an integrated point of view. Viaene and Zilcha (2002b), in a model with compulsory education, show that CMI raises income inequality in capital-importing economies, whereas the opposite happens in capital-exporting economies. Although inequality is not the central focus of our paper, our analysis produces an analogous result. The effect of CMI on inequality in our model is due to the assumption of heterogeneity of individuals in learning abilities, which gives rise to a positive relationship between the share of skilled labor and inequality of wage income.

Our goal is to derive empirically testable hypotheses on the relationship between international capital flows, participation in higher education and economic growth, taking into account possible adjustments of public education policy. As outlined above, for a given level of public education expenditures, educational attainment increases if CMI leads to a capital inflow, but decreases if it leads to an outflow. If public education expenditures are optimally adjusted, educational attainment increases even in the case of capital outflows, unless the outflows are large. The impact of CMI on growth comes from the positive impact of participation in higher education on total factor productivity. We provide an empirical assessment of the main hypotheses in an econometric modelling approach that follows the causal channels identified in the theoretical analysis as closely as possible. Instrumental variable and system regressions are applied to test for these channels. The empirical results confirm our theoretical prediction that capital inflows stimulate participation in higher education and thereby promote economic growth.

The paper is organized as follows. Section 2 presents the basic (static) version of the model. Section 3 analyzes the equilibrium for a given public education policy. Section 4 examines optimal education policy. Section 5 extends the basic model to a simple overlapping generations setting, to investigate the relationship between CMI and economic growth through effects on educational attainment. Section 6 presents empirical evidence on the main hypotheses derived from the theoretical analysis. The last section briefly summarizes. All proofs are relegated to the appendix.

2 The Basic Model

Consider first a static economy with a single homogeneous consumption good supplied under perfect competition. Output Y is produced according to the following constant-returns to scale technology:

$$Y = F(K, S, L) = A \left[bK^{\beta} + (1-b)L^{\beta} \right] S^{1-\beta}, \tag{1}$$

$b, \beta \in (0,1)$, where total factor productivity (TFP) $A > 0$ indicates the technological state of the economy (endogenized in section 5), K is physical capital input, and S and L are efficiency units of skilled and low-skilled labor, respectively. Note that (1) implies that physical capital and skilled labor are technological complements, in contrast to capital and low-skilled labor. As will become apparent, this capital-skill complementarity is crucial for our results (see Remark 2 below). It is well-supported by empirical evidence (see, e.g., Goldin and Katz, 1998).

There are two classes of individuals. Capitalists, who don't work, and a unit mass of workers, indexed $i \in [0, 1]$, who don't own capital. They choose whether or not to acquire higher education.

Preferences of worker i are represented by the utility function

$$U(i) = \ln l(i) + \ln C(i), \tag{2}$$

where $C(i)$ is i's consumption level, $l(i) = 1$ if i remains low-skilled and $l(i) = 1 - e(i)$ if i is skilled.[5] $e(i)$ may be interpreted as effort cost of acquiring education in terms

[5] Capitalists simply maximize their income.

of foregone leisure, $l(i)$. Assuming that effort costs are individual-specific captures heterogeneity of workers with respect to learning (or cognitive) ability. For simplicity, suppose e is uniformly distributed on the unit interval.

As has been stressed in the literature, governments may adjust education policy to CMI (e.g., Gradstein and Justman, 1995). Hence, in order to derive testable hypotheses for the effect of CMI on educational attainment, one has to examine how education policy affects the relationship between integration and educational choice. We assume that the skill level of an educated worker positively depends on public education spending.[6] More precisely, let G be the level of public education expenditure and denote by $s = 1 - L$ the mass ("number") of workers participating in education, i.e., per capita spending equals G/s. Then an individual choosing education acquires G/s units of skilled labor. When s individuals acquire education − each obtaining G/s efficiency units of skilled labor − total efficiency units of skilled labor are given by $S = G$. Thus, according to (1), $G > 0$ is necessary for the economy to be viable. If an individual remains low-skilled, (s)he is endowed with one unit of low-skilled labor. Workers inelastically supply their efficiency units of labor and all factor markets are perfect.

Remark 1. We could be more general in assuming that an educated worker obtains skill level G^θ/s^α, $0 \leq \alpha \leq 1$, $\theta \leq 1$. Consequently, $S = s^{1-\alpha}G^\theta$. This education technology allows for the two extreme cases of education being a pure public good ($\alpha = 0$) or fully rival ($\alpha = 1$), as well as for intermediate cases. Moreover, $\theta < 1$ implies that the marginal productivity of public education spending, G, is decreasing. We checked that, qualitatively, our results on educational attainment remain unaffected when allowing for $\alpha < 1$ and $\theta < 1$. To keep the analysis simple we focus on the case where public education is a fully rival good and the marginal productivity of G is

[6] A standard justification for public finance of education is the incapability of individuals to borrow for educational purposes. In most advanced countries, the bulk of secondary education is indeed financed by the public sector. In Continental Europe, for instance, this is true even for tertiary education. Glomm and Ravikumar (1992) showed that a public education system arises under majority voting for plausible assumptions on the income distribution. See Gradstein, Justman and Meier (2005) for an excellent review of the literature on political economy models of public education. Our main insights would be unchanged, however, if we allowed for private education investments as well.

constant.

Education is financed by a proportional tax on wage income, with tax rate $\tau \in (0, 1)$. Public education expenditure is given by

$$G = \tau \left(w_S S + w_L L \right), \tag{3}$$

where w_S and w_L denote the wage rate per efficiency unit of skilled and low-skilled labor, respectively.

In order to determine the effects of CMI, we examine a switch from autarky, with domestic capital stock $\bar{K}$, to a small open economy, facing interest rate $\bar{r}$. In the open economy, the consumption good is tradable, capital is mobile and labor is immobile.

3 Equilibrium Analysis

Consumption (= disposable income) of worker i is determined by

$$C(i) = \begin{cases} W_S \equiv (1-\tau) w_S G/s & \text{if skilled,} \\ W_L \equiv (1-\tau) w_L & \text{if low-skilled.} \end{cases} \tag{4}$$

Denote by $\omega = w_S/w_L$ the relative wage rate (per efficiency unit) of skilled to low-skilled labor. According to (2) and (4), an individual becomes skilled if and only if

$$e(i) \leq 1 - \frac{s}{\omega G} \equiv \hat{e}(s, \omega, G), \tag{5}$$

i.e., the effort cost of education is below some threshold ability level, $\hat{e}$.[7] As e is uniformly distributed on $[0, 1]$, this implies that the share of skilled workers, s, is given

[7]Instead of assuming that education costs are in terms of foregone leisure, we could alternatively assume that they are in terms of foregone wages as a low-skilled worker, without affecting our analysis. To see this, suppose that utility is given by some increasing function of consumption only. The consumption level is given by $(1 - e(i))W_S$ for a skilled individual with learning time $e(i)$ − the time in which this worker cannot work as low-skilled − and W_L for a low-skilled worker. Hence, individual i aquires education if and only if $(1 - e(i))W_S \geq W_L$, which gives rise to the inequality in (5).

by $s = \hat{e}(s, \omega, G)$. Using this in (5), we obtain the relationship

$$\omega = \frac{s}{(1-s)G}. \tag{6}$$

Thus, s is increasing in both ω (which is endogenous) and G. Throughout the paper, relative disposable income, W_S/W_L, is taken as measure for the dispersion of labor earnings. According to (4) and (6):

$$\frac{W_S}{W_L} = \frac{1}{1-s}. \tag{7}$$

Any increase in the share of skilled workers is associated with higher inequality of labor earnings. This is an implication of the fact that the marginal entrant into the higher education system has effort cost $\hat{e} = s$. Thus, if more individuals choose higher education, the compensation for becoming skilled must have increased.

Denote by r the rental rate of capital. According to (1), factor prices are given by

$$r = A\beta b\,(S/K)^{1-\beta}, \tag{8}$$

$$w_S = A\,(1-\beta)\left[bK^\beta + (1-b)\,L^\beta\right] S^{-\beta}, \tag{9}$$

$$w_L = A\beta(1-b)(S/L)^{1-\beta}. \tag{10}$$

Using $S = G$ and $L = 1-s$ we get from (9) and (10)

$$\omega = \frac{1-\beta}{\beta\,(1-b)} \frac{bK^\beta(1-s)^{1-\beta} + (1-b)\,(1-s)}{G}. \tag{11}$$

After substitution of (6) for ω in (11) the following relationship between capital stock, K, and the share of skilled workers, s, results:

$$(1-\beta)\left[bK^\beta(1-s)^{2-\beta} + (1-b)\,(1-s)^2\right] - \beta\,(1-b)\,s = 0. \tag{12}$$

Equation (12) gives us s as increasing function of capital stock K; we write $s = s(K)$.[8] This relationship reflects the capital-skill complementarity embodied in (1): If K rises, the relative marginal productivity of skilled labor (ω) increases; hence, there is a higher incentive to acquire education. In the autarky case, $K = \bar{K}$ is exogenous and the share of skilled workers (denoted s_{AUT}) is given by $s_{AUT} = s(\bar{K})$. Moreover, with $S = G$ and $K = \bar{K}$, condition (8) implies that the interest rate, r_{AUT}, is given by the function

$$r_{AUT}(A, \bar{K}, G) = A\beta b \left(G/\bar{K}\right)^{1-\beta} . \tag{13}$$

This again reflects the capital-skill complementarity. r_{AUT} increases in public education expenditure G, because each skilled worker becomes more productive when G is raised. Moreover, not surprisingly, r_{AUT} is increasing in TFP, A, and, due to decreasing marginal productivity of capital, decreasing in $\bar{K}$.

In a small open economy, the capital stock, K_{SOE}, is endogenously determined while the rental rate of capital $\bar{r}$ is given by the world market. Using $S = G$ in (8), we obtain $K_{SOE} = \xi G$, where

$$\xi = \xi(A, \bar{r}) = [A\beta b/\bar{r}]^{\frac{1}{1-\beta}} . \tag{14}$$

Thus, K_{SOE} is increasing in TFP, A, and education expenditure, G, whereas it is decreasing in the rental rate of capital, $\bar{r}$. The share of skilled workers in a small open economy is given by $s_{SOE} = s(K_{SOE}) = s(\xi(A, \bar{r})G) \equiv s_{SOE}(A, \bar{r}, G)$.

According to (12), $s_{SOE} > (=, <) s_{AUT}$ if $K_{SOE} > (=, <) \bar{K}$, which is equivalent to $\bar{r} < (=, >) r_{AUT}$. Due to capital-skill complementarity, the share of skilled workers under openness is higher than under autarky if and only if additional foreign capital can be attracted. This is the case if the world market rental rate of capital is lower than the domestic autarky interest rate. We therefore have the following impact of CMI (switch from autarky to capital mobility) on educational choice.

[8] $s(K)$ exists and is unique, as the left-hand side of (12) is positive for $s = 0$, negative for $s = 1$, and strictly decreasing in s.

Proposition 1. *Capital market integration raises (does not affect, reduces) the share of skilled workers if* $\bar{r} < r_{AUT}(A, \bar{K}, G)$ *(*$\bar{r} =, > r_{AUT}(A, \bar{K}, G)$*, respectively).*

Capital-skill complementarity in the production technology gives rise to an interesting interaction between international capital markets, skill formation and the distribution of wage income in the economy. Proposition 1 suggests that CMI is beneficial (harmful) for participation in higher education in countries with a high (low) productivity of capital. (In section 5 we examine the implications of this result for growth.) With respect to equality, the opposite holds true, since CMI simultaneously affects wage income dispersion in the same direction as educational attainment, according to (7).[9] For a given stock of domestic capital, the condition for an *increase* in schooling and inequality is that a country's total factor productivity or its education spending are relatively high so that the marginal efficiency of capital lies above the world level. If the rental rate of capital required by the world market is below the autarky rate, capital demand increases and thus the relative productivity of skilled labor rises. This enhances the incentives to acquire education. In contrast, if educational spending or TFP is comparably low, both skill formation and inequality may be reduced by opening up to international capital markets, even if the domestic capital stock is low. The mechanism for this result is consistent with the fact that capital does not necessarily flow from advanced to less developed countries (e.g., Lucas, 1990), as less developed economies are typically not only characterized by a low physical capital stock but also by both a low human capital stock and low productivity. Thus, there may be an outflow of capital from these countries after integration. Our analysis suggests that this triggers an adverse effect on skill formation.

In the open economy, domestic capital input has to be financed at the cost required by the international capital market, $\bar{r}$. These cost include possible premia for business risk and impediments to investment in the country. (In the empirical analysis we use data from the Business Environment Risk Intelligence to account for these cost.) The following proposition shows how variations in international capital cost affect participa-

[9] Galor and Moav (2000) derive a similar effect from technological change instead of CMI.

tion in higher education when the economy has opened up. Moreover, the proposition shows that opening up to the international capital market has consequences for the impact of education spending and factor productivity on skill formation.

Proposition 2. *s_{SOE} rises with declining international capital cost ($\bar{r}$). Moreover, an increase in education expenditure (G) or in TFP (A) has no effect on s_{AUT}, but raises s_{SOE}.*

In view of the positive relationship between earnings inequality (W_S/W_L) and the share of skilled workers, described by (7), Proposition 2 immediately implies that an increase in G or A raises W_S/W_L in an open economy but not under autarky. Under autarky, higher public spending on education, G, has two counteracting effects on education decisions. On the one hand, it raises efficiency units per skilled worker and thereby increases the incentives to acquire education, all other things equal. On the other hand, however, the relative wage rate ω declines for given educational choices, according to (11). This second effect exactly offsets the first effect. Thus, educational decisions in autarky do not depend on G. As the distribution of earnings can only change along with the share of skilled workers, s, also inequality is unaffected. In an open economy, there is an additional effect, which gives rise to the positive impact of an increase in G on both the share of skilled workers and earnings inequality. An increase in G, by raising aggregate skill level S, attracts capital to the economy. This raises the productivity of skilled labor and its relative wage so that the incentives to become skilled are higher than under autarky. These results will play an important role for the normative implications of CMI, analyzed in the next section.

A higher level of TFP, A, has similar effects as an increase in G. Under autarky, by raising marginal products of skilled and unskilled labor equally, an increase in A neither affects educational decisions nor inequality. With integrated capital markets, an increase in A induces capital inflow which makes education more attractive. The model suggests that, under international mobility of capital, technologically advanced countries have both higher educational attainment and higher inequality of wage income than less advanced countries, all other things equal.[10] (In section 5, we will allow for a feedback effect from participation in higher education to productivity growth, which enables us to study the relationship between CMI and growth in the model.)

Remark 2. The shown effects under capital-skill complementarity (exhibited by production technology (1)) on educational choice are considerably different to those implied by, say, a CES-production function:

$$F(K, S, L) = A\left[a_K K^\rho + a_S S^\rho + (1 - a_K - a_S)L^\rho\right]^{\frac{1}{\rho}}, \tag{15}$$

$a_K, a_S > 0$, $a_K + a_S < 1$, $\rho < 1$. To see this, note that (15) implies for the relative wage rate $\omega = (a_S/[1 - a_K - a_S])(L/S)^{1-\rho}$. After substitution of $S = G$, $L = 1 - s$ and (6), the share of unskilled workers is given by $(1 - a_K - a_S)s = a_S G^\rho (1 - s)^{2-\rho}$ in a closed as well as in an open economy. Hence, under (15), s neither depends on A nor on capital market variables ($\bar{K}$ or $\bar{r}$, respectively). International integration plays no role. A change in G has an ambiguous effect on s (and no effect in the Cobb-Douglas case, $\rho \to 0$).

The results derived in the preceding positive analysis point to an important policy issue. Suppose an economy chooses an "optimal" education spending level (according to some objective function) in autarky, G_{AUT}. How should the economy adjust education expenditure to CMI? Moreover, will the share of skilled workers increase or decrease under optimal policy adjustment when capital becomes internationally mobile? Answering the latter question is of particular importance for an empirical test of our theory, presented in section 6. If governments adjust their education policy to CMI, one has to account for the endogeneity of public education expenditures.

[10]Krusell, Ohanian, Ríos-Rull and Violante (2000) propose an explanation of the apparent rise in wage dispersion in the US in the 1980s and 1990s which is consistent with our analysis. They show empirically that higher investment in physical capital in the U.S. can explain the evolution of wage inequality and they emphasize the role of capital-skill complementarity, when discussing the economic intuition behind their findings.

4 Optimal Education Policy

To characterize the optimal education policy, conditional on the capital market regime (open or closed), we first have to specify the policy objective. We employ a Rawlsian welfare function. That is, education policy is optimal when utility of the low-skilled, $\ln W_L$, is maximized. (Remark 3 below shows that results would qualitatively be unchanged under a utilitarian welfare function.) Using (3), the net wage of the low-skilled, $W_L = (1-\tau)w_L$, can be written as $W_L = w_L - G/(\omega S + L)$. After substituting $S = G$, (6), (10) and $L = 1-s$, and rearranging terms, the expression for W_L reads

$$W_L = A\beta(1-b)\left(\frac{G}{1-s}\right)^{1-\beta} - \frac{(1-s)G}{1-s+s^2} \equiv V(A,s,G). \tag{16}$$

Optimal education spending under autarky, denoted by G_{AUT}, is given by $G_{AUT}(A,\bar{K}) = \arg\max_{G\geq 0} V(A, s(\bar{K}), G)$. It is easy to see that there exists an interior and unique solution for G_{AUT}, with the following property.

Proposition 3. *G_{AUT} is increasing in A.*

Under autarky, technologically advanced economies should spend more on education than technologically backward economies. This is because skilled and low-skilled labor are complementary factors of production; when G (and thus S) increases, also wage rate w_L increases. According to (10), this increase is more pronounced if A is high.

Under openness, $W_L = V\left(A, s_{SOE}\left(A,\bar{r},G\right),G\right) \equiv \tilde{V}(A,\bar{r},G)$. Welfare $\tilde{V}\left(A,\bar{r},G\right)$ may be ever increasing in public education expenditure G, due to the positive interaction between G and capital inflow in an open economy. That is, there may be no interior solution for the optimal policy problem. However, the following can be shown.

Lemma 1. *If $A < \frac{(\bar{r}/\beta)^{\beta}}{b(1-\beta)^{1-\beta}} \equiv \hat{A}$, $\tilde{V}\left(A,\bar{r},G\right)$ has an interior and unique maximum.*

Proposition 1 has shown, for given education expenditure G, how the impact of CMI on the share of skilled labor, s, depends on the pattern of capital flows. We now turn to the question how s changes after CMI when public education expenditure is adjusted optimally to $G_{SOE}(A, \bar{r}) \equiv \arg\max_{G \geq 0} \tilde{V}(A, \bar{r}, G)$. That is, we compare the share of skilled labor $s^*(A, \bar{r}) \equiv s_{SOE}(A, \bar{r}, G_{SOE}(A, \bar{r}))$ with the pre-integration level, $s_{AUT} = s(\bar{K})$. Moreover, we explore in which direction optimal adjustment of public education expenditure tends to go when we start from G_{AUT}, the optimal education policy under autarky. That is, we analyze whether $G_{AUT} < G_{SOE}$ or $G_{AUT} > G_{SOE}$.

Suppose first that the cost of capital to be paid in the integrated capital market equals the autarky interest rate. That is, $\bar{r} = r_{AUT}(A, \bar{K}, G_{AUT}(A, \bar{K}))$, and consequently, $K_{SOE} = K_{AUT}$ and $s_{SOE} = s_{AUT}$. The following proposition states that in this case G_{AUT} is too low under capital mobility.

Proposition 4. *Suppose $A < \hat{A}$ and $\bar{r} = r_{AUT}(A, \bar{K}, G_{AUT})$. Then $G_{SOE} > G_{AUT}$.*

Proposition 4 shows that even integration with identical other economies has severe consequences for the competitive position of an economy. Our analysis suggests to expand education expenditure after integration if the economy's rental rate of capital resembles the rate in the other economies.[11] Before discussing this result, we consider how the impact of CMI on s depends on the pattern of capital flows when education policy is adjusted optimally.

Proposition 5. *Suppose $A < \hat{A}$. If $\bar{r} \leq r_{AUT}(A, \bar{K}, G_{AUT})$, then $s^*(A, \bar{r}) > s(\bar{K})$. By contrast, if $\bar{r} > r_{AUT}(A, \bar{K}, G_{AUT})$, then $s^*(A, \bar{r}) <, =, > s(\bar{K})$ is possible. Moreover, s^* is increasing in A.*

According to Proposition 4, if education spending was at its optimal level under autarky and the return to capital before integration is at the level required by the world market, education spending should increase when capital becomes internationally mobile ($G_{SOE} > G_{AUT}$). This is because the economy can attract foreign capital by raising G (as $K_{SOE} = \xi G$). In turn, this enhances incentives to acquire education (recall $s'(K) > 0$). In sum, the share of skilled labor increases under optimal policy

[11] This may give rise to an inefficient equilibrium in a non-cooperative game between governments, like in Gradstein and Justman (1995) and Viaene and Zilcha (2002a). As our goal is to derive testable hypotheses with respect to the effects of CMI, we do not explore this issue further.

adjustment, i.e., $s^* > s_{AUT}$. This result also holds when the autarky interest rate is higher than the international capital cost ($\bar{r} < r_{AUT}$). This is because, for $\bar{r} < r_{AUT}$, according to Proposition 1, s rises after integration even if education policy remains unchanged. In contrast, if $\bar{r} > r_{AUT}$, s decreases after integration when G is held constant. According to Proposition 5, even if integration tends to raise the optimal G, the adjustment should not necessarily be strong enough to offset this negative effect on the demand for education. As a result, s may or may not remain below its autarky level. The final result in Proposition 5 implies that, under openness, the share of skilled labor under optimal education policy should be higher when the economy is more advanced technologically.

Remark 3. Our main results would be unchanged when a utilitarian rather than a Rawlsian welfare function is employed. To see this, note that in view of (2), (4) and $l(i) = 1 - e(i)$, we have $\int_0^1 U(i)di = \int_0^{\hat{e}} [\ln(1-e(i)) + \ln W_S]\, di + \int_{\hat{e}}^1 \ln W_L di$, where $\hat{e}$ is the threshold defined by (5). By definition, $\ln W_S = \ln W_L - \ln(1-\hat{e})$. Using this, we can write[12]

$$\int_0^1 U(i)di = \ln W_L + \int_0^{\hat{e}} [\ln(1-e(i)) - \ln(1-\hat{e})]\, di, \tag{17}$$

where the second summand on the right-hand side of (17) is an increasing function of $\hat{e}$. In the autarky equilibrium, $\hat{e} = s(\bar{K})$. Thus, under autarky, Rawlsian welfare ($\ln W_L$) and utilitarian welfare only differ by a constant such that normative results are the same. Under openness $\hat{e} = s_{SOE}(A, \bar{r}, G)$. Since $s_{SOE}(A, \bar{r}, G)$ increases in G (Proposition 2) there is an additional incentive for the social planner to invest in education compared to Rawlsian welfare. This strengthens our result that CMI tends to increase public education expenditures and participation in higher education.

Some further remarks are in order. With respect to an optimal adjustment of education policy, only the case $\bar{r} = r_{AUT}(A, \bar{K}, G_{AUT})$ has been considered in Proposition 4. For examining the optimal response of education policy in the case $\bar{r} \neq$

[12] Note that $\int_0^1 \ln W_L = \ln W_L$, since W_L does not depend on $e\,(i)$.

$r_{AUT}(A, \bar{K}, G_{AUT})$ one should know how G_{SOE} is affected by changes in $\bar{r}$. For instance, if G_{SOE} decreases in $\bar{r}$, then the effect underlying Proposition 4 is strengthened, so that $\bar{r} < r_{AUT}(A, \bar{K}, G_{AUT})$ would also imply $G_{SOE} > G_{AUT}$.

Table 1: Optimal education policy under openness ($b = \beta = A = 0.5$).

$\bar{r}$	G_{SOE}	s^*
0.02	0.06	0.584
0.05	0.02	0.449
0.08	0.02	0.426
0.11	0.03	0.421
0.14	0.04	0.418

However, numerical analysis reveals that the impact of a change in $\bar{r}$ on optimal education expenditure can go in both directions. According to Tab. 1, if $\beta = b = A = 0.5$, G_{SOE} first decreases but then increases with $\bar{r}$. Thus, although CMI gives an incentive for the public sector to increase G when there is no interest rate differential, general results with respect to the optimal adjustment of G are difficult to obtain. (Tab. 1 also illustrates the role of the world market interest rate for s^* as stated in Proposition 5, showing that s^* monotonically declines when $\bar{r}$ rises.)

The answer given in Proposition 5 on how s is expected to react under optimal adjustment of G to integration, together with the prediction derived for a given education policy (Propositions 1 and 2), will turn out very useful for deriving a testable hypothesis for the relationship between capital market integration, education policy, and participation in higher education in section 6, where we provide empirical evidence.

5 Capital Market Integration and Growth

This section extends the basic model to a simple growth framework in discrete time $t = 0, 1, 2, ...$ in order to study the implications of CMI for growth. Suppose there are overlapping generations with two-period lives. In the first period of life, individuals live by their parents and decide whether or not to acquire education. In the second period (adulthood), they consume and work full-time, again, inelastically supplying their skills to a perfect labor market. An individual i born in $t-1$ is endowed with one unit of time in $t-1$ and characterized by $e_{t-1}(i)$, the time required to acquire education. That is, $l_{t-1}(i) = 1 - e_{t-1}(i)$ is leisure in the first period of life. We assume that the distribution of e is time-invariant and again uniform on $[0,1]$. Like in the basic model, utility of member i of generation $t-1$ is given by $U_{t-1}(i) = \ln l_{t-1}(i) + \ln C_t(i)$, where $C_t(i)$ is consumption as adult. Taxes are levied on individuals who are currently working, where the government's budget is balanced in each period. That is, workers from generation $t-1$ (working in t) finance the education of individuals from generation t. The production and education technology are the same as in the basic model. Thus, $S_t = G_{t-1}$.

The key assumption in this section is that the TFP growth rate, $g^A_{t+1} = A_{t+1}/A_t - 1$, is an increasing and concave function of the share of skilled labor in t, s_t. This formulation is a reduced-form for the positive effects of human capital for growth which have been suggested by the literature.[13] In addition, we account for the possibility that g^A_{t+1} depends on total efficiency units of skilled labor, S_t. Finally, to allow for (conditional) convergence, we suppose that g^A_{t+1} is a decreasing function of the level of TFP. Formally, $g^A_{t+1} = \tilde{g}(s_t, S_t, A_t)$, where $\tilde{g}_s > 0$, $\tilde{g}_{ss} \leq 0$, $\tilde{g}_S \geq 0$ and $\tilde{g}_A < 0$; $A_0 > 0$ is given. For the sake of concreteness, we specify $\tilde{g}(s, S, A) = (s/A)^\gamma S^\varepsilon - \delta$, $0 < \gamma < 1$, $\varepsilon \geq 0$ and $\delta > 0$.[14] This implies that A evolves over time according to

$$A_{t+1} = s_t^\gamma A_t^{1-\gamma} S_t^\varepsilon + (1-\delta) A_t \equiv f(s_t, S_t, A_t). \tag{18}$$

Applying the equilibrium analysis of section 3, $s_t = s(\bar{K})$ for all t under autarky and $s_t = s_{SOE}(A_t, \bar{r}, G_{t-1})$ under capital mobility.[15] Thus, under openness, growth

[13]That TFP growth positively depends on human capital measures is well-supported empirically (and used in various theoretical frameworks; see, e.g., Galor and Moav, 2000, among others), be it through externalities as suggested by Lucas (1988), through political institutions (Glaeser, La Porta, Lopez-de-Silanes and Shleifer, 2004) or through (R&D-driven) productivity improvements (Hojo, 2003).

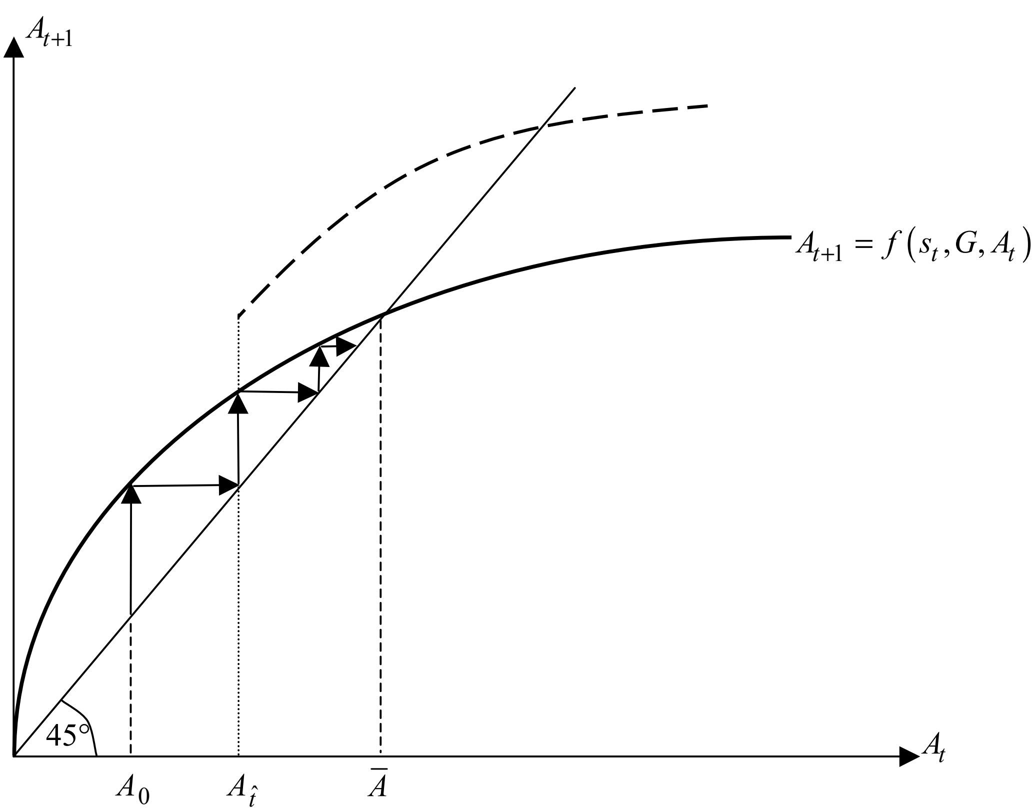
[14]$\delta > 0$ reflects depreciation of knowledge over time.

[15]Individuals base educational decisions in their first period of life on publicly provided resources in

fosters education by raising the level of TFP (Proposition 1) and, conversely, education determines TFP growth, according to (18). The next result characterizes dynamic properties of TFP which arise from these links.

Proposition 6. *Let $G_{t-1} = G$ for all t. (i) Under autarky and, if $\beta \leq 1/2$, also under capital mobility, TFP converges to a unique level $\bar{A} = (G^{\varepsilon}/\delta)^{1/\gamma}\,\bar{s}$, where $\bar{s} = s(\bar{K})$ under autarky and $\bar{s} = s_{SOE}(\bar{A}, \bar{r}, G)$ under capital mobility. (ii) If $A_0 < \bar{A}$, then under autarky and, provided that $\beta \leq 1/2$, also under capital mobility, the TFP growth rate, g^{A}_{t+1}, is strictly decreasing over time.*

Figure 1: The evolution of total factor productivity ($G_{t-1} = G_t$ for all t).



As shown in the proof of Proposition 6, under autarky and, for $\beta \leq 1/2$, also under capital mobility, TFP evolves as depicted in Fig. 1. To avoid uninteresting technical

this period (which also determine their effective labor supply in the second period) and on the level of TFP in the next period, which evolves according to (18).

discussions, we focus on $\beta \leq 1/2$ in the following.[16]

Suppose that $G_{t-1} = G$ for all t. Then from Proposition 6 it follows that under autarky steady state TFP level, $\bar{A}$, is increasing in G if $\varepsilon > 0$ and independent of G if $\varepsilon = 0$. As G does not affect educational decisions under autarky (Proposition 2), education policy affects $\bar{A}$ only when there is a direct link of S to the evolution of TFP (i.e., when $\varepsilon > 0$). In contrast, under openness, higher education expenditures foster TFP regardless of ε, because an increase in G attracts capital and thereby raises the incentives to become skilled. Consequently, under openness, if $\beta \leq 1/2$, $\bar{A}$ is increasing in G.

What is the impact of CMI on steady state TFP level and TFP growth rate (when $\beta \leq 1/2$)? Suppose that CMI takes place in period $\hat{t}$ and individuals adjust their education decision already in $\hat{t}-1$. If $\bar{r} = r_{AUT}(A_{\hat{t}}, \bar{K}, G)$, the share of skilled workers, $s_{\hat{t}}$, is unchanged for any given TFP level (Proposition 1); therefore curve $f(s_t, G, A_t)$ in Fig. 1 is unchanged by integration in this case. This implies that both the steady state TFP level, $\bar{A}$, and the TFP growth process remain unaffected, i.e., with or without CMI growth slows down over time as TFP converges to $\bar{A}$.[17] If $\bar{r} < r_{AUT}(A_{\hat{t}}, \bar{K}, G)$, however, then, according to Proposition 1, $s_{\hat{t}}$ rises in reaction to capital inflows. This shifts the curve $f(s_t, G, A_t)$ upward after CMI in $\hat{t}$, as indicated by the dashed curve in Fig. 1. This raises TFP growth in the subsequent period. Later on, effects of CMI on the TFP growth rate are unclear, because the speed of convergence increases after CMI. But clearly, $\bar{A}$ rises in response to CMI in this case. Finally, if $\bar{r} > r_{AUT}(A_{\hat{t}}, \bar{K}, G)$, then $\bar{A}$ declines and TFP growth slows down in response to CMI in period $\hat{t}$ because $s_{\hat{t}}$ decreases.

So far we have focussed on TFP rather than on GDP per worker, Y_t. For analyzing GDP, we first rewrite (12) in the form $bK^{\beta} + (1-b)(1-s)^{\beta} = \kappa s (1-s)^{-(2-\beta)}$, where $\kappa \equiv \beta(1-b)/(1-\beta)$. Substituting this into (1) and using $L_t = 1 - s_t$, $S_t = G_{t-1}$, we

[16] In fact, also for $\beta > 1/2$ TFP can evolve like in Fig. 1. $\beta \leq 1/2$ is sufficient but not necessary for the results in this section.

[17] Recall that G is held constant in this section.

obtain

$$Y_t = \kappa A_t \frac{s_t}{(1-s_t)^{2-\beta}} (G_{t-1})^{1-\beta} . \tag{19}$$

Hence, when $G_{t-1} = G$, the steady state level of GDP is given by $\bar{Y} = \kappa \bar{A} \bar{s}(1-\bar{s})^{-(2-\beta)} G^{1-\beta}$, where $\bar{s} = s(\bar{K})$ under autarky and $\bar{s} = s_{SOE}(\bar{A}, \bar{r}, G)$ under capital mobility. Consequently, $\bar{Y}$ increases in G under both autarky or openness.[18] Thus, with respect to steady state levels, the only qualitative difference between the results for $\bar{Y}$ and $\bar{A}$ is that $\bar{Y}$ is increasing in G also if $\varepsilon = 0$, as $S = G$ enters the production function directly.

If education spending does not change over time, the GDP growth rate, $g^Y_{t+1} = Y_{t+1}/Y_t - 1$, is given by

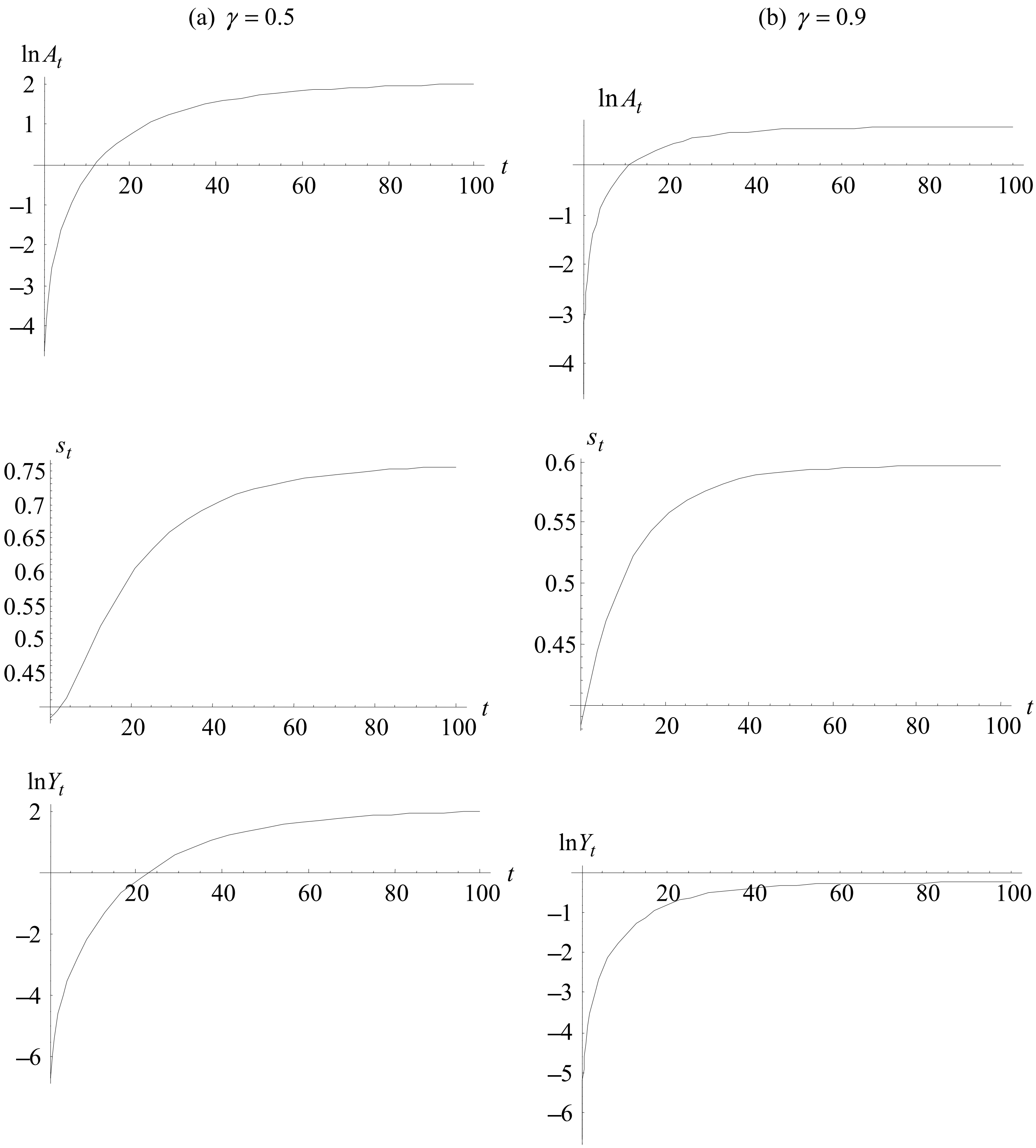
$$g^Y_{t+1} = (g^A_{t+1} + 1) \frac{s_{t+1}/(1-s_{t+1})^{2-\beta}}{s_t/(1-s_t)^{2-\beta}} - 1, \tag{20}$$

according to (19). Under autarky, where $s_t = s(\bar{K})$ for all t, (20) implies $g^Y_{t+1} = g^A_{t+1}$. Thus, the result of Proposition 6 on g^A_{t+1} one to one carries over to GDP growth. For given education spending, g^Y_{t+1} is decreasing over time in autarky. Under openness, the situation is more complicated since $s_t = s_{SOE}(A_t, \bar{r}, G)$ changes with productivity growth. We were not able to derive analytically a sufficient condition for convergence of g^Y_t with a general economic interpretation. So we checked convergence numerically. Fig. 2 illustrates, for two different values of γ (denoting the elasticity of TFP with respect to s), the evolution of $\ln Y_t$, together with the evolution of $\ln A_t$ and s_t. It shows the slowdown of TFP growth rate g^A_{t+1} as well as a slowdown of GDP growth over time. It is interesting to note from Fig. 2 that the share of skilled labor s_t converges rather quickly along with TFP and GDP.

The following proposition establishes that, qualitatively, the results regarding the impact of CMI on TFP variables carry over to GDP variables.

[18]For the case of an open capital market regime, recall that $\bar{Y}$ exists if $\beta \leq 1/2$ and that s_{SOE} is increasing in G, according to Proposition 2.

Figure 2: Numerical illustrations of growth and participation in higher education in the open economy ($G = \overline{r} = 0.1$, $b = \beta = \varepsilon = 0.5$).



Proposition 7. *Suppose that capital markets become integrated in period $\hat{t}$ and GDP growth rate g^Y_{t+1} declines over time for a given capital market regime. If $\bar{r} = r_{AUT}(A_{\hat{t}}, \bar{K}, G)$, then both the steady state GDP level, $\bar{Y}$, and the GDP growth process remain unaffected by CMI. If $\bar{r} < r_{AUT}(A_{\hat{t}}, \bar{K}, G)$, then both $\bar{Y}$ and $g^Y_{\hat{t}+1}$ rise in response to CMI. If $\bar{r} > r_{AUT}(A_{\hat{t}}, \bar{K}, G)$, then both $\bar{Y}$ and $g^Y_{\hat{t}+1}$ decline in response to CMI.*

Together, CMI effects and convergence properties imply that technological progress and GDP growth are lower after integration (than before) in economies with capital outflows. If CMI leads to capital inflows, integration and convergence effects work in opposite directions. Since GDP growth slows down during the transition to the steady state when all other things remain equal, even capital-importing economies may see a decline in GDP growth when some time has passed after integration. But this is an implication of convergence properties rather than the impact of integration. The immediate growth effect of CMI is positive in these economies, as technological progress is unambiguously spurred. The reason is that educational attainment increases in economies which attract capital when capital markets integrate.

Before turning to the empirical test of our theoretical results, we want to point to a novel channel regarding the link between inequality of labor earnings, technological change and growth. According to our analysis, integration either affects both inequality and TFP positively or both negatively, i.e., there is always a positive relationship between inequality and technological change. The mechanism behind this relationship is very different to those suggested by the literature on skill-biased technological change.[19] In our model, the direct impact of technological change is neutral, but there are indirect effects from capital mobility. Capital inflows affect the economy like skill-

[19] For an excellent review of this literature, see Acemoglu (2002). The hypothesis on skill-biased technological change has been primarily motivated by the observation that an increase in the supply of skilled labor and rising skill differentials evolved in parallel in the 1980s and 1990s, particularly in the US and the UK. Our analysis suggests that also increased international capital flows can account for this pattern, especially when allowing for changes in (optimal) public education expenditure as response to CMI. The US has experienced large capital inflows especially in the 1990s. This may be part of the reason why earnings inequality appears to have increased so much more than in Continental Europe. The causes of this pattern are still under debate (see, e.g., Acemoglu, 2002) and our model may prove useful to contribute to it in future research.

biased technological change does, whereas capital outflows are like low-skilled-biased technological change. Moreover, integration affects participation in higher education, which has feedback effects on both inequality and technological progress.

6 Empirical Analysis

The theoretical analysis suggests a set of testable hypotheses that can be summarized in the following way:

1. Net capital inflows (outflows) induce an increase (a decline) in participation rates for higher education at a given level of public education expenditures (Proposition 1). In the empirical implementation, we employ logarithm of inflows minus logarithm of outflows as a measure of net capital flows. This variable is used as one determinant to explain participation in higher schooling. Under the null hypothesis, net capital inflows exhibit a non-positive impact on higher schooling. The corresponding alternative hypothesis is referred to as H_1^a.

2. A reduction in investment barriers (leading to lower capital cost) and an increase in public education expenditure stimulate participation in higher education through higher capital inflows (Proposition 2). Moreover, changes in investment barriers induce adjustments of public education expenditure (Propositions 4 and 5). We refer to this hypothesis as H_1^b. Under the corresponding null hypothesis, a reduction in investment barriers and an increase in endogenous public education expenditure exhibit a non-positive impact on a country's higher schooling through capital inflows.

3. Net capital inflows induce an increase in the growth of GDP per worker through their positive effect on participation in higher education, given the domestic capital stock and initial GDP (Proposition 7). We will test the corresponding null hypothesis of a non-positive impact of endogenous higher education on the growth of GDP per worker against its alternative hypothesis H_1^c.

For empirical inference, we first specify the average annual change of a country's higher schooling as a function of net capital inflows (H_1^a) and other controls, and then as one of a reduction in investment barriers and changes in endogenous public education expenditures (working through capital inflows - H_1^b) as well as other controls. We think of capital flows as ones of production capital and therefore use flows of direct foreign investment rather than portfolio investment. Finally, we run regressions of growth in GDP per worker on the change in higher schooling (H_1^c) among other controls such as the initial level of GDP per worker.[20] Thereby, we treat first the change in higher schooling (reflecting H_1^a) and then also the net capital inflows (reflecting H_1^b) as endogenous. In doing so, we use those explanatory variables of higher schooling (H_1^a and H_1^b) as instruments, which do not directly affect growth in GDP per worker. We also account for the endogeneity of public education expenditure.

For the higher schooling variable in the empirical models, we rely on data that are provided in the updated dataset by Barro and Lee (2000). This dataset covers the time span 1960-2000. Specifically, we use the years of schooling for higher (post-secondary) education in the total population as a measure of higher schooling. As we show in a sensitivity analysis, our results are qualitatively independent of which measure of higher schooling is employed.[21] From the Penn World Table, we use data on the initial level and average annual growth of real GDP per worker (U.S. dollars in 1996 constant prices, chain series), the initial level and average annual growth of the number of workers, and the initial level of real domestic investment (U.S. dollars in 1996 constant prices, chain series) per worker as a proxy for capital stocks.[22] Data on the level and change in the share of public education spending are taken from the World Bank's World

[20]The initial level of higher schooling as well as primary schooling variables enter the regressions as determinants for capital flows and the change in higher schooling.

[21]Alternative measures would be enrollment rates in higher education or the share of population which completed higher education. According to the theoretical model, both measures are the same. In reality however, they may differ and time spent in the education system matters for skill acquisition. Therefore, we think that years of higher schooling are an adequate measure for participation in higher education. In the sensitivity analysis, we consider alternative higher education variables.

[22]The chain series approach avoids the potential bias of real growth figures associated with fixed-weighted approaches such as the Laspeyres or the Paasche index formulas applied to long time spans. With chain series, the base year changes periodically.

Development Indicators. To construct the net capital flow variable, we use information on outward and inward foreign direct investment from the World Investment Report (2002, and earlier years). Finally, we employ data on investment barriers from the Business Environment Risk Intelligence (BERI) to measure the change in investment cost over time.[23] All change variables reflect average annual growth rates. In the Appendix, we give a list of the covered countries. Also, an overview of the descriptive statistics for the data in use is given there.

Table 2 summarizes our findings with respect to the first and the second alternative hypothesis: the positive impact of an increase in net inward investment on higher schooling (H_1^a), and the positive impact of a reduction in investment barriers and (endogenous) public education spending (H_1^b).

The results from three regressions are reported.[24] In Model (1), we include both the change in net capital inflows and the change in public expenditure on education. To account for size effects in education expenditure and capital inflows, we include the change in the number of workers as a separate explanatory variable. In addition, we control for the initial levels of public education expenditure, GDP per worker, and the number of workers. They are included to estimate the net impact of the direct determinants (changes in international capital flows and adjustments in public education expenditure) on higher schooling. We find a significant positive effect of both the change in net capital inflows and that in public education expenditure on higher schooling. However, our theoretical analysis suggests that the impact of public education expenditure works primarily through net capital inflows.

To cope with this, we treat net capital inflows as an endogenous variable in Model (2) and estimate the parameters by two-stage least-squares (IV-2SLS), using the following identifying instruments:[25] the change in public education expenditure, both the

[23]This measure is also used by Blonigen, Davies and Head (2003) and Blonigen, Davies, Waddell and Naughton (2004), who are interested in the FDI decisions of multinational firms.

[24]Our theoretical model puts forward hypotheses related to *higher* schooling. From an alternative set of regressions based on *primary* schooling (not reported for the sake of brevity) we know that the same determinants affect primary schooling very differently from higher schooling. The results are available from the authors upon request.

[25]In the first-stage regression, net capital inflows are projected on the full set of exogenous variables. The latter includes the exogenous variables of the second-stage regression that determine the change

Table 2: Net capital inflows induce an increase in participation in higher education (H_1^a). Investment barriers and education spending work through net capital inflows (H_1^b)

	Dependent variable is average annual change in years of higher schoooling[a]					
	(1)		(2)[b]		(3)[c]	
Explanatory variables	β	std.	β	std.	β	std.
Change variables (average annual change)						
Net capital inflows	0.2974	0.1796 *	1.3329	0.6204 **	-	-
Reduction in investment barriers	-	-	-	-	0.0517	0.0304 *
Ln public education expenditure	0.0178	0.0092 *	-	-	0.1143	0.0682 *
Ln number of workers	0.0603	0.1220	0.0387	0.1287	0.0016	0.2115
Constant	-0.0473	0.0056 ***	-0.0518	0.0083 ***	-0.1083	0.0384 ***
Level variables (initial period)						
Ln public education expenditure	0.0010	0.0003 ***	0.0011	0.0004 ***	0.0010	0.0005 **
Ln real GDP per worker	0.0031	0.0009 ***	0.0033	0.0011 ***	0.0040	0.0015 ***
Ln number of workers	-0.0012	0.0030	-0.0022	0.0034	-0.0021	0.0036
Observations (countries)	87		79		79	
Estimation approach	OLS		IV-2SLS		IV-2SLS	
R^2	0.6090		0.7604		0.7786	
Root mean squared error in higher schooling equation	0.0044		0.0051		0.0057	
Exogeneity of net capital inflows (p-value of Hausman-Wu F-test)	-	-	0.0146		0.0222	
Instrument relevance (p-value of F-test)	-	-	0.0246		0.0684	
Instrument adequacy (p-value of Hansen J statistic)	-	-	0.1730		0.1497	

Notes:

[a] Using the variable labelled "HYR" in the Barro and Lee (2000) dataset.

[b] Net capital inflows are endogenous, using the following instruments: the change in ln public education expenditure, both initial level and change in primary schooling, initial level in higher schooling, initial level of net capital inflows, reduction in investment barriers.

[c] Public education spending is endogenous, using the following instruments: both initial level and change in primary schooling, initial level in higher schooling, initial level of net capital inflows.

Reported standard errors are robust to heteroskedasticity.

***, **, * indicates that coefficients are significant at 1 percent, 5 percent, and 10 percent, respectively.

initial level and the change in primary schooling, the initial level in higher schooling, the initial level of net capital inflows, and the reduction in investment barriers.[26] Changes in public education expenditure affect the marginal productivity of capital and thus the demand for capital. A reduction in investment barriers leads to lower capital cost and should therefore stimulate net foreign investment. Initial education levels are used as instruments to capture the fact that whether CMI leads to an inflow or outflow of capital depends on the economy's marginal productivity of capital under autarky, which is positively related to the autarky education level (due to capital-skill complementarity). As indicated by the p-value of the Hausman-Wu test, the null hypothesis of the exogeneity of net capital inflows is rejected at 5 percent, given the chosen specification. According to the p-values of the tests on instrument relevance and adequacy (overidentification), the choice of instruments seems appropriate from an econometric point of view. We find that an increase in net capital inflows is significantly positively related to higher schooling as predicted by Proposition 1. The coefficient of net capital inflows is now significant at 5 percent and much higher than in Model (1). According to the parameter estimates and the descriptive statistics reported in Table 6 in the Appendix, net capital inflows induce a change in higher schooling of $0.0005 * 1.3329 = 0.0007$ or about one tenth of the average change in higher schooling (which is 0.0077). Furthermore, as predicted by Proposition 2, the reduction in investment barriers and changes in public education spending primarily work through adjustments in net capital flows.[27]

In Model (3), we investigate the role of endogenous public education expenditure. To reduce the potential efficiency loss from weak instruments, we specify an alternative IV-2SLS approach and employ net capital inflows in a reduced form, there. In this model, we use the following set of identifying instruments: both the initial level and the change in primary schooling, the initial level in higher schooling, and the initial

in higher schooling directly, plus the identifying instruments of net capital inflows that influence the change in higher schooling only indirectly.

[26]The observations of eight countries are lost from Model (2) onwards due to lacking data on investment barriers. These countries are Benin, Central African Republic, Dominican Republic, Fiji, Lesotho, Mauritius, Nepal, and Rwanda.

[27]The instruments pass the overidentification test, indicating that they do not have an additional direct effect on the change in higher schooling years beyond their impact working through changes in net capital inflows.

level of net capital inflows. Again, the choice of instruments seems appropriate from an econometric point of view and the exogeneity of public education expenditures is significantly rejected, according to the p-value of the Hausman-Wu test. This confirms Propositions 4 and 5. Note that both the reduction in investment barriers and the growth of public education expenditure exert a significant positive impact on higher schooling once they replace net capital inflows in a reduced form. Hence, we may conclude that these determinants affect higher schooling primarily through the channel of net capital inflows, as hypothesized in the theoretical model (Proposition 2).

Table 3 assesses the question how net capital inflows affect growth of real GDP per worker through a change in higher schooling (H_1^c). In the treatment of the endogenous change in higher schooling, we account for H_1^a and H_1^b – confirmed in Table 2. The initial level of higher schooling is not included as a separate explanatory variable in the growth of GDP per worker Models (4)-(6). Rather, we use the initial level of higher schooling – like initial levels of education spending and primary schooling – as an explanatory variable of the change in higher schooling and the change in net capital inflows. This points to a specific channel through which the initial level of higher schooling can work.[28]

In Model (4), we run a two-stage least squares instrumental variable regression (IV-2SLS). The corresponding first-stage model regresses the change in higher schooling on all identifying instruments plus the explanatory variables in the second-stage model. Hence, for inference of the impact of an identifying instrument on an endogenous variable, we always have to condition on the explanatory variables in the second-stage regression. Alternatively, we run three-stage least squares system regressions (SYS-3SLS). First of all, a SYS-3SLS approach allows us to treat net capital flows and public education expenditures as two endogenous variables that are explained

[28]In a robustness analysis, we have included the initial level of higher schooling as a separate control variable in the growth of GDP per worker regressions. However, a significant additional effect of this variable could not be identified, when controlling for the change in higher years of schooling, the initial level of the capital stock per worker, and the initial level of real GDP per worker. Therefore, we have excluded this variable in the models displayed in Table 3.

Table 3: Net capital inflows induce an increase in growth of GDP per worker through participation in higher education (H_1^c)

	Dependent variable is average annual change in ln real GDP per worker (1996; chain series)					
	(4)[a]		(5)[b]		(6)[c]	
Explanatory variables	β	std.	β	std.	β	std.
Change variables (average annual change)						
Higher schooling years	3.9437	1.2553 ***	4.3774	0.7637 ***	2.2150	0.9129 **
Ln public education expenditure	-	-	-	-	0.6621	0.1121 ***
Ln number of workers	-0.5046	0.6870	-0.2645	0.3775	-1.2278	0.3772 ***
Constant	0.1842	0.0435 ***	0.2015	0.0346 ***	0.1280	0.0303 ***
Level variables (initial period)						
Ln capital stock per worker	0.0042	0.0021 **	0.0037	0.0027	0.0081	0.0026 ***
Ln real GDP per worker	-0.0256	0.0058 ***	-0.0277	0.0054 ***	-0.0225	0.0041 ***
Observations (countries)	79		79		79	
Estimation approach	IV-2SLS		SYS-3SLS		SYS-3SLS	
Root mean squared error in growth of GDP per worker equation	0.0286		0.0201		0.0242	
Relevance of explanatory variables (p-value of F-test in growth of GDP per worker equation)	0.0003		0.0000		0.0000	
Relevance of explanatory variables (p-value of F-test in higher schooling years equation)	0.0293		0.0000		0.0000	
Relevance of explanatory variables (p-value of F-test in net capital inflow equation)	reduced form		0.0247		reduced form	
Relevance of explanatory variables (p-value of F-test in education expenditure equation)	reduced form		reduced form		0.0085	

Notes:

Using the variable labelled "HYR" in the Barro and Lee (2000) dataset as an endogenous measure of higher schooling.

[a] Higher schooling is endogenous, using the following instruments: initial level of ln education spending, initial level in primary schooling, initial level and reduction in investment barriers, initial level of net capital inflows, initial level in higher schooling, initial level of ln number of workers. P-value of Hausman-Wu F-test on exogeneity of higher schooling years is 0.0000. P-value of Hansen J-statistic on instrument adequacy (over-identification) is 0.2044.

[b] Higher schooling and net capital inflows are endogenous, using the following explanatory variables. Higher schooling: change and initial level of net capital inflows, initial level of ln real GDP per worker, initial level of higher schooling, initial level of ln education spending, initial level of ln capital per worker, change and initial level of ln number of workers. Net capital inflows: initial level of ln real GDP per worker, initial level of primary schooling, initial level of higher schooling, initial level of ln education spending, reduction in investment barriers, initial level of ln number of workers.

[c] Higher schooling and public education spending are endogenous, using the following explanatory variables. Higher schooling: initial ln GDP per worker, initial ln capital per worker, change in education expenditures, change in ln workers. Public education expenditures: initial ln capital per worker, reduction in and initial level of investment bariers, initial level of net capital inflows, initial level of ln workers.

Reported standard errors are robust to heteroskedasticity.

***, **, * indicates that coefficients are significant at 1 percent, 5 percent, and 10 percent, respectively.

by differing sets of explanatory variables.[29] Hence, we can account for the economic mechanisms identified in the theoretical model more adequately. For instance, we can exclude direct determinants of the growth in GDP per worker equation from the growth in higher schooling equation, if they are irrelevant in the latter equation. Second, we can allow endogenous variables to exert an impact on each other in a way that lies beyond the possibilities of IV-2SLS.[30] Third, SYS-3SLS is efficient and, in small samples, it can obtain parameter estimates that are (slightly) different from their IV-2SLS counterparts. The precision of the estimates is improved as indicated by the root mean squared error in each equation (e.g., that one for the growth in GDP per worker).[31]

The specifications of the underlying first-stage regression of the IV-2SLS Model (4) are summarized in the footnote at the bottom of the table. Similarly, we report details on the specifications of the SYS-3SLS Models (5) and (6), there. In all models, the change in higher schooling is treated as an endogenous variable. According to H_1^a, higher schooling depends on net capital inflows which in turn depend on investment barriers and endogenous public education expenditure, according to H_1^b. In Model (4), we apply a reduced form approach with respect to endogenous net capital inflows and endogenous public education expenditure. Hence, the determinants (identifying instruments) of the latter two variables are used as instruments in the higher schooling first-stage regression. In particular, the reduction in investment barriers is included to account for H_1^b. In the system regression models (5) and (6), we do not run the full system of structural equations. It turns out that treating the growth rates of GDP per worker, higher schooling, education expenditures, and net capital inflows jointly as endogenous in a system of equations and accounting for their interdependence exceeds

[29]Note that this is not the case with an IV-2SLS approach, where all endogenous variables are projected on the same set of instruments.

[30]For instance, in a system of three equations, we may allow endogenous public education expenditure to co-determine higher schooling, with the latter affecting GDP per capita growth.

[31]Note that the R^2-values of IV-2SLS and SYS-3SLS are difficult to compare. Therefore, the respective values are not displayed in Table 3. What matters is the comparison of standardized statistics such as the relevance of identifying variables. Also, standardized estimates such as the root mean squared errors of the equations are comparable across specifications. These are summarized in the table.

the possibilities in this dataset. It seems preferable to replace at least one of these endogenous variables by its reduced form (see the table for details). Accordingly, the results of Models (5) and (6) are based on a system of three rather than four equations. In both SYS-3SLS models, we treat the growth rate of GDP per worker and that of higher schooling as two structural equations. Model (5) specifies the change in net capital inflows in a structural way. The model accounts for the dependence of higher schooling on capital flows which in turn depend on investment barriers. Endogenous adjustments in public education expenditure are employed in a reduced form. Similar to Model (4), Model (5) does not account for a direct impact of education spending on the growth of GDP per worker, as the change in education spending is replaced by its explanatory variables in the respective reduced form approach. In comparison to this, Model (6) uses a reduced form for net capital flows and introduces a separate equation for the change in public education expenditure, instead. In particular, we account for the possibility that public education expenditure is adjusted in response to changes in investment barriers. Changes in public education expenditure are allowed to affect growth directly or through changes in the higher schooling variable.

As expected from the large body of research on Barro-type convergence regressions, we identify a significant negative impact of initial real GDP per worker on its growth (see Barro and Sala-i-Martin, 1995, for an overview). The initial level of capital stock per capita is positively related to growth of GDP per worker. The average annual change in the number of workers exhibits a significantly negative impact in Model (6) but turns out to be insignificant in Models (4) and (5). Most importantly, the growth in GDP per worker is significantly positively related to the change in higher schooling throughout. The treatment of higher schooling as an endogenous variable and the underlying choice of instruments (explanatory variables) is justified from an econometric point of view.[32] Thus, the results also confirm the hypothesis that an increase in net capital flows in response to reduced investment barriers fosters economic

[32] The instruments are relevant and adequate in the first-stage of Model (4). They pass the Hansen J-test on over-identifying restrictions, indicating that the instruments need not be included in the second-stage model. Similarly, the explanatory variables are highly relevant in all equations of the SYS-3SLS models.

growth through increased participation in higher schooling.

It is worth noting that accounting for endogeneity matters in general. To see this, we also estimated an alternative model, where the average annual change in higher schooling was treated as exogenous (not reported for the sake of brevity). By disregarding the endogeneity of this variable, the corresponding parameter estimate is severely downward biased, amounting to only 0.982. Also, based on a Hausman-Wu test in Model (4), we would conclude that the average annual change in higher schooling should not be treated as exogenous, given the chosen specification (the corresponding test statistic is significant at 1 percent throughout). According to Model (6), there is a direct impact of education expenditures on the growth of GDP per worker, in addition to the effects on participation in higher schooling. This is well in line with our theoretical analysis in section 5.

Our results on (i) the impact of net capital inflows on participation in higher education and (ii) the impact of the latter on the growth in real GDP per worker are very robust with respect to the use of alternative schooling measures. This conclusion is based on the results summarized in Tables 4 and 5. Whereas the results in Table 4 should be compared to Model (2) in Table 2, those in Table 5 refer to the ones of Model (5) in Table 3. Hence, all of the results in Table 4 are based in IV-2SLS and those in Table 5 are based on SYS-3SLS estimation.

In Models (2.1) and (5.1), we use higher schooling years of males rather than that of the total population, being identical to Models (2) and (5), respectively, in all other respects. This is to account for the fact that labor market participation of females varies considerably across different societies. The results are very similar to the original ones in qualitative terms. In Models (2.2) and (5.2), the secondary years of schooling serve as higher schooling measure. Again, the results are quite similar to those of our baseline regressions, with the main difference that the coefficient of the net capital inflow variable is smaller and insignificant in Model (2.2).[33] Finally, in Models (2.3) and (5.3) we rely on the percentage of higher schooling attained (i.e.,

[33]This indicates that secondary schooling is too broad a concept for the higher education issues addressed in this paper.

Table 4: Net capital inflows induce an increase in participation in higher education (H_1^a). Investment barriers and education spending work through net capital inflows (H_1^b). Robustness to choice of higher schooling measure

	Dependent variable is average annual change in respective measure of higher schoooling					
	(2.1)[a]		(2.2)[b]		(2.3)[c]	
Explanatory variables	β	std.	β	std.	β	std.
Change variables (average annual change)						
Net capital inflows	1.1637	0.6490 *	0.4933	2.1581	60.8323	35.1594 *
Ln number of workers	0.0656	0.1468	0.8584	0.4742 *	1.5148	5.4913
Constant	-0.0524	0.0084 ***	-0.0760	0.0282 ***	-1.7173	0.3019 ***
Level variables (initial period)						
Ln public education expenditure	0.0013	0.0005 **	0.0030	0.0013 **	0.0345	0.0129 ***
Ln real GDP per worker	0.0027	0.0012 **	0.0020	0.0039	0.1134	0.0401 ***
Ln number of workers	0	0.0039	-0.0122	0.0139	-0.0562	0.1152
Observations	79		79		79	
Estimation approach	IV-2SLS		IV-2SLS		IV-2SLS	
R^2	0.7835		0.7295		0.6766	
Root mean squared error in higher schooling equation	0.0053		0.0190		0.1900	
Exogeneity of net capital inflows (p-value of Hausman-Wu F-test)	0.0400		0.0814		0.0196	
Instrument relevance (p-value of F-test)	0.0201		0.0741		0.1184	
Instrument adequacy (p-value of Hansen J statistic)	0.1459		0.1247		0.5952	

Notes:

In this table, we estimate the same specifications as in Model (2) in Table 2, but using other schooling variables.

[a] Using the change in higher schooling of males ("HYRM" in Barro and Lee, 2000).

[b] Using the change in secondary schooling years ("SYR" in Barro and Lee, 2000).

[c] Using the change in percentage of higher schooling attained ("LH" in Barro and Lee, 2000).

Reported standard errors are robust to heteroskedasticity.

***, **, * indicates that coefficients are significant at 1 percent, 5 percent, and 10 percent, respectively.

Table 5: Net capital inflows induce an increase in growth of GDP per worker through participation in higher education (H_1^c). Robustness to choice of higher schooling measure

	Dependent variable is average annual change in ln real GDP per worker (1996; chain series)					
	(5.1)[a]		(5.2)[b]		(5.3)[c]	
Explanatory variables	β	std.	β	std.	β	std.
Change variables (average annual change)						
Higher schooling	2.7419	0.7055 ***	0.4029	0.1373 ***	0.0818	0.0246 ***
Ln number of workers	-0.4558	0.4564	-0.3541	0.3683	-0.4217	0.4626
Constant	0.1422	0.0306 ***	0.0619	0.0176 ***	0.1490	0.0348 ***
Level variables (initial period)						
Ln capital stock per worker	0.0051	0.0025 **	0.0043	0.0021 **	0.0057	0.0025 **
Ln real GDP per worker	-0.0207	0.0048 ***	-0.0096	0.0031 ***	-0.0215	0.0053 ***
Observations (countries)	79		79		79	
Estimation approach	SYS-3SLS		SYS-3SLS		SYS-3SLS	
Root mean squared error in growth of GDP per worker equation	0.0151		0.0123		0.0153	
Relevance of explanatory variables (p-value of F-test in growth of GDP per worker equ.)	0.0002		0.0005		0.0010	
Relevance of explanatory variables (p-value of F-test in higher schooling years equ.)	0.0000		0.0000		0.0000	
Relevance of explanatory variables (p-value of F-test in net capital inflow equ.)	0.0977		0.0244		0.0765	
Relevance of explanatory variables (p-value of F-test in education expenditure equ.)	reduced form		reduced form		reduced form	

Notes:

In this table, we estimate the same specifications as in Model (5) in Table 3, but using other schooling variables.

[a] Using the change in higher schooling of males ("HYRM" in Barro and Lee, 2000).

[b] Using the change in secondary schooling years ("SYR" in Barro and Lee, 2000).

[c] Using the change in percentage of higher schooling attained ("LH" in Barro and Lee, 2000).

Reported standard errors are robust to heteroskedasticity.

***, **, * indicates that coefficients are significant at 1 percent, 5 percent, and 10 percent, respectively.

the share of population that has acquired higher education) rather than the years of higher schooling. Since the units of measurement are different as compared to the originally employed higher schooling variable, the magnitude of the coefficients is not directly comparable to Models (2) and (5), respectively. However, the results are qualitatively similar across the different specifications. Overall, our finding of a (significantly) positive impact of (endogenous) net capital inflows on participation in higher schooling and of (endogenous) higher schooling on the growth of GDP per worker are robust with respect to the choice of the schooling measure employed.[34]

7 Conclusion

This research has been motivated by the strongly increasing international capital flows in the last decades, the apparent complementarity between skilled labor and physical capital, and the evidence on human capital as a factor of economic growth. We have presented theory and evidence on the impact of CMI on participation in higher education and on economic growth. We have shown that when public education expenditure is held constant, integration leads to an increase in the share of high-skilled labor, inequality and growth in capital-importing economies, whereas the opposite occurs when CMI leads to capital outflows. If we allow for optimal adjustment of public education expenditure, CMI tends to raise participation in higher education, provided induced capital-exports are not too large.

Our empirical analysis largely confirms the main hypotheses derived in this paper: First, net capital inflows − whether or not they are treated as endogenous − significantly affect participation in higher schooling, irrespective of the measure of higher education. Second, changes in investment barriers and endogenous public education spending are important determinants of net capital flows and therby affect participation in higher education. Third, capital flows significantly affect economic growth

[34]In a further sensitivity analysis, we ran Models (2) and (5) on two time subsamples of our data: 1960-1985 and 1985-2000. The results are qualitatively unchanged, with the effects of interest − the impact of net capital inflows on participation in higher education and the impact of participation in higher education on growth − being stronger in the later period.

through their effect on higher education.

8 Appendix

8.1 Theoretical Appendix

Proof of Proposition 2. Use (12) together with the facts that $K = \bar{K}$ under autarky and $K = K_{SOE} = \xi(A, \bar{r})G$ in a small open economy. ■

Proof of Proposition 3. First, note that $V_{GA} > 0$ and $V_{GG} < 0$, according to (16). G_{AUT} is given by first-order condition $V_G(A, s(\bar{K}), G_{AUT}) = 0$. (Subscripts of V denote partial derivatives.) Thus, $\partial G_{AUT}/\partial A = -V_{GA}/V_{GG} > 0$. ■

Proof of Lemma 1. First, substituting $K = \xi(A, \bar{r})G$ in (12) we see that G and s_{SOE} must satisfy the following equation:

$$(1-\beta)\left[b\xi(A,\bar{r})^{\beta}G^{\beta}(1-s)^{2-\beta} + (1-b)(1-s)^2\right] - \beta(1-b)s = 0. \tag{A.1}$$

Since the left-hand side of (A.1) is increasing in G and decreasing in s, equation (A.1) defines a monotonically increasing one-to-one relationship between G and s_{SOE}. We have the following properties: $\lim_{G\to 0} s_{SOE}(A, \bar{r}, G) = \underline{s}$, where

$$\underline{s} \equiv \frac{1}{2(1-\beta)}\left(2 - \beta - \sqrt{4\beta - 3\beta^2}\right) \tag{A.2}$$

and $\lim_{G\to\infty} s_{SOE}(A, \bar{r}, G) = 1$.

Moreover, solving (A.1) for G we get for $s \in (\underline{s}, 1)$

$$G = \frac{1}{\xi(A,\bar{r})}\left(\frac{1-b}{b(1-s)^{2-\beta}}\left[\frac{\beta s}{1-\beta} - (1-s)^2\right]\right)^{\frac{1}{\beta}} \equiv \hat{G}(A, \bar{r}, s) \tag{A.3}$$

with $\lim_{s\to\underline{s}} \hat{G}(A, \bar{r}, s) = 0$ and $\lim_{s\to 1} \hat{G}(a, \bar{r}, s) = \infty$. (Note that $\beta s/(1-\beta) > (=)\,(1-s)^2$ if $s >$ (=, resp.) $\underline{s}$.) $\hat{G}(a, \bar{r}, \cdot)$ is the inverse of $s_{SOE}(A, \bar{r}, \cdot)$.

Now let us define $\hat{V}(A,\bar{r},s) \equiv V(A,s,\hat{G}(A,\bar{r},s))$. Since, for $s \in (\underline{s},1)$, $s_{SOE}\left(A,\bar{r},\hat{G}\left(A,\bar{r},s\right)\right)$ $= s$, we have $\hat{V}\left(A,\bar{r},s\right) = V\left(A, s_{SOE}\left(A,\bar{r},\hat{G}\left(A,\bar{r},s\right)\right), \hat{G}\left(A,r,s\right)\right) = \tilde{V}\left(A,\bar{r},\hat{G}\left(A,\bar{r},s\right)\right)$. Therefore, $\tilde{s} \in (\underline{s},1)$ is a maximizer of $\hat{V}\left(A,\bar{r},s\right)$ if and only if $\hat{G}\left(A,\bar{r},\tilde{s}\right) \in (0,\infty)$ is a maximizer of $\tilde{V}\left(A,\bar{r},G\right)$. (Recall that $\hat{G}_s > 0$.)

We proceed with the proof by the following two steps. In step 1, we show that there exists a $\tilde{s} \in (\underline{s},1)$ which is a local maximizer of $\hat{V}(A,\bar{r},s)$ if $A < \hat{A}$. In step 2, we show that $\hat{V}(A,\bar{r},s)$ has a unique local extremum, so that $\tilde{s}$ is the unique and global maximizer of $\hat{V}(A,\bar{r},s)$. We therefore know that $\tilde{V}(A,\bar{r},G)$ has a unique maximum at $\hat{G}\left(A,\bar{r},\tilde{s}\right) \in (0,\infty)$.[35]

Step 1: Substituting (A.3) into (16) and rearranging terms gives us

$$\hat{V}(A,\bar{r},s) = \frac{1}{\xi(A,\bar{r})}\left(\frac{1-b}{b}\right)^{\frac{1}{\beta}} B^{\frac{1-\beta}{\beta}}\left[\beta bA\xi(A,\bar{r})^{\beta} - \frac{(1-s)^2 B}{(1-s+s^2)}\right], \tag{A.4}$$

where

$$B \equiv \frac{\beta s}{(1-\beta)(1-s)^2} - 1. \tag{A.5}$$

Note that $B > 0$ if $s > \underline{s}$, according to (A.2). We show that for $A < \hat{A}$ there exists $\tilde{s} \in (\underline{s},1)$ which is a local maximizer of $\hat{V}(A,\bar{r},s)$ by confirming the following three properties: (i) $\hat{V}_s(A,\bar{r},s)$ is continuous in s for $s \in (\underline{s},1)$, (ii) $\hat{V}_s(A,\bar{r},s) > 0$ if $s \in (\underline{s},1)$ is sufficiently close to $\underline{s}$ and (iii) $\hat{V}_s(A,\bar{r},s) < 0$ if $A < \hat{A}$ and $s \in (\underline{s},1)$ is sufficiently close to 1. Using (A.4) and (A.5), it is tedious but straightforward to show that $\hat{V}_s(A,\bar{r},s) = q(A,\bar{r},s)Q(A,\bar{r},s)$, where $q(A,\bar{r},s) \equiv (1/b-1)^{\frac{1}{\beta}}B^{\frac{1-\beta}{\beta}}(1+s)/\left[\xi(A,\bar{r})\left(1-s\right)\right]$, with $q(A,\bar{r},s) > 0$ for $s \in (\underline{s},1)$, and

$$Q(A,\bar{r},s) \equiv \frac{\beta(1-\beta)bA\xi(A,\bar{r})^{\beta}}{\beta s-(1-\beta)(1-s)^2} - \frac{(1-\beta)\left(1-s+s^2\right)+(1-s)^2}{(1-\beta)(1-s+s^2)^2}. \tag{A.6}$$

Recall that $\beta s-(1-\beta)(1-s)^2 > 0$ if $s > \underline{s}$, approaching zero when s diminishes towards $\underline{s}$. Properties (i) and (ii) then immediately follow. To see property (iii), substitute ξ

[35] Employing function $\hat{V}(A,\bar{r},s)$ to prove Lemma 1, rather than employing $\tilde{V}(A,\bar{r},G)$, turns out to be more tractable. Moreover, the derivations in this proof will be useful to prove our subsequent results in a shorter and more elegant way.

from (14) into (A.6) to find that $Q(A, \bar{r}, 1) < 0$ if and only if $A < \hat{A}$, with $\hat{A}$ as defined in Lemma 1. This concludes step 1.

Step 2: For step 2, first rewrite the expression for $\hat{V}_s$ to $\hat{V}_s(A, \bar{r}, s) = z(A, \bar{r}, s)Z(A, \bar{r}, s)$, where

$$z(A, \bar{r}, s) \equiv \frac{q(A, \bar{r}, s)}{\beta s - (1-\beta)(1-s)^2}, \tag{A.7}$$

with $z(A, \bar{r}, s) > 0$ for $s \in (\underline{s}, 1)$, and

$$Z(A, \bar{r}, s) \equiv \beta(1-\beta)bA\xi(A, \bar{r})^{\beta} - \beta + \left[\frac{2(1-s)^2}{1-s+s^2} - \frac{s(1-s)^2}{(1-\beta)\left(1-s+s^2\right)^2}\right]. \tag{A.8}$$

Hence,

$$Z_s = -\frac{(1-s)(1+s)}{\left(1-s+s^2\right)^2}\Phi(s, \beta), \text{ where } \Phi(s, \beta) \equiv 2 + \frac{1}{1-\beta}\left(1 - \frac{2s(1+s)}{1+s^3}\right). \tag{A.9}$$

Since $\Phi_s(s, \beta) < 0$ for $s < 1$, we have: If $\beta \leq 0.5$, then $\Phi(s, \beta) > 0$ and therefore $Z_s < 0$ for all $s < 1$. If $\beta > 0.5$, then there exists a critical value $s^c(\beta)$ defined by $\Phi(s, \beta) = 0$ such that $Z_s < 0$ for $s < s^c(\beta)$ and $Z_s > 0$ for $s > s^c(\beta)$. Noting that $\hat{V}_{ss}(A, \bar{r}, \tilde{s}) = z(A, \bar{r}, \tilde{s})Z_s(A, \bar{r}, \tilde{s})$ whenever $\hat{V}_s(A, \bar{r}, \tilde{s}) = 0$ and recalling the fact that $z(A, \bar{r}, s) > 0$ for $s \in (\underline{s}, 1)$, we conclude that any local extremum $\tilde{s} \in (\underline{s}, 1)$ of $\hat{V}(A, \bar{r}, s)$ is a local maximum if $\beta \leq 0.5$. For the case $\beta > 0.5$, suppose there exists a $\tilde{s} \in (\underline{s}, 1)$ which is a local minimizer of $\hat{V}(A, \bar{r}, s)$. For this, a necessary condition is $\tilde{s} > s^c(\beta)$. However, property (iii) in step 1 says that $\hat{V}_s(A, \bar{r}, s) < 0$ if $A < \hat{A}$ and $s \in (\underline{s}, 1)$ is sufficiently close to 1. Hence, $\tilde{s}$ can only be a local minimizer if there exists a local maximizer $\check{s} > \tilde{s} > s^c(\beta)$. But this is a contradiction since $Z_s(A, \bar{r}, s) > 0$ for $s > s^c(\beta)$. Hence, we can conclude that also in the case $\beta > 0.5$ any local extremum $\tilde{s} \in (\underline{s}, 1)$ of $\hat{V}(A, \bar{r}, s)$ is a local maximum. Combining this with step 1, we have: $\hat{V}(A, \bar{r}, s)$ has a unique local (and thus global) maximum in s if $A < \hat{A}$. ∎

Proof of Proposition 4. G_{SOE} satisfies first-order condition $\tilde{V}_G(A, \bar{r}, G) = 0$, i.e.,

$$V_G(A, s_{SOE}(A, \bar{r}, G), G) + V_s(A, s_{SOE}(A, \bar{r}, G), G)\frac{\partial s_{SOE}(A, \bar{r}, G)}{\partial G} = 0. \tag{A.10}$$

G_{AUT} is given by $V_G(A, s_{AUT}, G_{AUT}) = 0$. If $\bar{r} = r_{AUT}(A, \bar{K}, G_{AUT})$, then $s_{SOE} = s_{AUT}$. Thus, at $G = G_{AUT}$, the first term of the left-hand side of (A.10) vanishes, whereas the second term is strictly positive ($V_s > 0$ and $\partial s_{SOE}/\partial G > 0$, according to (16) and Proposition 2, respectively). $\tilde{V}_G(A, \bar{r}, G_{AUT}) > 0$ implies $G_{SOE} > G_{AUT}$. ■

Proof of Proposition 5. In the proof of Lemma 1, we have shown that there exists a unique $s^*(A, \bar{r}) \in (\underline{s}, 1)$ solving $\hat{V}_s(A, \bar{r}, s^*) = 0$. Moreover, $\hat{V}_{ss}(A, \bar{r}, s^*) < 0$. Applying the implicit function theorem, we obtain $\partial s^*/\partial A > 0$ and $\partial s^*/\partial \bar{r} < 0$ from (A.7), (A.8) and (14). According to Proposition 4, $G_{SOE} > G_{AUT}$ if $\bar{r} = r_{AUT}(A, \bar{K}, G_{AUT})$ and $s_{SOE}(A, \bar{r}, G_{AUT}) = s_{AUT}$. Hence, in this case, $s^*(A, \bar{r}) = s_{SOE}(A, \bar{r}, G_{SOE}) > s_{AUT}$. (Note $\partial s_{SOE}/\partial G > 0$.) $\partial s^*/\partial \bar{r} < 0$ implies $s^*(A, \bar{r}) > s_{AUT}$ if $\bar{r} < r_{AUT}(A, \bar{K}, G_{AUT})$, but if $\bar{r} > r_{AUT}(A, \bar{K}, G_{AUT})$, $s^*(A, \bar{r})$ may drop below s_{AUT}. ■

Proof of Proposition 6. From (18), both parts of Proposition 6 are easy to confirm in the autarky case, using $s_t = s(\bar{K})$ for all t and $\gamma \in (0, 1)$. To prove part (i) under capital mobility, we need to show that the following three properties hold when $\beta \leq 1/2$. First, $\tilde{f}(A, \bar{r}, G) \equiv f(s_{SOE}(A, \bar{r}, G), G, A)$ is an increasing and strictly concave function of A, second, $\lim_{A \to 0} \tilde{f}_A(A, \bar{r}, G) > 1$, and third, $\lim_{A \to \infty} \tilde{f}_A(A, \bar{r}, G) < 1$. (Note that $f(0, \bar{r}, G) = 0$.) A sufficient condition for $\tilde{f}(A, \bar{r}, G)$ to be increasing and strictly concave as function of A is that $s_{SOE}(A, \cdot)$ is increasing and concave as function of A. Substituting (14) into (A.1), s_{SOE} is implicitly given by

$$(1-\beta)\left[\Gamma A^{\frac{\beta}{1-\beta}}(1-s)^{2-\beta} + (1-s)^2\right] - \beta s = 0, \tag{A.11}$$

where $\Gamma \equiv b^{\frac{1}{1-\beta}}(\beta/\bar{r})^{\frac{\beta}{1-\beta}} G^{\beta}/(1-b) > 0$. Hence,

$$\frac{\partial s_{SOE}}{\partial A} = \frac{\beta \Gamma A^{\frac{2\beta-1}{1-\beta}}(1-s)^{2-\beta}}{(1-\beta)\left[(2-\beta)\Gamma A^{\frac{\beta}{1-\beta}}(1-s)^{1-\beta} + 2(1-s)\right] + \beta} > 0, \tag{A.12}$$

implying that $\tilde{f}(A, \bar{r}, G)$ is increasing in A. It is straightforward to show that the right-hand side of (A.12) is decreasing in s. Furthermore, it declines in A if $\beta \leq 1/2$. Thus,

$\beta \leq 1/2$ is sufficient for $\partial^2 s_{SOE}/\partial A^2 < 0$, which confirms that $\tilde{f}(A, \bar{r}, G)$ is strictly concave as function of A. Next, we differentiate $\tilde{f}(A, \bar{r}, G)$ with respect to A. From (18), we get

$$\tilde{f}_A(A, \bar{r}, G) = G^{\varepsilon}\left[\gamma\left(s_{SOE}\right)^{\gamma-1}\frac{\partial s_{SOE}}{\partial A}A^{1-\gamma} + (1-\gamma)\left(\frac{s_{SOE}}{A}\right)^{\gamma}\right] + 1 - \delta \tag{A.13}$$

$$= G^{\varepsilon}\left(s_{SOE}\right)^{\gamma-1}A^{-\gamma}\left[\frac{\Gamma\gamma}{\frac{1-\beta}{\beta}\left[\frac{(2-\beta)\Gamma}{1-s_{SOE}} + \frac{2A^{-\beta/(1-\beta)}}{(1-s_{SOE})^{1-\beta}}\right] + \frac{A^{-\beta/(1-\beta)}}{(1-s_{SOE})^{2-\beta}}} + (1-\gamma)s_{SOE}\right] + 1 - \delta,$$

where the latter equation follows from substituting (A.12) and rearranging terms. Using $\lim_{A\to 0} s_{SOE} = \underline{s}$, we obtain $\lim_{A\to 0}\tilde{f}_A(A, \bar{r}, G) = \infty$. Finally, using $\lim_{A\to\infty} s_{SOE} = 1$, we find $\lim_{A\to\infty}\tilde{f}_A(A, \bar{r}, G) = 1 - \delta$. This confirms part (i) for the open economy.

It remains to prove part (ii) under capital mobility. Differentiating $\tilde{g}(s_{SOE}, S, A) = (s_{SOE}/A)^{\gamma} S^{\varepsilon} - \delta$ with respect to A, we obtain (using $S = G$)

$$\frac{\partial \tilde{g}}{\partial A} = \gamma\left(\frac{s_{SOE}}{A}\right)^{\gamma} G^{\varepsilon}\left(\frac{\partial s_{SOE}}{\partial A}\frac{1}{s_{SOE}} - \frac{1}{A}\right). \tag{A.14}$$

Since s_{SOE} is positive, increasing and, if $\beta \leq 1/2$, strictly concave in A, we have $\partial s_{SOE}/\partial A < s_{SOE}/A$ and thus $\partial\tilde{g}/\partial A < 0$ if $\beta \leq 1/2$. Therefore, as we know that A increases over time when $A_0 < \bar{A}$, g^A must decrease over time. This concludes the proof. ■

8.2 Empirical Appendix

Country sample:

Argentina, Australia, Austria, Bangladesh, Belgium, Benin, Bolivia, Botswana, Brazil, Cameroon, Canada, Central African Republic, Chile, China, Colombia, Republic of Congo, Costa Rica, Cyprus, Denmark, Dominican Republic, Arab Republic of Egypt, El Salvador, Fiji, Finland, France, The Gambia, Germany, Ghana, Greece, Guatemala, Guyana, Haiti, Honduras, Hungary, India, Indonesia, Islamic Republic of Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Lesotho, Malawi, Malaysia, Mali, Mauritius, Mexico, Mozambique, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Rwanda, Senegal, Sierra Leone, Singapore, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Syrian Arab Republic, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, United Kingdom, United States, Uruguay, RB Venezuela, Zambia, Zimbabwe.

Table 6 summarizes the descriptive statistics of the variables employed in the empirical analysis.

Table 6: Descriptive statistics

Variables	Mean	Std. dev.	Minimum	Maximum
Dependent variables				
Average annual change in years of higher schooling ("HYR" in Barro and Lee, 2000)	0.0077	0.0067	-0.0003	0.0276
Average annual change in net inward foreign direct investment flows	0.0005	0.0022	-0.0051	0.0098
Average annual change in ln real GDP per worker (1996; chain series)	0.0172	0.0144	-0.0120	0.0595
Average annual change in ln education spending	0.0270	0.0390	-0.1785	0.1245
Independent variables				
Average annual change in ln number of workers	0.0011	0.0045	-0.0088	0.0159
Average annual change in years of primary schooling ("PYR" in Barro and Lee, 2000)	0.0330	0.0224	-0.0163	0.0867
Average annual reduction of investment barriers	1.0085	0.0218	0.9395	1.0731
Initial level of average years of higher schooling ("HYR")	0.0834	0.1163	0.0000	0.5300
Initial level of average years of primary schooling ("PYR")	2.6511	1.9135	0.0450	7.3160
Initial level of ln education spending	25.4173	2.3324	20.4331	31.0808
Initial level of ln real GDP per worker (1996; chain series)	8.7845	0.9577	6.7365	10.5837
Initial level of ln number of workers	-0.9353	0.2012	-1.3513	-0.5021
Initial level of ln real capital stock per worker (1996; chain series)	6.6199	1.6766	2.0067	9.1671
Initial level of investment barriers	34.6453	5.1667	18.3571	45.3429
Dependent variables used in robustness analysis				
Average annual change in years of higher schooling of males ("HYRM" in Barro and Lee, 2000)	0.0082	0.0068	-0.0004	0.0287
Average annual change in years of secondary schooling ("SYR" in Barro and Lee, 2000)	0.0300	0.0223	-0.0372	0.0880
Average annual change in years of higher schooling attained ("LH" in Barro and Lee, 2000)	0.2320	0.2157	-0.0077	0.9718
Independent variables used in robustness analysis				
Initial level of average years of higher schooling of males ("HYRM" in Barro and Lee, 2000)	0.1101	0.1386	0.0000	0.6020
Initial level of average years of secondary schooling ("SYR" in Barro and Lee, 2000)	0.7768	0.9219	0.0120	5.0770
Initial level of average years of higher schooling attained ("LH" in Barro and Lee, 2000)	2.6035	3.8748	0.0000	20.0000

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