

# Capital Market Integration, Education and Growth under Capital-Skill Complementarity\*

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PRELIMINARY VERSION

August 31, 2005

## Abstract

This paper examines the impact of capital market integration (CMI) on human capital formation, earnings inequality and economic growth under capital-skill complementarity. When public education expenditure is held constant, integration leads to an increase (a decline) in the share of skilled labor, inequality and growth in capital-importing (-exporting) economies. From a normative point of view, we find that public education expenditure of an economy should increase after integration with similar economies. Moreover, our analysis suggests that, under optimal adjustment of education policy, educational attainment rises after CMI, provided induced capital outflows are not too large. Using foreign direct investment (FDI) as measure for capital flows, we present empirical evidence which largely confirms our main hypothesis: an increase in net capital inflows in response to CMI induces higher educational attainment and therefore fosters economic growth.

**Key words:** Capital mobility; Capital-Skill Complementarity; Earnings Inequality, Economic Growth; Educational Choice; Education Policy.

**JEL classification:** F20, H52, J24, O10.

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\* *Acknowledgements:* We are grateful to Stephanie Bade and Nicole Brändle for excellent research assistance.

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# 1 Introduction

In the last decades, capital markets have become increasingly integrated. For instance, the average annual growth rate of foreign direct investment (FDI) inflows in the world has been almost 25 percent in the period 1986-90, 20 percent in 1991-95 and almost 32 percent in 1996-99 (Markusen, 2002, Tab. 1.1).<sup>1</sup> 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 human capital formation and growth. Examining this link is motivated by two sets of empirical regularities. First, there is overwhelming empirical support for the hypothesis that physical and human capital are strongly complementary production factors (Goldin and Katz, 1998, Krusell et al., 2000). Hence, capital inflows increase individual incentives to acquire education by raising the relative marginal productivity of skilled to unskilled labor. Second, recent evidence by Glaeser et al. (2004) strongly suggests that human capital is the most fundamental factor for growth.<sup>2</sup> Taken together, capital-skill complementarity and human capital as the basic cause of growth suggest the following hypothesis we attempt to advance in this paper. CMI raises both educational attainment and economic growth in economies which experience a (net) inflow of capital after integration, whereas the share of skilled labor and therefore growth is reduced in economies where integration causes a capital outflow, all other things being equal. 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

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<sup>1</sup>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.

<sup>2</sup>Glaeser et al. (2004) particularly examine the alternative hypothesis that cross-country variation of measures of institutional quality (proposed by the recent growth literature) explains the observed variation in growth rates of income per capita across countries. They find that (i) if anything, causality runs from growth to these measures rather than vice versa, (ii) initial levels of human capital are a better predictor of growth patterns than measures of institutional quality, and (iii) increases in human capital promote economic growth through their effects on institutions. Hence, in our empirical analysis, we adopt a reduced form approach which allows for various channels of how human capital formation affects growth, like institutions.

higher total factor productivity. Hence, holding public education expenditure constant, our analysis suggests that the impact of CMI on economic growth through increased enrollment in higher education depends on initial conditions which affect the marginal productivity of capital ex ante. 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: For given public education policy, an increase in net capital inflows in response to CMI fosters economic growth by inducing higher educational attainment.<sup>3</sup>

This raises the question how governments should react to changes in the demand for education caused by CMI. According to our analysis, public education expenditure raises the share of skilled labor in an integrated economy primarily through its effect of attracting foreign capital investment.

We find that this implies, from a normative point of view, that public education expenditure of an economy should increase after integration with similar economies. Moreover, our analysis suggests that, typically, under optimal adjustment of education policy educational attainment rises after CMI. The situation may be different, however, in an economy with unfavorable initial conditions which induce large capital outflows after integration. In this case, it may not be optimal to raise education expenditure to a point which fully offsets the negative effect (arising for given public education spending) of CMI on individual incentives to acquire human capital.

There is a large literature on macroeconomic effects of capital mobility. According to neoclassical growth models, international capital flows induced by CMI speed up convergence of growth rates in per capita income. For instance, Barro, Mankiw and Sala-i-Martin (1995) show that, under borrowing constraints for financing human capital accumulation, this increase in the speed of convergence is small enough to be consistent with observed convergence patterns among open economies. Viaene and Zilcha (2002a) show that CMI raises income inequality in capital-importing economies,

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<sup>3</sup>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 et al., 2004; Khawar, 2005).

whereas the opposite occurs in capital-exporting economies. Our analysis arrives at a similar conclusion. However, in contrast to Viaene and Zilcha (2002a), who abstract from individual education decisions, our result critically depends on the endogeneity of the share of skilled labor in the economy: As outlined above, educational attainment increases (for given public education expenditure) if CMI leads to a capital inflow, but decreases if it leads to an outflow. The effect of CMI on inequality, in turn, is due to our assumption of heterogeneity of individuals in learning abilities, which gives rise to a positive relationship between the share of skilled labor and earnings inequality.

Gradstein and Justman (1995) and Viaene and Zilcha (2002b) argue that CMI typically gives rise to overprovision of public education expenditures in symmetric Nash equilibrium of a policy game among two identical countries, calling for policy coordination. In contrast, in our normative analysis, we focus on the effects of CMI on educational attainment – the key variable in our empirical analysis – under optimal adjustment of public education policy. Moreover, none of the previous contributions addresses our question, namely: What is the impact of CMI on educational attainment and thereby on economic growth driven by human capital?

The paper is organized as follows. Section 2 presents the basic (static) version of the model. Section 3 analyzes the equilibrium for 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 concludes.

## **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:

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

$b, \beta \in (0, 1)$ , 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 1 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 schooling.<sup>4</sup>

Preferences of worker  $i$  are represented by the utility function

$$U(i) = \ln l(i) + \ln C(i), \quad (2)$$

where  $C(i)$  is  $i$ 's consumption level,  $l(i) = 1$  if  $i$  remains unskilled and  $l(i) = 1 - e(i)$  if  $i$  is skilled.  $e(i)$  may be interpreted as effort cost of acquiring education in terms of foregone leisure,  $l(i)$ . Assuming that effort costs are individual-specific reflects heterogeneity of workers with respect to learning (or cognitive) ability. For simplicity, suppose  $e$  is uniformly distributed on the unit interval.<sup>5</sup>

One aim of the paper is to analyze the interplay between CMI and public education finance, and to derive implications of integration for optimal public education policy. For this purpose, we assume that the skill level of an educated worker is determined by public spending on education.<sup>6</sup> More precisely, let  $G$  be the level of public education

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<sup>4</sup>Schooling may be thought of secondary or tertiary education, as primary education is compulsory in most countries and thus not a choice variable for individuals.

<sup>5</sup>Capitalists simply maximize their income.

<sup>6</sup>One 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

expenditure and denote by  $s = 1 - L$  the mass (“number”) of educated workers, i.e., per capita spending equals  $G/s$ . Then an individual choosing education acquires  $G/s$  units of skilled labor whenever  $G < \bar{G}$ , and  $\bar{G}/s$  units otherwise,  $\bar{G} > 0$ . This captures in a simple way the possibility that educational spending is subject to diminishing returns, i.e., the education technology is concave in public expenditure  $G$ . When  $s$  individuals acquire education – obtaining  $\min\{G/s, \bar{G}/s\}$  efficiency units of skilled labor – total efficiency units of skilled labor are given by  $S = \min\{G, \bar{G}\}$ .<sup>7</sup> Thus,  $G > 0$  is necessary for the economy to be viable, according to (1). If an individual remains unskilled, (s)he is endowed with one unit of unskilled labor. Workers inelastically supply their efficiency units of labor and all factor markets are perfect.

It should be noted that the main results regarding the impact of CMI on schooling enrollment, inequality and growth would not change if we allowed for private educational investments as well. The reason why we focus on public education is twofold. First, governments may adjust education policy to CMI. In order to derive testable hypotheses, one has to examine how this would affect the relationship between integration and educational choice. Second, our empirical estimates in section 6 suggest that public education expenditure has significant effects on schooling enrollment. Thus, our theory should be able to account for this.

Education is financed by a proportional tax on wage income, with tax rate  $\tau \in (0, 1)$ . The government budget is balanced (in each period). The budget constraint of the public sector is thus given by

$$G = \tau (w_S S + w_L L), \quad (3)$$

where  $w_S$  and  $w_L$  denote the wage rate per efficiency unit of skilled and low-skilled

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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.

<sup>7</sup>We could be slightly more general in assuming that an educated worker obtains skill level  $G/s^\alpha$ ,  $0 \leq \alpha \leq 1$ . 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. Consequently,  $S = s^{1-\alpha}G$ . The main results remain unaffected when allowing for  $\alpha < 1$ . So we focus on the case where public education is a fully rival good in order to keep the analysis simple.

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 an open economy, the consumption good is tradable, capital is fully mobile and labor is fully immobile.

### 3 Equilibrium Analysis

Consumption (= disposable income) of worker  $i$  is given by<sup>8</sup>

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

Denote  $\omega = w_S/w_L$  as 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

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

i.e., the effort cost of education is below some threshold ability level,  $\hat{e}$ . As  $e$  is uniformly distributed on  $[0, 1]$ , this implies that the share of skilled workers,  $s$ , is given by  $s = \hat{e}(s, \omega, G)$ . Thus, (5) can be rewritten as

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

Hence,  $s$  is increasing in both  $\omega$  (which is endogenous) and  $G$ . Throughout the paper, relative wage income,  $W_S/W_L$ , is taken as measure for the dispersion of (labor) earnings. According to (4) and (6), it is given by

$$\frac{W_S}{W_L} = \frac{1}{1 - s}. \quad (7)$$

Thus, any increase in the share of skilled workers is associated with higher earnings

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<sup>8</sup> $G \leq \bar{G}$  is assumed here. Obviously,  $G > \bar{G}$  is no meaningful policy.

inequality. This is an implication of the fact that the marginal entrant into schooling, with effort requirement  $\hat{e} = s$ , is indifferent between attending school or remaining unskilled. Thus, if more individuals choose schooling, the compensation for becoming skilled must have increased.

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

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

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

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

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

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

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

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

Equation (12) gives us  $s$  as increasing function of the capital stock  $K$ ; we write  $s = s(K)$ .<sup>9</sup> This relationship reflects the capital-skill complementarity embodied in (1): If  $K$  rises, the relative marginal productivity of skilled labor ( $\omega$ ) 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

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

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<sup>9</sup> $s(K)$  exists and is unique, as the left-hand side of (12) is positive for  $s = 0$ , negative for  $s = 1$ , and strictly decreasing in  $s$ .

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 by the world market interest rate  $\bar{r}$ . Using  $S = G$  in (8), we obtain  $K_{SOE} = \xi G$ , where

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

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  $s_{SOE} = s(K_{SOE}) = s(\xi(A, \bar{r})G) \equiv s_{SOE}(A, \bar{r}, G)$ .

>From (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 interest rate. We therefore derive the following impact of CMI (switch from autarky to full capital mobility) on educational choice.

**Proposition 1.** *Capital market integration raises (does not affect, reduces) both the share of skilled workers and earnings inequality 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 thus gives rise to an interesting interaction between international capital markets, skill formation and earnings inequality in the economy. Proposition 1 suggests that CMI is beneficial (harmful) in terms of educational attainment for 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. Hence, our model shows that CMI simultaneously affects both educational attainment and earnings dispersion in the same direction.<sup>10</sup>

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<sup>10</sup>Galor and Moav (2000) derive a similar effect from technological change instead of CMI.

For a given stock of domestic capital, the condition for an *increase* in schooling enrollment 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 falls after integration, capital demand increases and thus the relative productivity of skilled labor rises. This enhances the incentives to acquire education. According to (7), an increase in  $s$  goes along with increased earnings inequality. In contrast, if educational spending or TFP is comparably low, both skill formation and inequality may be reduced by free 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, while earnings inequality declines.

The role of capital-skill complementarity in our model for the effects of CMI and education policy on skill formation is also highlighted by the following comparative-static results. (All proofs are relegated to the appendix.)

**Proposition 2.** *An increase in education expenditure ( $G$ ) or in TFP ( $A$ ) has no effect on  $s_{AUT}$ , but raises  $s_{SOE}$ . Moreover, an increase in the domestic capital stock ( $\bar{K}$ ) raises the share of skilled labor under autarky,  $s_{AUT}$ , and an increasing world interest rate ( $\bar{r}$ ) lowers both  $s_{SOE}$  and the capital stock under openness,  $K_{SOE}$ .*

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 the following.

**Proposition 3.** *An increase in  $G$  or  $A$  raises  $W_S/W_L$  in an open economy but not under autarky. Moreover,  $W_S/W_L$  is raised in autarky when  $\bar{K}$  increases and in an open economy when  $\bar{r}$  decreases.*

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 relative earnings of the skilled,  $W_S/W_L$ , all other things equal. This gives an incentive to acquire education. On the other hand, however, the relative wage rate  $\omega$  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 (Proposition 3). 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 stated in Proposition 2 and 3, respectively. An increase in  $G$ , by raising effective skilled labor, attracts capital to the economy. This raises the productivity of skilled labor disproportionately, and thus enhances the incentives to become skilled. 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 free mobility of capital, technologically advanced countries have both higher schooling enrollment and higher earnings inequality than less advanced countries, all other things equal. (In section 5, we will allow for a feedback effect from educational attainment to productivity growth, which enables us to study the relationship between inequality and growth in the model.) Other sources of higher capital investment – a decrease in  $\bar{r}$  under openness or a rise in  $\bar{K}$  in the closed economy – have the same effect.<sup>11</sup>

**Remark 1.** The shown effects under capital-skill complementarity (exhibited by

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<sup>11</sup>Krusell et al. (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 emphasize the role of capital-skill complementarity.

production technology (1)) on educational choice are considerably different to those implied by, say, a CES-production function:

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

$a_K, a_S > 0$ ,  $a_K + a_S < 1$ ,  $\rho < 1$ . To see this, note that (15) implies  $\omega = (a_S/[1 - a_K - a_S])(L/S)^{1-\rho}$ . 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),  $s$  does neither depend 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,  $\rho \rightarrow 0$ ).

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?

## 4 Optimal Education Policy

To characterize the optimal education policy, conditional on the capital market regime (open or closed), we first have to specify an objective function. We employ a Rawlsian welfare function. That is, education policy is optimal when utility of the unskilled,  $\ln W_L$ , is maximized. This ensures that our normative results are not driven by the positive effect of an increase in  $G$  on earnings inequality under openness (Proposition 3). Using (3), the net wage of the unskilled,  $W_L = (1 - \tau)w_L$ , can be written as  $W_L = w_L - G/(\omega S + L)$ . After substituting  $S = G$ , (6), (9) and  $L = 1 - s$ , and rearranging terms, the expression for  $W_L$  reads

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

Let us define  $\tilde{V}(A, \bar{r}, G) \equiv V(A, s_{SOE}(A, \bar{r}, G), G)$ . Optimal education spending without and with CMI, denoted by  $G_{AUT}$  and  $G_{SOE}$ , are given by  $G_{AUT} = G_{AUT}(A, \bar{K}) = \arg \max_{G \leq \bar{G}} V(A, s(\bar{K}), G)$  and  $G_{SOE} = G_{SOE}(A, \bar{r}) = \arg \max_{G \leq \bar{G}} \tilde{V}(A, \bar{r}, G)$ , respectively. Since  $V(A, s(\bar{K}), G)$  as function of  $G$  is strictly concave there exists a *unique* solution for  $G_{AUT}$ . If  $\bar{G}$  is sufficiently high, we have an interior solution with the following properties.

**Proposition 4.** *Suppose  $G_{AUT} < \bar{G}$ . Then  $G_{AUT}$  is increasing in both  $A$  and  $\bar{K}$ .*

Under autarky, technologically advanced economies should spend more on education than technologically backward economies. This is because skilled and unskilled 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 the higher  $A$  is. An increase in  $\bar{K}$  raises  $s_{AUT}$  (Proposition 2). This raises the marginal productivity of unskilled labor and, because skilled and unskilled labor are complements, calls for an increase in  $G$ . In other words, the increase in educational attainment in response to a larger capital stock should be accommodated by higher educational spending.

In contrast to the autarky case, under openness, welfare measure  $W_L = \tilde{V}(A, \bar{r}, G)$  may be ever increasing in public education expenditure  $G$ . That is, due to the positive interaction between  $G$  and capital inflow in an open economy, there may be no interior solution for the optimal policy problem even if  $\bar{G} \rightarrow \infty$ . (Recall that  $\bar{G}$  is the spending level above which higher spending is ineffective.) One can show that this occurs, for instance, if  $A$  is sufficiently high. We will rule out uninteresting cases by focussing on a parameter domain with a unique interior solution in the following analysis.

Proposition 1 has shown how the impact of CMI on the share of skilled labor,  $s$ , depends on the interest rate differential between the considered economy under autarky and the rest of the world for given education expenditure,  $G$ . We now turn to the question how  $s$  changes after CMI when public education expenditure is adjusted optimally. That is, we compare the share of skilled labor  $s^*(A, \bar{r}) \equiv s_{SOE}(A, \bar{r}, G_{SOE})$  with the pre-integration level,  $s_{AUT} = s(\bar{K})$ . Moreover, we explore in which direction an optimal adjustment of public education expenditure tends to go when we start

from  $G_{AUT}$ , the optimal education policy under autarky. That is, we ask whether  $G_{AUT} < G_{SOE}$  or  $G_{AUT} > G_{SOE}$ .

Suppose first that the world market interest rate equals the autarky interest rate, given that  $G = G_{AUT}$ . 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 next proposition states that in this case  $G_{AUT}$  is too low under capital mobility.

**Proposition 5.** *Suppose  $G_{SOE} < \bar{G}$  and  $\bar{r} = r_{AUT}(\cdot, G_{AUT})$ . Then  $G_{SOE} > G_{AUT}$ .*

Proposition 5 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 when economies are similar.<sup>12</sup> Before discussing this result, we consider how the impact of CMI on  $s$  depends on the interest rate differential when education policy is adjusted optimally.

**Proposition 6.** *Suppose  $G_{SOE} < \bar{G}$ . If  $\bar{r} \leq r_{AUT}(\cdot, G_{AUT})$ , then  $s^*(A, \bar{r}) > s(\bar{K})$ . By contrast, if  $\bar{r} > r_{AUT}(\cdot, G_{AUT})$ , then  $s^*(A, \bar{r}) <, =, > s(\bar{K})$  is possible. Moreover,  $s^*(A, \bar{r})$  is increasing in  $A$  and decreasing in  $\bar{r}$ .*

According to Proposition 5, if education spending was at its optimal level under autarky and there is no interest rate differential to the rest of the world before integration (i.e.,  $s_{SOE} = s_{AUT}$ ), 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 adjustment, i.e.,  $s^*(A, \bar{r}) > s_{AUT}$ . As skilled and unskilled labor are complementary factors of production, the marginal productivity of unskilled labor goes up as well, thus raising  $W_L$ . Result  $s^*(A, \bar{r}) > s(\bar{K})$  also holds when the autarky interest rate is higher than the world market rate ( $\bar{r} < r_{AUT}$ ). This is because  $s$  rises after integration

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<sup>12</sup>Of course, this may give rise to an inefficient equilibrium in a non-cooperative game between governments, as shown in Gradstein and Justman (1995) and Viaene and Zilcha (2002b). As our goal is to derive testable hypotheses with respect to the effects of CMI, taking into account possible policy adjustments of governments, we do not explore this issue further.

when  $\bar{r} < r_{AUT}$  even if education policy remains unchanged, according to Proposition 1. However, if  $\bar{r} > r_{AUT}$  (given that  $G = G_{AUT}$ ),  $s$  decreases after integration when  $G$  is held fixed. According to Proposition 6, 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 the autarky level.

Some remarks are in order. With respect to an optimal adjustment of education policy, only the case  $\bar{r} = r_{AUT}(\cdot, G_{AUT})$  has been considered in Proposition 5. For examining the optimal response of education policy in the case  $\bar{r} \neq r_{AUT}(\cdot, G_{AUT})$  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 5 is strengthened, so that  $\bar{r} < r_{AUT}(\cdot, G_{AUT})$  would also imply  $G_{SOE} > G_{AUT}$ .

<Table 1>

However, as shown in Tab. 1, 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  $\beta = b = 0.5$ ,  $G_{SOE}$  first decreases but then increases with  $\bar{r}$  when  $A = 0.5$ , whereas  $G_{SOE}$  decreases with  $\bar{r}$  for the chosen range when  $A = 1$ . 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 6, showing quite reasonable adjustments for  $s^*$  when  $G_{SOE} < \bar{G}$ .)

The definite answer given in Proposition 6 on how  $s$  should react under optimal adjustment of  $G$  to integration, together with the relationship derived for given education policy (Proposition 1), will turn out very useful for deriving a testable hypothesis of the relationship between capital flows and educational attainment 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  $t = 0, 1, 2, \dots$  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. 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,  $g_{t+1}^A \equiv A_{t+1}/A_t - 1$ , is an increasing and concave function of the share of skilled labor in  $t$ ,  $s_t$ . This formulation is a short-cut for the positive effects of human capital for growth which have been suggested by the literature.<sup>13</sup> Moreover, we allow for the possibility that  $g_{t+1}^A$  also depends on total efficiency units of skilled labor,  $S_t$ . Finally, to allow for (conditional) convergence, we suppose that  $g_{t+1}^A$  is a decreasing function of the level of TFP. Formally,  $g_{t+1}^A = \tilde{g}(s_t, S_t, A_t)$ , 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  $\delta > 0$ .<sup>14</sup> This implies that  $A$  evolves over time according to

$$A_{t+1} = s_t^\gamma A_t^{1-\gamma} S_t^\varepsilon + (1 - \delta)A_t \equiv f(s_t, S_t, A_t). \quad (17)$$

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<sup>13</sup>That TFP growth positively depends on human capital measures is well-supported empirically (and assumed 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 et al., 2004) or through (R&D-driven) productivity improvements (Hojo, 2003).

<sup>14</sup> $\delta > 0$  reflects depreciation of knowledge over time.

Applying the equilibrium analysis in 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.<sup>15</sup> Thus, under openness, growth fosters education by raising the level of TFP (Proposition 1) and, conversely, education determines TFP growth, according to (17). The next result characterizes dynamic properties of TFP which arise from these links.

**Proposition 7.** *Let  $G_{t-1} = G$  for all  $t$ . 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  $\bar{s} = s(\bar{A}, \bar{r}, G)$  under capital mobility. Moreover, if  $A_0 < \bar{A}$ , then under autarky and, provided that  $\beta \leq 1/2$ , also under capital mobility, the TFP growth rate,  $g_{t+1}^A$ , is strictly decreasing over time.*

<Figure 1>

Note that  $f(s(\bar{K}), G, A)$  is strictly concave as function of  $A$ . Moreover, as shown in the proof of Proposition 7, for  $\beta \leq 1/2$ ,  $s_{SOE}$  is a strictly concave function of  $A$ , which implies that also  $f(s_{SOE}(A, \bar{r}, G), G, A)$  is strictly concave as function of  $A$ . In turn, under both autarky and capital mobility, this gives rise to an evolution of TFP as depicted in Fig. 1. To avoid uninteresting technical discussions, we focus on  $\beta \leq 1/2$  in the following.<sup>16</sup> The following comparative-static results are immediately implied by Propositions 2 and 7.

**Proposition 8.** *Let  $G_{t-1} = G$  for all  $t$ . Under autarky, steady state TFP level,  $\bar{A}$ , is increasing in  $\bar{K}$  and, if  $\varepsilon > (=) 0$ , increasing in (independent of)  $G$ . Under openness, if  $\beta \leq 1/2$ ,  $\bar{A}$  is increasing in  $G$  and decreasing in  $\bar{r}$ .*

Thus, even though the evolution of TFP does not directly depend on physical capital employed in the economy, capital market variables affect steady state TFP

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<sup>15</sup>Individuals base educational decisions in their first period of life on publicly provided resources in 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 (17).

<sup>16</sup>In fact,  $\beta \leq 1/2$  is a rather strong sufficient condition for TFP to evolve like in Fig. 1 under openness. Neither is it necessary for  $s_{SOE}$  to be concave as function of  $A$ , nor is concavity of  $s_{SOE}$  as function of  $A$  necessary for  $f(s_{SOE}(A, \bar{r}, G), G, A)$  to be a strictly concave function of  $A$  under openness.

through their effects on educational attainment  $\bar{s}$ . Moreover, as  $G$  does not affect educational decisions under autarky (Proposition 1), education policy affects  $\bar{A}$  under autarky only when there is a direct link of  $S$  to the evolution of TFP (i.e., when  $\varepsilon > 0$ ). The next proposition shows the impact of CMI on TFP growth as well as on steady state TFP level. It is again implied by Propositions 2 and 7.

**Proposition 9.** *Let  $G_{t-1} = G$  for all  $t$  and  $\beta \leq 1/2$ . Suppose that CMI occurs in period  $\hat{t}$ . This raises (does not affect, reduces)  $\bar{A}$  if  $\bar{r} < (=, >) r_{AUT}(A_{\hat{t}}, \bar{K}, G)$ . Moreover, if  $\bar{r} \geq r_{AUT}(A_{\hat{t}}, \bar{K}, G)$ ,  $g_{t+1}^A < g_{\hat{t}+1}^A$  for  $t > \hat{t}$ . If  $\bar{r} < r_{AUT}(A_{\hat{t}}, \bar{K}, G)$ ,  $g_{t+1}^A >, =, < g_{\hat{t}+1}^A$  for  $t > \hat{t}$  is possible.*

The dashed curve in Fig. 1 indicates that  $f(s_t, G, A_t)$  shifts upward after CMI in  $\hat{t}$  when  $\bar{r} < r_{AUT}(A_{\hat{t}}, \bar{K}, G)$  (given that individuals adjust their education decision already in  $\hat{t} - 1$ ). The reason is that, in this case, the share of skilled workers increases for any given TFP level (Proposition 1), i.e.,  $s_{\hat{t}}$  increases. But as  $g_{t+1}^A$  is decreasing over time for a given capital market regime (autarky or openness), according to Proposition 7, TFP growth may accelerate or slow down after integration. If  $s_{\hat{t}}$  is unchanged by integration (i.e.,  $\bar{r} = r_{AUT}(A_{\hat{t}}, \bar{K}, G)$ ), the steady state TFP level,  $\bar{A}$ , remains unchanged. Moreover, due to convergence of TFP over time, in this case TFP growth unambiguously declines after integration, when all other things remain equal. When integration induces a capital outflow,  $s_{\hat{t}}$  decreases and so does  $\bar{A}$ . In addition to the convergence property, the decline in  $s_{\hat{t}}$  induces a further slowdown of subsequent TFP growth.

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

$$Y_t = \kappa A_t \frac{s_t}{(1 - s_t)^{2-\beta}} (G_{t-1})^{1-\beta}. \quad (18)$$

Hence, if education spending does not change over time, the GDP growth rate,  $g_{t+1}^Y \equiv$

$Y_{t+1}/Y_t - 1$ , is given by

$$g_{t+1}^Y = (g_{t+1}^A + 1) \frac{s_{t+1}/(1 - s_{t+1})^{2-\beta}}{s_t/(1 - s_t)^{2-\beta}} - 1. \quad (19)$$

In the following, we show that, qualitatively, the main results concerning TFP level and TFP growth rate carry over to GDP variables. We start with the steady state level of GDP,  $\bar{Y}$ .

**Proposition 10.** *Let  $G_{t-1} = G$  for all  $t$ . Under autarky,  $\bar{Y}$  is increasing in both  $\bar{K}$  and  $G$ . Under openness, if  $\beta \leq 1/2$ ,  $\bar{Y}$  is increasing in  $G$  and decreasing in  $\bar{r}$ . The impact of CMI on  $\bar{Y}$  is qualitatively similar to that on  $\bar{A}$  (stated in Proposition 9).*

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.

Finally, we turn to the GDP growth rate,  $g_{t+1}^Y$ . Under autarky, as  $s_t = s(\bar{K})$  for all  $t$ , (19) implies  $g_{t+1}^Y = g_{t+1}^A$ . Thus, for given education spending,  $g_{t+1}^Y$  is decreasing over time in autarky, according to Proposition 7. Moreover, it is easy to see that the impact of CMI on the GDP growth rate is similar to that on TFP growth (stated in Proposition 9) if, all other things equal,  $g_{t+1}^Y$  is monotonically decreasing over time also under capital mobility. Fig. 2 illustrates the evolution of  $\ln Y_t$  over time, together with the evolution of  $\ln A_t$  and  $s_t$ . From this, we can conclude that GDP growth indeed slows down over time, as does TFP growth rate  $g_{t+1}^A$ . Also note from Fig. 2 that in an open economy,  $s_t$  converges rather quickly along with TFP.

<Figure 2>

In sum, CMI tends to reduce technological progress and GDP growth in economies with capital outflows. Regarding economies with capital inflows, one has to be careful since GDP growth slows down during the transition to the steady state when all other things remain equal. So even capital-importing economies may see a decline in GDP growth after integration but this is an implication of convergence properties rather than

reflecting the impact of integration. In economies with a high productivity of capital, integration indeed mitigates or may even overturn the growth slowdown, as technological progress is unambiguously spurred. The reason is that educational attainment increases in these economies when capital markets integrate.

In view of Proposition 3, the analysis also suggests a novel channel regarding the link between earnings inequality, technological change and growth. Integration either affects both inequality and TFP positively or both negatively, i.e., there is always a positive relationship between inequality and technological change. Noteworthy, the mechanism behind this relationship is very different to those suggested by the literature on skill-biased technological change.<sup>17</sup> In our model, the direct impact of technological change is neutral, but there are indirect effects from capital mobility through educational attainment on inequality. Capital inflows affect the economy like skill-biased technological change does, whereas capital outflows are like unskilled-biased technological change. Moreover, as we have shown in this section, integration affects technological progress itself by changing educational attainment, which has feedback effects on both inequality and schooling enrollment.

## 6 Empirical Analysis

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

1. Net capital inflows (outflows) induce an increase (a decline) in enrollment rates for higher education at a given level of public education expenditures (Proposition 1). In the empirical implementation, we employ log inflows minus log outflows as net capital flow variable. This variable is used as one determinant of the growth of a country's 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  $H_1^a$ .

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<sup>17</sup>For an excellent review of this literature, see Acemoglu (2002).

2. A reduction in barriers to capital movement (leading to lower capital cost) induce an increase in enrollment rates for higher education when taking into account responses of public education policy to CMI (Proposition 6). We refer to this hypothesis as  $H_1^b$ . Under the corresponding null hypothesis, a reduction in these barriers exhibits a non-positive impact on a country's higher schooling.
  
3. Net capital inflows induce an increase in the growth of GDP per worker through (endogenous) enrollment rates for higher education, given the domestic capital stock and initial GDP (Propositions 1, 9 and 10). We will test the corresponding null hypothesis of a non-positive impact of endogenous enrollment rates 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 ( $H_1^b$ ) in addition to net capital inflows and other controls. We think of these flows as ones of production capital and therefore account for direct foreign investment rather than portfolio investment. Public education spendings play a specific role among the explanatory variables in our analysis. Proposition 2 suggests that they have only an indirect effect on higher education by attracting capital inflows. Therefore, in some regressions, public education expenditure is used as instrument for net capital inflows.<sup>18</sup> Finally, we run regressions of growth in GDP per worker on the initial level and the change in higher schooling ( $H_1^c$ ) among other controls such as the initial level of GDP per worker. In the latter model, we treat the change in higher schooling (and partly also the net capital inflows) as endogenous, using those variables as instruments that appear in the change in higher schooling specifications ( $H_1^a$  and  $H_1^b$ ) but do not directly affect growth in GDP per worker.

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<sup>18</sup>See also the recent literature on the knowledge-capital model of the foreign direct investment (Carr, Markusen, and Maskus, 2001; Markusen, 2002). This line of research establishes the importance of knowledge capital and, hence, higher schooling for multinational firms. Countries where skilled labor is abundant more likely headquarter multinational firms. In a similar vein, Borensztein et al. (1998) argue that FDI raises productivity only if human capital in the host country exceeds a minimum threshold.

Regarding 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 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 we employ. From the Penn World Table, we employ data on the real average annual growth of GDP per worker (U.S. dollars in 1996 constant prices, chain series), the average annual change in 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.<sup>19</sup> Further, we use data on the level and change in the share of education spending in GDP from the World Bank’s World Development Indicators. Finally, we use data on investment barriers from the Business Environment Risk Intelligence (BERI) to measure the change in investment barriers over time.<sup>20</sup> All change variables reflect average annual growth rates. In the Appendix, we give a list of the covered countries. Also, we summarize the descriptive statistics of the data, there.

In the growth in GDP per worker specifications, we treat the change in higher schooling as endogenous and run two-stage least squares instrumental variable regressions. The corresponding first-stage regressions regress 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. Table 2 summarizes our findings with respect to the first alternative hypothesis of the positive impact of an increase in net inward investment on higher schooling ( $H_1^a$ ).

<Table 2>

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<sup>19</sup>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.

<sup>20</sup>This measure is also used by Blonigen et al. (2003) and Blonigen et al. (2004), who are interested in the FDI decisions of multinational firms.

In Table 2, we report the results from four regressions.<sup>21</sup> In Model (1), we include both the change in net capital inflows and the change in government spending on education. The other variables in the table must be thought of as additional controls that appear in the second-stage GDP per worker growth models below. They are included to estimate the net impact of the direct determinants of higher schooling. Principally, we would expect that the impact of education spending cannot be estimated significantly, since it works primarily through net capital inflows. From Model (2) we even see that education spending does not affect the change in higher schooling in a reduced form regression that excludes net capital inflows. However, the effect of education spending is significant once we interact it with the initial level of primary schooling in Model (3).<sup>22</sup> In Model (4) we treat net capital inflows as an endogenous variable and estimate the parameters by two-stage least-squares (IV-2SLS), using the following instruments: the average annual change in public education spending interacted with the initial level of primary schooling, both the 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. A reduction in investment barriers captures an increasingly integrated capital market, which should affect net capital flows. Initial education levels are used as instruments to capture our theoretical result that whether CMI leads to an capital inflow or outflow of an economy depends on the economy's marginal productivity of capital ex ante, which is positively related to the ex ante 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 (over-identification), the choice of instruments seems appropriate from an econometric point

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<sup>21</sup>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 higher schooling very differently from primary schooling. The results are available from the authors upon request.

<sup>22</sup>Of course, for education spending to raise higher education a certain level of primary schooling is a prerequisite. It is important to note that this effect is not entirely driven by the level of primary schooling itself. If one additionally includes the main effect of primary schooling in the initial period, this is neither significant nor does it change the parameter estimate of the interaction term.

of view. We find that an increase in net capital inflows is significantly positively related to higher schooling as predicted by Proposition 1.

<Table 3>

In Table 3, we run models that are similar to the ones in Table 2, but include our variable which captures the reduction in investment barriers ( $H_1^b$ ). Based on our insights from Table 2, we treat net capital inflows as endogenous throughout. Again, this and the choice of instruments seems appropriate from an econometric point of view (see the p-values of the corresponding test statistics in the table). We report two models, one where the main effect of the investment barrier reduction is included (Model 5), and another one that is based on the interaction term of this variable with the change in public education spending (Model 6), motivated by Proposition 5 and Proposition 6. Note that in the theoretical model the positive impact of education spending on higher schooling works primarily through open capital markets (Proposition 2). In turn, CMI tends to stimulate education spendings by governments (Proposition 5) and, taking this into account, tends to increase enrollment into higher education (Proposition 6) even in the case where for *given* education expenditure ( $G$ ) CMI does not trigger capital inflows (and therefore does not foster higher education for given  $G$ ).<sup>23</sup> This is supported by the results in Table 3, where we find that a reduction in the barriers to capital flows exerts a positive impact on higher schooling only as far as education spending increases as well (controlling for the effect of CMI on net capital inflows). The effect of an increase in net capital inflows (instrumented as described) remains positive (in fact, is even increasing in magnitude) and significant in Model 6.

<Table 4>

Table 4 assesses the impact of an endogenous change in higher schooling on the growth in real GDP per worker ( $H_1^c$ ). The specifications of the underlying first-stage models are summarized in the footnotes at the bottom of the table. In Models (7) and

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<sup>23</sup>Compare Proposition 2 with Proposition 6.

(8), we treat net capital inflows as an exogenous variable. Hence, the corresponding parameter estimates should be interpreted with care. In Models (9) and (10), we exclude the average annual change in net capital inflows from the set of instruments and specify reduced form first-stage models.

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 investment per capita is positively related to growth of GDP per worker. The initial level of higher schooling does not exhibit a significant impact on growth. Most importantly, 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 is justified from an econometric point of view.<sup>24</sup>

It seems worth noting that instrumentation 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 0.811. Also, based on a Hausman-Wu test we would conclude that the average annual change in higher schooling should not be treated as exogenous (the corresponding test statistic is significant at 1 percent, throughout), given the chosen specification.

<Table 5>

Beyond that, the positive sign of higher education on growth in real GDP per worker is very robust with respect to using alternative schooling measures. This conclusion is based on the results summarized in Table 5. There, we treat both the average annual change in (higher) schooling and the change of net capital inflows as endogenous in three-stage least-squares systems of equations (SYS-3SLS). Three-stage least-squares

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<sup>24</sup>The instruments are relevant in the first-stage models. Also, except for model (7), they are adequate since they pass the Hansen  $J$ -test on over-identifying restrictions, which indicates that the instruments need not be included in the second-stage model.

is efficient and, in small samples, it can obtain parameter estimates that are (slightly) different from their two-stage least-squares counterparts.

Note that the only difference between Models 11 and 10 is the treatment of higher education and net capital inflows as separate equations in the system (with initial net capital inflows and the reduction in investment barriers as the identifying variables in the latter equation). Accordingly, it is not surprising that the parameter estimates are very similar to those of Model 10 in Table 4. In Model 12, we use higher schooling of males rather than that of the total population, being identical to Model 11 in all other respects. This is to account for the fact that the labor market participation of females varies considerably across different societies. However, the results are very similar to those in Model 11. In Model 13, the total years of schooling (comprising those of primary schooling as well) serve as our measure of interest. Since our model predicts that higher schooling is particularly important, it is not surprising that the parameter estimate drops substantially as compared to Models 11 and 12. Finally, in Model 14 we rely on the percentage of higher schooling attained rather than the years of higher schooling. Since the units of measurement are different as compared to Model 11, the magnitude of the coefficients is not directly comparable between Models 11 and 14. However, the results are qualitatively similar. Overall, we may therefore conclude that our findings are robust with respect to the higher schooling measure employed.

## 7 Conclusion

This research has been motivated by the dramatically increasing capital flows in the last decades, the apparent complementarity between skilled labor and physical capital, and the evidence on human capital as the basic factor which causes economic growth. We have presented theory and evidence on the impact of CMI on enrollment in higher education and economic growth. We have shown that when public education expenditure is held constant, integration leads to an increase in the share of 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 ed-

ucation expenditure, CMI tends to raise educational attainment everywhere, provided induced capital-exports are not too large.

Our empirical analysis largely confirms the main hypotheses derived in this paper: (1) Net capital inflows – whether or not these are treated as endogenous – significantly affect educational attainment, independent of the measure of higher education. (2) Changes in investment barriers do not affect educational attainment independently of capital flows, unless public education expenditure changes as well. (3) Capital flows significantly affect economic growth through their effect on higher education.

We shall conclude with some remarks on our results with respect to earnings inequality. Because our model suggests that all factors which determine inequality work exclusively through effects on educational attainment, inequality effects may be viewed as a by-product of our analysis and therefore have not been considered in the empirical part of the paper. But it may be worthwhile to confront our results on the relationship between CMI and earnings dispersion with alternative hypotheses, like that on skill-biased technological change, which is beyond the scope of this paper. The latter hypothesis 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. Strikingly, the US has experienced large capital inflows especially in the 1990s. Our analysis suggests that 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.

## 8 Appendix

### 8.1 Theoretical Appendix

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

**Proof of Proposition 4.** First, note that  $V_{Gs} > 0$ ,  $V_{GA} > 0$ ,  $V_{GG} < 0$ , according to (16), and  $s'(\bar{K}) > 0$  from Proposition 2.  $G_{AUT}$  is given by first-order condition  $V_G(A, s(\bar{K}), G_{AUT}) = 0$ .<sup>25</sup> Thus,  $\partial G_{AUT}/\partial A = -V_{GA}/V_{GG} > 0$  and  $\partial G_{AUT}/\partial \bar{K} = -V_{Gs}s'(\bar{K})/V_{GG} > 0$ . ■

**Proof of Proposition 5.**  $G_{SOE}$  satisfies first-order condition  $\tilde{V}_G(A, \bar{r}, G) = 0$ , i.e.,

$$V_G(A, s_{SOE}(A, \bar{r}, G), G) + V_s(A, s_{SOE}(A, \bar{r}, G), G) \frac{\partial s_{SOE}(A, \bar{r}, G)}{\partial G} = 0. \quad (\text{A.1})$$

Now suppose  $G = G_{AUT}$ , which is given by  $V_G(A, s_{AUT}, G_{AUT}) = 0$ . Thus, if  $\bar{r} = r_{AUT}(A, \bar{K}, G_{AUT})$  and thus  $s_{SOE} = s_{AUT}$ , evaluating the left-hand side of (A.1) at  $G = G_{AUT}$  implies that the first term of it vanishes whereas the second is strictly positive since  $V_s > 0$  and  $\partial s_{SOE}/\partial G > 0$ , according to (16) and Proposition 2, respectively. Since  $G_{SOE}$  is unique under the considered parameter domain<sup>26</sup>,  $G_{SOE} > G_{AUT}$  immediately follows from  $\tilde{V}_G(A, \bar{r}, G_{AUT}) > 0$ . ■

**Proof of Proposition 6.** First, note that substituting  $K = \tilde{\xi}(A, \bar{r})G (= K_{SOE})$  for  $G \leq \bar{G}$  into (12) implies that  $s_{SOE}$  is given by

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

Hence, for  $s_{SOE} \in (0, 1)$  and we can write

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

<sup>25</sup>Subscripts of  $V$  denote partial derivatives.

<sup>26</sup>A formal discussion on existence and uniqueness of an interior solution to the welfare maximization problem is relegated to a supplement, which is available from the authors upon request.

Thus, as  $S = G > 0$  for the economy to be viable,  $\beta s_{SOE} / (1 - \beta) > (1 - s_{SOE})^2$  must hold. This is the case when

$$s_{SOE} > \frac{1}{2(1 - \beta)} \left( 2 - \beta - \sqrt{4\beta - 3\beta^2} \right) \equiv \hat{s}(\beta), \quad (\text{A.4})$$

with  $\hat{s}(\beta) \in (0, 1)$  if  $\beta \in (0, 1)$ . Now let us define  $\hat{V}(A, \bar{r}, s) \equiv V(A, s, \tilde{G}(A, \bar{r}, s))$ . Substituting (A.3) into (16) and rearranging terms reveals that

$$\hat{V}(A, \bar{r}, s) = \frac{1}{\xi(A, \bar{r})} \left( \frac{1 - b}{b} \right)^{\frac{1}{\beta}} B(s, \beta)^{\frac{1 - \beta}{\beta}} \left[ \beta b A \xi(A, \bar{r})^\beta + 1 - \frac{s}{(1 - \beta)(1 - s + s^2)} \right], \quad (\text{A.5})$$

where

$$B(s, \beta) \equiv \frac{\beta s}{(1 - \beta)(1 - s)^2} - 1. \quad (\text{A.6})$$

Note that  $\partial B / \partial s > 0$  and, if  $s > \hat{s}(\beta)$ ,  $B > 0$ . Now recall  $\tilde{V}(A, \bar{r}, G) = V(A, s_{SOE}(A, \bar{r}, G), G)$ . If  $\hat{V}_s = V_s + V_G \tilde{G}_s = (>)0$ , then  $\tilde{V}_G = V_s(\partial s_{SOE} / \partial G) + V_G = (>)0$ , as  $\partial s_{SOE} / \partial G = 1 / \tilde{G}_s > 0$ . In a similar vein, it can be shown that  $\hat{V}_{ss}(A, \bar{r}, s) < 0$  implies  $\tilde{V}_{GG}(A, \bar{r}, G) < 0$  (and vice versa).<sup>27</sup> Hence, if  $\arg \max_{s \in (\hat{s}(\beta), 1)} \hat{V}(A, \bar{r}, s)$  has a unique solution  $s^*(A, \bar{r})$ , then  $G_{SOE} = \tilde{G}(A, \bar{r}, s^*)$  is also unique, provided that  $\bar{G}$  is sufficiently high.<sup>28</sup> According to (A.5), when  $G_{SOE} < \bar{G}$ ,  $s^*(A, \bar{r})$  satisfies  $\hat{V}_s(A, \bar{r}, s) = 0$  which is equivalent

<sup>27</sup> Again, the properties of  $\hat{V}(A, \bar{r}, s)$  directly translate into the properties of  $\tilde{V}(A, \bar{r}, G)$ . To see this, note that

$$\begin{aligned} \hat{V}_{ss} &= V_{ss} + 2V_{sG} \tilde{G}_s + V_{GG} (\tilde{G}_s)^2 + V_G \tilde{G}_{ss} \\ \tilde{V}_{GG} &= V_{ss} (\partial s_{SOE} / \partial G)^2 + 2V_{sG} (\partial s_{SOE} / \partial G) + V_{GG} + V_s (\partial^2 s_{SOE} / \partial G^2) \end{aligned}$$

Using  $\frac{\partial s_{SOE}}{\partial G} = \frac{1}{\tilde{G}_s} = -\frac{V_G}{V_s}$ , it can be shown that  $\frac{\partial^2 s_{SOE}}{\partial G^2} = -\left\{ V_{ss} + V_{GG} (\tilde{G}_s)^2 \right\} \frac{(\partial s_{SOE} / \partial G)^2}{V_s}$  and that  $\tilde{G}_{ss} = -\left\{ V_{ss} + V_{GG} (\tilde{G}_s)^2 \right\} \frac{1}{V_G}$ . Hence,  $\frac{\partial^2 s_{SOE}}{\partial G^2} = \tilde{G}_{ss} \frac{V_G}{V_s} (\frac{\partial s_{SOE}}{\partial G})^2$  substituting into the  $\tilde{V}_{GG}$ -equation, it is easy to show that  $\tilde{V}_{GG} = \hat{V}_{ss} (\tilde{G}_s)^2$ .

<sup>28</sup> A formal discussion on existence and uniqueness of  $s^*(A, \bar{r})$  is relegated to a supplement, which is available from the authors upon request.

to

$$\frac{1-\beta}{\beta} B^{\frac{1}{\beta}-2} \frac{\partial B}{\partial s} \left[ \beta b A \xi(A, \bar{r})^\beta + 1 - \frac{s}{(1-\beta)(1-s+s^2)} \right] - \frac{B^{\frac{1-\beta}{\beta}}}{1-\beta} \frac{1-s^2}{(1-s+s^2)^2} = 0. \quad (\text{A.7})$$

Thus, using the implicit function theorem,  $\partial s^*/\partial A > 0$  and  $\partial s^*/\partial \bar{r} < 0$  (recall  $\partial \xi/\partial A > 0$  and  $\partial \xi/\partial \bar{r} < 0$ , respectively), provided that  $\hat{V}_{ss}(A, \bar{r}, s^*) < 0$ . According to Proposition 5,  $G_{SOE} > G_{AUT}$  if  $\bar{r} = r_{AUT}(A, \bar{K}, G_{AUT})$  and  $s_{SOE}(A, \bar{r}, G_{AUT}) = s_{AUT}$ , respectively. Hence, in this case,  $s^*(A, \bar{r}) = s_{SOE}(A, \bar{r}, G_{SOE}) > s_{AUT}$ . Moreover, since  $\partial s^*(A, \bar{r})/\partial \bar{r} < 0$ , we also have  $s^*(A, \bar{r}) > s_{AUT}$  if  $\bar{r} < r_{AUT}(\cdot, G_{AUT})$ , but not necessarily if  $\bar{r} > r_{AUT}(\cdot, G_{AUT})$ . This concludes the proof. ■

**Proof of Proposition 7.** From (17), the result is obvious in the autarky case, as  $s_t = s(\bar{K})$  for all  $t$  and  $\gamma \in (0, 1)$ . Under capital mobility, we need to prove that  $f(s_{SOE}(A, \bar{r}, G), G, A)$  is strictly concave as function of  $A$ . A sufficient condition is that  $s_{SOE}(A, \cdot)$  is concave as function of  $A$ . Substituting (14) into (A.2),  $s_{SOE}$  is given by

$$(1-\beta) \left[ \Gamma A^{\frac{\beta}{1-\beta}} (1-s)^{2-\beta} + (1-s)^2 \right] - \beta s = 0, \quad (\text{A.8})$$

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

$$\frac{\partial s_{SOE}}{\partial A} = \frac{\beta \Gamma A^{\frac{2\beta-1}{1-\beta}} (1-s)^{2-\beta}}{(1-\beta) \left[ (2-\beta) \Gamma A^{\frac{\beta}{1-\beta}} (1-s)^{1-\beta} + 2(1-s) \right] + \beta}. \quad (\text{A.9})$$

From (A.9), it is tedious but straightforward to show that  $\partial^2 s_{SOE}/\partial A^2 < 0$  iff

$$\begin{aligned} 0 < & \beta \left[ \frac{1-2\beta}{1-\beta} (1-s_{SOE}) + (2-\beta) A (1-s_{SOE}) \right] + \\ & (1-\beta)(2-\beta) \Gamma A^{\frac{\beta}{1-\beta}} (1-s_{SOE})^{2-\beta} + 2(1-2\beta)(s_{SOE}-s)^2 + \\ & 2(1-\beta)^2 A (1-s_{SOE}) \frac{\partial s_{SOE}}{\partial A} + (1-\beta)(2-\beta) \Gamma A^{\frac{1}{1-\beta}} (1-s_{SOE})^{1-\beta} \frac{\partial s_{SOE}}{\partial A}. \end{aligned} \quad (\text{A.10})$$

Thus,  $\partial^2 s_{SOE}/\partial A^2 < 0$  if  $\beta \leq 1/2$ , which confirms the first part of Proposition 7.

It remains to be shown that the TFP growth rate,  $g_{t+1}^A$ , declines over time. Using

$\tilde{g}(s_{SOE}, S, A) = (s_{SOE}/A)^\gamma S^\varepsilon - \delta$ , totally differentiating (and using  $S = G = const.$ , thus  $dS = 0$ ) yields  $dg^A = \gamma (s_{SOE}/A)^\gamma G^\varepsilon (ds_{SOE}/s_{SOE} - dA/A)$ . Moreover,  $ds_{SOE} = (\partial s_{SOE}/\partial A)dA$ , and thus  $ds_{SOE}/s_{SOE} = (\partial s_{SOE}/\partial A)(A/s_{SOE})(dA/A)$ . Hence,  $dg^A < 0$  if and only if  $\partial s_{SOE}/\partial A < s_{SOE}/A$ . Since  $s_{SOE} > 0$  for all  $A$ , and  $\partial^2 s_{SOE}/\partial A^2 < 0$  if  $\beta \leq 1/2$ ,  $d\vartheta < 0$  holds if  $\beta \leq 1/2$ . This concludes the proof. ■

**Proof of Proposition 10.** Using  $G_{t-1} = G$ , (18) implies  $\bar{Y} = \kappa \bar{A} \bar{s} (1 - \bar{s})^{-(2-\beta)} G^{1-\beta}$ . Using that  $\bar{s} = s(\bar{K})$  under autarky and  $\bar{s} = s(\bar{A}, \bar{r}, G)$  under capital mobility, and recalling Propositions 2 and 8, confirms comparative-static results. ■

## 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>

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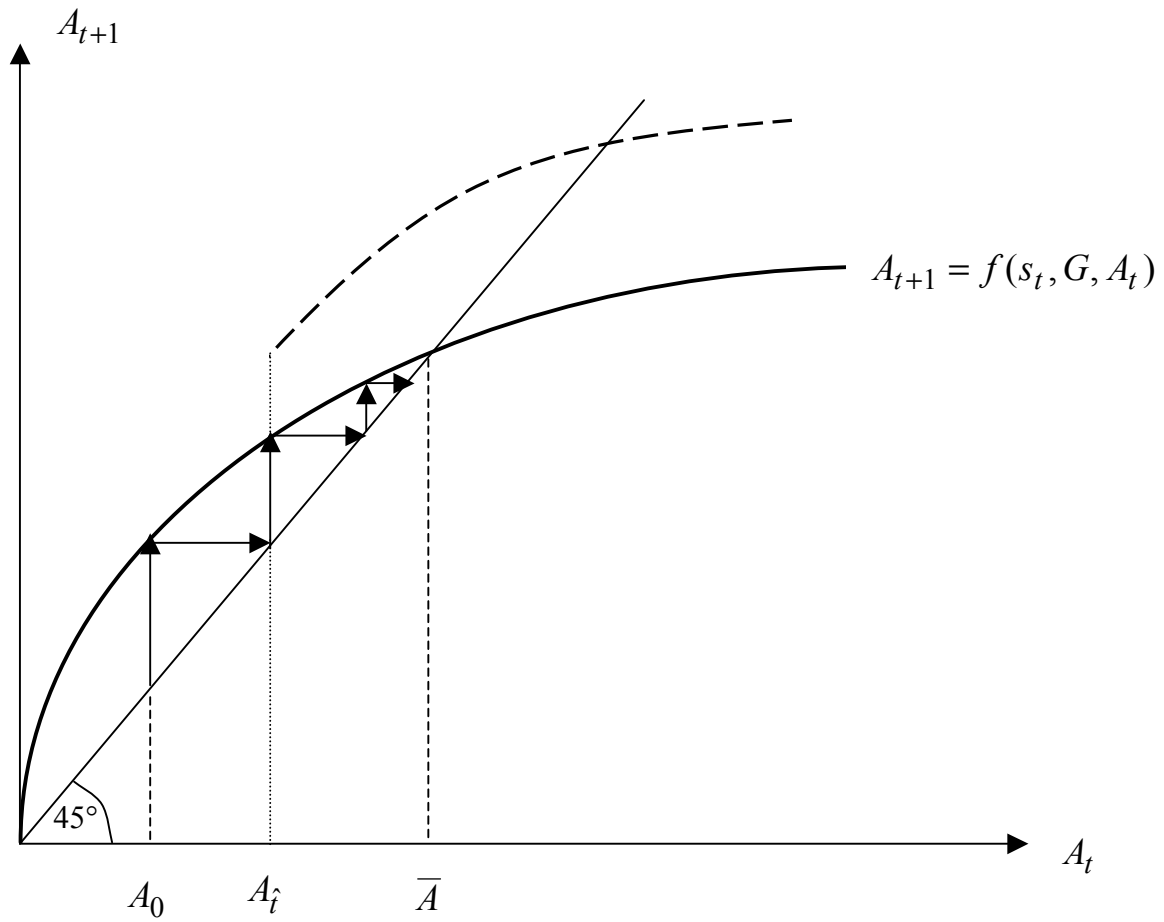
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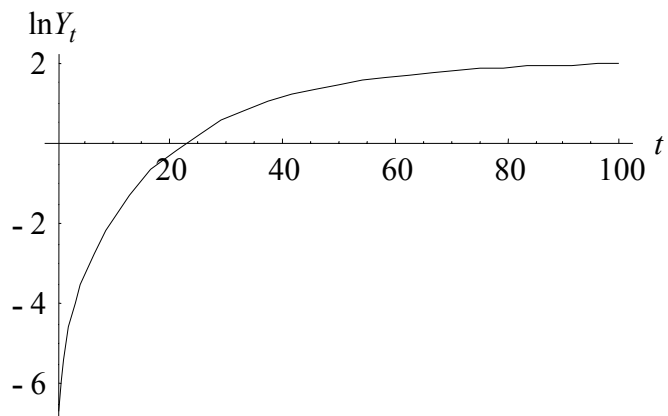
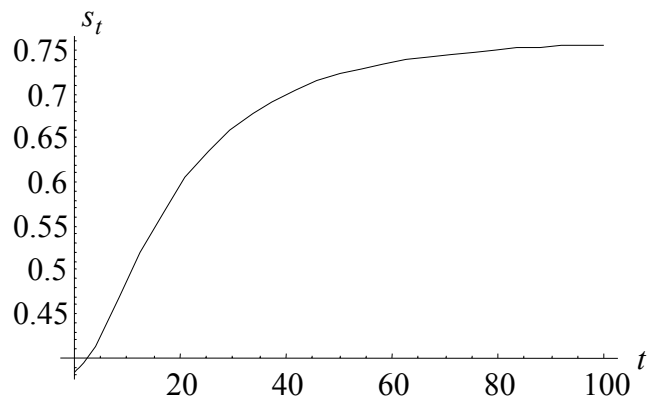
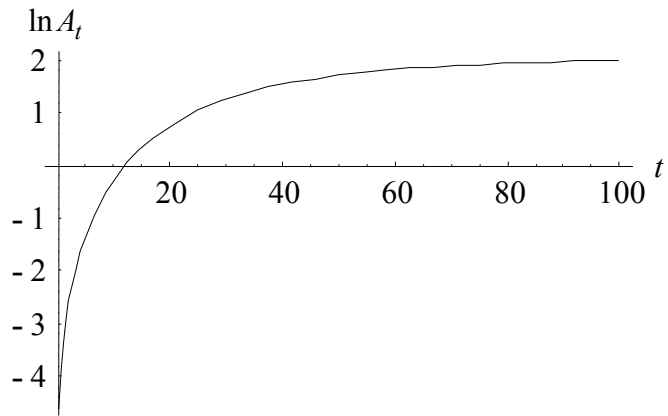


**Figure 1:** The evolution of total factor productivity for  $(S_t =)G_{t-1} = G$ .

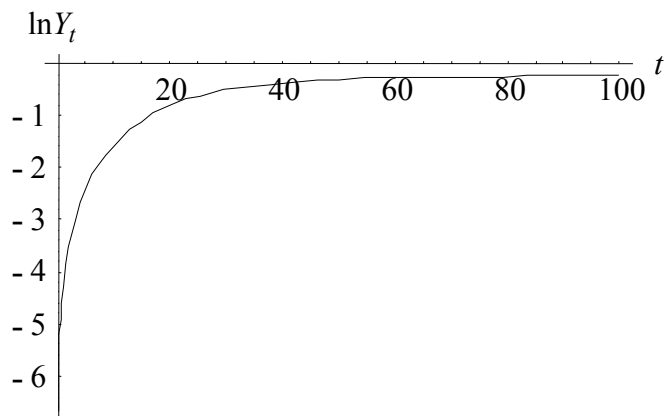
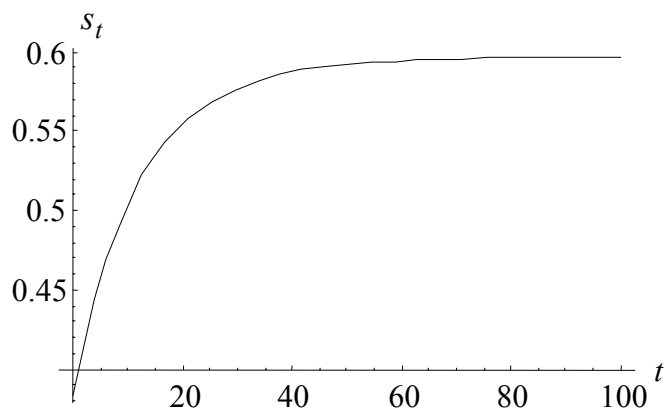
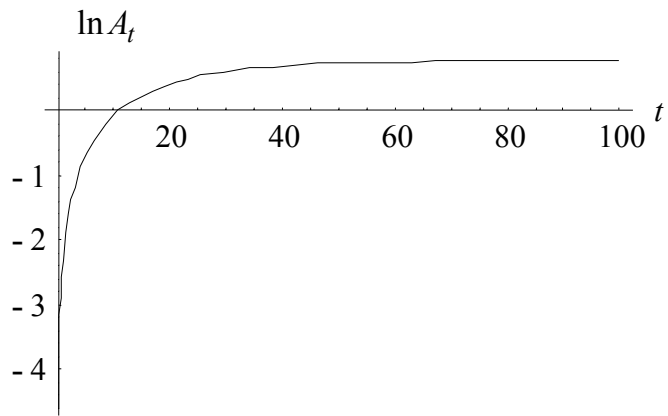
$\bar{r}$	$A = 0.5$		$A = 1$	
	$G_{SOE}$	$s^*$	$G_{SOE}$	$s^*$
0.02	0.06	0.584	$\bar{G}$	0.838
0.05	0.02	0.449	$\bar{G}$	0.738
0.08	0.02	0.426	0.22	0.579
0.11	0.03	0.421	0.1	0.501
0.14	0.04	0.418	0.08	0.472

**Table 1:** Optimal education policy, where  $b = \beta = 0.5$  and  $\bar{G} = 1$ .

*Note:* When  $G_{SOE} = \bar{G}$ , no interior solution exists even for  $\bar{G} \rightarrow \infty$ .



(a)  $\gamma = 0.5$



(b)  $\gamma = 0.9$

**Figure 2:** Numerical illustrations for the open economy, where  $G = \bar{r} = 0.1$ ,  $b = \beta = \varepsilon = 0.5$ .

Table 2 - Net Capital Inflows Induce an Increase in Enrollment Rates For Higher Education ( $H_1^a$ )

Explanatory variables	Dependent variable is average years of higher schooling <sup>a</sup>							
	(1)		(2)		(3)		(4) <sup>c</sup>	
	$\beta$	std.	$\beta$	std.	$\beta$	std.	$\beta$	std.
Change variables (average annual change)								
Net capital inflows	0.3085	0.1882 *	-	-	-	-	1.2617	0.6196 **
Log workers	0.1108	0.1093	0.1254	0.1099	0.1120	0.1113	0.1339	0.1208
Education spendings	0.0159	0.0100	0.0111	0.0112	-	-	-	-
Education spendings $\times$ Primary schooling in initial period <sup>b</sup>	-	-	-	-	0.0113	0.0063 *	-	-
Constant	-0.0496	0.0084 ***	-0.0479	0.0084 ***	-0.0462	0.0088 ***	-0.0568	0.0122 ***
Level variables (initial period)								
Log capital stock per worker	0.0004	0.0007	-0.0004	0.0006	-0.0005	0.0005	-0.0012	0.0009
Education spendings	0.0007	0.0004 **	0.0011	0.0003 ***	0.0010	0.0003 ***	0.0012	0.0004 **
Log real GDP per worker	0.0032	0.0010 ***	0.0035	0.0011 ***	0.0034	0.0011 ***	0.0047	0.0015 ***
Observations (countries)	87		87		87		79	
R <sup>2</sup>	0.6103		0.6009		0.6153		0.7830	
Estimation approach	OLS		OLS		OLS		IV-2SLS	
Exogeneity of net capital inflows (p-value of Hausman-Wu F-test)	-	-	-	-	-	-	0.0257	
Instrument relevance (p-value of F-test)	-	-	-	-	-	-	0.0326	
Instrument adequacy (p-value of Hansen J statistic)	-	-	-	-	-	-	0.1621	

Notes:

<sup>a</sup> Using the variable labelled "HYR" in the Barro and Lee (2000) dataset.

<sup>b</sup> Using the variable labelled "PYR" in the Barro and Lee (2000) dataset.

<sup>c</sup> Using the following instruments for net capital inflows: average annual change in education spending  $\times$  initial level of primary schooling, both initial level and change in primary schooling, initial level in higher schooling, initial level of net capital inflows, reduction in investment barriers.

Reported standard errors are robust to heteroskedasticity.

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

Table 3 - A Reduction in Barriers to Capital Movement Induces an Increase in Enrollment Rates For Higher Education  
Independent of Actual Capital Flows ( $H_1^b$ )

Explanatory variables	Dependent variable is average annual change in average years of higher schooling <sup>a</sup>			
	$\beta$	(5) <sup>b</sup> std.	$\beta$	(6) <sup>b</sup> std.
Change variables (average annual change)				
Reduction in investment barriers	0.0187	0.0261	-	-
Reduction in investment barriers $\times$ Change in education expenditures	-	-	0.0510	0.0266 *
Net capital inflows	1.5642	0.7718 **	2.2159	0.9314 **
Log workers	0.1418	0.1272	0.0154	0.1917
Constant	-0.0791	0.0334 **	-0.0605	0.0138 ***
Level variables (initial period)				
Log capital stock per worker	-0.0013	0.0010	-0.0008	0.0010
Education spendings	0.0013	0.0005 ***	0.0011	0.0005 **
Log real GDP per worker	0.0049	0.0016 ***	0.0050	0.0017 ***
Observations (countries)	79		79	
R <sup>2</sup>	0.7519		0.6844	
Estimation approach	IV-2SLS		IV-2SLS	
Exogeneity of net capital inflows (p-value of Hausman-Wu F-test)	0.0107		0.0004	
Instrument relevance (p-value of F-test)	0.0493		0.0487	
Instrument adequacy (p-value of Hansen J statistic)	0.1529		0.4985	

Notes:

<sup>a</sup> Using the variable labelled "HYR" in the Barro and Lee (2000) dataset.

<sup>b</sup> Using the following instruments for net capital inflows: average annual change in education spending  $\times$  initial level of primary schooling, 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.

Table 4 - Net Capital Inflows Induce an Increase in Growth of GDP Per Worker Through Enrollment Rates For Higher Education ( $H_1^c$ )

Explanatory variables	(7) <sup>a</sup>		(8) <sup>b</sup>		(9) <sup>c</sup>		(10) <sup>d</sup>	
	$\beta$	std.	$\beta$	std.	$\beta$	std.	$\beta$	std.
Change variables (average annual change)								
Higher schooling years	3.8784	1.1876 ***	4.8871	1.3112 ***	4.5973	1.1629 ***	4.4806	1.1406 ***
Log workers	-0.3393	0.6061	-0.5008	0.6697	-0.3819	0.6448	-0.4736	0.6280
Constant	0.1719	0.0431 ***	0.1956	0.0468 ***	0.1932	0.0440 ***	0.1840	0.0445 ***
Level variables (initial period)								
Log capital stock per worker	0.0049	0.0018 ***	0.0039	0.0022 *	0.0047	0.0020 **	0.0041	0.0021 *
Higher schooling years	-0.0298	0.0344	-0.0428	0.0456	-0.0361	0.0397	-0.0388	0.0421
Log real GDP per worker	-0.0243	0.0059 ***	-0.0271	0.0062 ***	-0.0272	0.0060 ***	-0.0256	0.0058 ***
Observations (countries)	86		78		86		78	
R <sup>2</sup>	0.3006		0.0728		0.1108		0.1869	
Estimation approach	IV-2SLS		IV-2SLS		IV-2SLS		IV-2SLS	
Exogeneity of higher schooling years (p-value of Hausman-Wu F-test)	0.0002		0.0000		0.0000		0.0000	
Instrument relevance (p-value of F-test)	0.0000		0.0827		0.0033		0.0625	
Instrument adequacy (p-value of Hansen J statistic)	0.0500		0.2429		0.4127		0.1043	

Notes:

In this table, we use the variable labelled "HYR" in the Barro and Lee (2000) dataset as an endogenous measure of higher schooling.

<sup>a</sup> Using the variables as in Model (1) in Table 2 as instruments for the change in higher schooling.

<sup>b</sup> Using the variables as in Model (6) in Table 3 (without instrumenting net capital inflows) as instruments for the change in higher schooling.

<sup>c</sup> Using the following instruments for the change in higher schooling: level of education spending in initial period, change in education spending x initial level of primary schooling.

<sup>d</sup> Using the following instruments for the change in higher schooling: average annual reduction in investment barriers, average annual change in education spending x initial level of primary schooling, initial level of primary schooling, initial level of education spending, 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.

Table 5 - Net Capital Inflows Induce an Increase in Growth of GDP Per Worker Through Enrollment Rates For Higher Education ( $H_1^c$ ), Robustness to Choice of Higher Schooling Measure

Explanatory variables	(11) <sup>a</sup>		(12) <sup>b</sup>		(13) <sup>c</sup>		(14) <sup>d</sup>	
	$\beta$	std.	$\beta$	std.	$\beta$	std.	$\beta$	std.
Change variables (average annual change)								
Higher schooling years	4.0799	0.7102 ***	3.9235	0.6530 ***	0.3395	0.0470 ***	0.1378	0.0256 ***
Log workers	-0.4341	0.4605	-0.4999	0.4527	-0.4219	0.3252	-0.6408	0.4956
Constant	0.1777	0.0316 ***	0.1681	0.0295 ***	0.0655	0.0182 ***	0.1901	0.0349 ***
Level variables (initial period)								
Log capital stock per worker	0.0042	0.0026 *	0.0041	0.0025	0.0005	0.0019	0.0048	0.0027 *
Higher schooling years	-0.0251	0.0176	-0.0178	0.0148	0.0035	0.0008 ***	-0.0011	0.0006 *
Log real GDP per worker	-0.0247	0.0049 ***	-0.0237	0.0046 ***	-0.0099	0.0029 ***	-0.0266	0.0053 ***
Observations (countries)	78		78		78		78	
R <sup>2</sup>	0.5997		0.5714		0.2387		0.5918	
Estimation approach	SYS-3SLS		SYS-3SLS		SYS-3SLS		SYS-3SLS	
Instrument adequacy (p-value of Hansen J statistic)	-		-		-		-	

Notes:

In this table, the equations for the change in higher schooling and net capital inflows are specified as in Model (4) of Table 2, but they form two separate equations of the system of three equations, here.

<sup>a</sup> Using the change in higher schooling ("HYR" in Barro and Lee, 2000).

<sup>b</sup> Using the change in higher schooling of males ("HYRM" in Barro and Lee, 2000).

<sup>c</sup> Using the change in total schooling years ("TYR" in Barro and Lee, 2000).

<sup>d</sup> 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 6 - Descriptive Statistics

Variables	Mean	Std. dev.	Minimum	Maximum
Dependent variables				
Average annual change in average years of higher schooling	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 log real GDP per worker (1996; chain series)	0.0172	0.0144	-0.0120	0.0595
Independent variables				
Average annual change in log (numbers of) workers	0.0011	0.0045	-0.0088	0.0159
Average annual change in average years of primary schooling	0.0330	0.0224	-0.0163	0.0867
Average annual change in education spending	0.0264	0.0377	-0.1785	0.1245
Average annual change in education spending $\times$ Initial level of average years of primary schooling	0.0742	0.0860	-0.2114	0.3614
Average annual reduction of investment barriers	1.0085	0.0218	0.9395	1.0731
Average annual reduction of investment barriers $\times$ Average annual change in education spending	0.0293	0.0386	-0.1785	0.1346
Initial level of average years of higher schooling	0.0834	0.1163	0.0000	0.5300
Initial level of average years of primary schooling	2.6511	1.9135	0.0450	7.3160
Initial level of real GDP per worker (1996; chain series)	8.7845	0.9577	6.7365	10.5837
Initial level of log real capital stock per worker (1996; chain series)	6.6199	1.6766	2.0067	9.1671
Dependent variables used in robustness analysis				
Average annual change in average years of higher schooling of males	0.0082	0.0068	-0.0004	0.0287
Average annual change in average years of total schooling	0.0684	0.0328	0.0126	0.1531
Average annual change in average years of higher schooling attained	0.2320	0.2157	-0.0077	0.9718
Independent variables used in robustness analysis				
Initial level of average years of higher schooling of males	0.1101	0.1386	0.0000	0.6020
Initial level of average years of total schooling	3.4538	2.6624	0.0740	9.5550
Initial level of average years of higher schooling attained	2.6035	3.8748	0.0000	20.0000