Human Capital Formation, Learning and Growth in Open Economies

Juana Patricia Téllez Corredor
Department of Economics
Queen Mary, University of London

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Abstract

During the last decades two factors have been recognised as major determinants of economic growth. Firstly, the ongoing integration of international capital markets has rendered foreign physical capital a crucial factor in the performance of open economies. Secondly, in addition to greater capital mobility, there has been an increasing awareness among economists that economic growth swivels around the production and use of knowledge. The connections relating those two crucial factors (i.e. physical capital mobility and knowledge production) have been, however, seldom explored in the relevant literature. This is an important omission which we seek to remedy in this thesis.

The main objective of this dissertation is, essentially, to explore the joint role of physical capital and knowledge accumulation in the economic growth process, when physical capital mobility exists. Another important objective is to study the role of knowledge accumulation in attracting foreign physical capital. For this purpose, we advance two theoretical models of growth to explore these connections, from an exogenous and an endogenous point of view respectively. An empirical application complements the theoretical approach concentrating on the long-term linkages between human capital accumulation and physical capital movements.

The thesis comprises three chapters. In Chapter 1 we construct a two-country Solow-Swan growth model in which 'knowledge production' is treated as pure human capital accumulation. In this model, physical capital moves freely across borders and human capital is immobile, whilst the interest rate is determined endogenously.

In Chapter 2 we develop a two-country endogenous growth model with capital flows. This time, 'knowledge production' is achieved by means of a learning-by-doing process in both countries, this being a side-effect of world physical capital accumulation. Once again, physical capital is mobile between countries, whilst labour is immobile, and the interest rate is determined endogenously.

In Chapter 3 we build on the connections between knowledge production and physical capital accumulation explored theoretically in previous chapters. Essentially, we investigate the extent to which human capital differences across countries could account for differences in physical capital inflows, after controlling for other factors.

The main result obtained throughout our investigation is the confirmation of the existence of strong links relating knowledge production to international capital flows. Both theory and data seem to strongly support this conclusion.
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Preface and acknowledgements

This thesis is the result of several years of strenuous effort and constant challenges. Carrying out my doctoral research in a foreign country and in a foreign language was as much a hard as a rewarding experience, and living in London taught me poignant lessons that will enlighten the years to come. All in all, the continuous support and encouragement received from my teachers, family, friends and colleagues was invaluable for the completion of this project.

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Lastly, but certainly not least, I owe an enormous debt of gratitude to my husband, Jorge Restrepo, who never stopped cheering me up, especially during those repeated occasions when I was about to give up on what seemed to be an impossible task. Jorge’s meticulous and intelligent reading and re-reading of numerous drafts of my dissertation were an invaluable help. Without his love and care during these years, this project would have never finished.

Finally, I certify that this thesis, and the research to which it refers, are the product of my own work, and that any ideas or quotations from the work of other people, published or otherwise, are fully acknowledged in accordance with the standard referencing practices of the discipline.
Introduction and literature review

The ongoing integration of international capital markets during the last thirty years has rendered foreign physical capital a crucial factor in determining the performance of open economies. In this regard, many authors have stressed the potential benefits that capital markets integration may bring in fostering higher economic growth.¹

In addition to greater capital mobility, there has been an increasing awareness among economists in particular and social scientists in general that economic growth swivels around the production and use of knowledge. However, the relationship between these two determinants of growth (i.e. physical capital mobility and knowledge production) has received little (if any) consideration in the literature.

In effect, from a theoretical perspective, economists have focused on: i) either explaining how knowledge production may contribute to enhance growth prospects (this is the case of models of exogenous and endogenous growth, including human capital notions, e.g. Mankiw et al. (1992) and Barro et al. (1995)); ii) or discussing


Meanwhile, from an empirical perspective, authors have identified a number of relevant (domestic) factors, which might play a role in attracting international capital flows, mainly in the short run, such as the degree of openness or various indicators reflecting macroeconomic and institutional conditions. Human capital or other alternative measures of knowledge production, which can be viewed as determinants of growth in the medium to long run, have, however, not been included in those studies as a critical factor.

Therefore we observe that there is an important gap in the literature, as the increase in the average level of knowledge of a society (by whichever means) is likely to be associated with greater and more profitable opportunities for foreign direct investment and other types of capital inflows. This thesis is precisely a contribution towards filling this gap.

Essentially we endeavour to show firstly whether a relationship between knowledge accumulation and international movements of capital can be documented; and secondly, to explain the extent to which different modes of knowledge production affect the processes of international and domestic physical capital accumulation and, in consequence, the growth rate of open economies. Here we do both theoretically and empirically.

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To put it differently, the main aim of this thesis is to explore the roles of both physical capital and knowledge accumulation within the process of economic growth, assuming mobility of physical capital. The main questions around which the thesis will be structured are thus as follows:

- How can traditional models of economic growth be extended to account for knowledge production and physical capital mobility between countries simultaneously?
- What insights can be derived for the behaviour of major macroeconomic variables, such as the rate of growth and the interest rate, with different modelling assumptions?
- How do these conclusions vary when considering groups of countries with different (domestic) physical capital accumulation and/or knowledge production structures?
- Can differences in knowledge production account for differences in physical capital inflows? More specifically, can low rates of the former explain the low levels of physical capital mobility from capital-rich to capital-poor nations observed in practice, in spite of its (potentially) high returns?

In order to address these questions, we explore the connection between knowledge production, physical capital mobility and economic growth, considering 'knowledge production' to be the critical variable in the analysis. Essentially, we proceed in three successive stages in which 'knowledge production' is approached
from two different perspectives to show its impact on the other variables, i.e. domestic and foreign physical capital accumulation and growth.

During the first stage, ‘knowledge production’ is treated as human capital accumulation, a process that requires savings to be put into building up the stock of this type of productive capital. This is consistent with using a traditional two-country growth model, augmented to include human capital accumulation in both countries, as well as free physical capital mobility. The consequences of changes in (domestic and foreign) human capital accumulation upon (domestic and foreign) physical capital accumulation and the rate of growth of national income are then studied. The effect of knowledge as human capital on international capital movements is studied in detail. The other factors influencing international capital movements are also considered.

In the second stage, we see ‘knowledge production’ as a process derived from the physical capital accumulation process. Assuming almost perfect technological diffusion across countries, we construct a two-country endogenous growth model, with knowledge production conceived as a learning-by-doing process. Physical capital moving across countries can affect rates of growth, not only directly, but also via its impact on the rates of learning and technology diffusion.

Finally, from an econometric perspective, we address the thorny issue of measuring knowledge production. Our strategy here is once again to assimilate ‘knowledge production’ into human capital accumulation, and more precisely into a measure of educational attainment. In this fashion we construct multi-country panel
data to estimate by groups of countries the differential effect of human capital accumulation on capital inflows in the medium run.

Therefore, this thesis represents an original contribution in many ways, since: 1) it builds a link between two hitherto unrelated strands of literature; 2) it conveys strong theoretical arguments about the effects of knowledge production on international assets; 3) it builds innovative theoretical models with an endogenous determined interest rate and using a two-country analytical device; 4) it supports the former theoretical findings with conclusive empirical evidence, by means of an innovative panel data study based on recently released data; 5) it therefore provides potentially significant economic policy insights for both developed and developing economies.

Let us now put the analysis in context and explain in detail the nature of our project.

**Literature review**

In order to appreciate the extent and scope of our contribution, we briefly summarise here the state of the theoretical and empirical literature in the field and illustrate the existing gaps our dissertation aims to fill. For purposes of systematisation, we divide these works into four relevant categories.
A first strand of literature includes those works that have stressed the role of knowledge production as a determinant of growth, without considering simultaneously the role of international capital flows.

With the aim of reconciling the predictions of the Solow-Swan growth model with the empirical evidence, Mankiw et al. (1992) were the first to augment the traditional version of the growth model by including human capital accumulation. In this model, human capital, as physical capital, accumulates exogenously at a fixed fraction of income. A few years before, Paul Romer (1986) and Robert Lucas (1988) introduced their innovative growth models in which, thanks to a technological process without decreasing returns to scale, the long run rate of growth is determined endogenously. In Romer’s model, innovation as a result of research and development activities leads to endogenous growth. In Lucas’s model, externalities associated with human capital accumulation explain the absence of decreasing returns. By contrast, in the model we present in Chapter 2 learning occurs as a side-effect of the accumulation of international physical capital in the domestic economy. Whatever the form in which knowledge accumulates, this is one of the major strands in contemporary economic growth literature. Important references here are the works of Benhabib and Spiegel (1994), Islam (1995), Caselli et al. (1996), Pritchett (2001), Temple (1999, 2001), Storesletten and Zilibotti (2000), Bassanini and Scarpetta (2002), McDonald and Roberts (2002), Hojo (2003) and Chen and Dahlman (2004).
ii. Secondly, there is a vast amount of literature centering on the links between international capital mobility and economic growth. Notice that these works, however, do not consider the role of human capital accumulation. Outstanding references are Ruffin (1979), Buiiter (1981), Ruffin (1985), Ruffin and Yoon (1993), Leiderman and Razin (1994), Barro et al. (1995), Yoon (1998), Viaene and Zilcha (2002a, 2002b) and Alfaro et al. (2004).

iii. Thirdly, and related to our proposed research relationship between knowledge production and international capital mobility, a number of contributions endeavour to establish the so-called ‘determinants’ of capital flows. We stop to consider this literature in more detail as it is central to our objectives.

Short run

For the most part, this literature has focused on short-run considerations, whereby capital flows are determined mainly through a portfolio selection approach, that is, by risk and return characteristics of assets in the portfolio of international investors.

A convention followed in this type of literature is to distinguish between determinants primarily internal to recipient nations (pull factors) and determinants linked to conditions in the global economy (push factors). Fernández-Arias (1996) developed an analytical framework that seeks to distinguish the effects of these different types of factors. According to the author, the decision to invest in a developing country depends on the domestic returns, country creditworthiness and
expected returns in advanced countries. He finds that the initial surge in capital flows in the eighties appears to have been “pushed” by low returns in developed countries.\(^4\)

In the same way, Calvo et al. (1993) find that capital flows respond to push factors, such as regional external shocks, a finding that is again stressed in Calvo et al. (1996). Taylor and Sarno (1997) apply the same analytical framework as Fernández-Arias (1996), finding evidence that USA long-term equity and bond flows and USA short-term equity flows are equally sensitive to both push and pull factors. Griffin et al. (2002) using daily data on net equity flows for nine emerging market countries, find that equity flows respond to both push and pull factors. Equity flows are positive related to host country returns as well as market performance abroad.

On the other hand, Bacchetta and Wincoop (1998) hold that structural reforms and financial liberalisation are the fundamental factors pulling capital flows. They present a theoretical model to account for the impact of these reforms in the dynamics of capital flows and to model the steady state level of capital flows. Chen and Khan (1997) present an asymmetric information model, in which pull factors have great relevance. They show that inefficiency in financial markets combined with countries’ growth profile can lead to different patterns of capital flows.

A summary of the main writings belonging to this type of literature is presented in Table 1.

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3 Pull factors comprise rates of return, credit ratings, secondary market prices of sovereign debt and domestic financial regulation; push factors include rates of return in the developed world and institutional or legal reforms in its markets.

4 A limitation of this work comes from the fact that to measure creditworthiness Fernández-Arias uses the level of foreign interest rates, a push factor.
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Medium and long run

A small number of contributions to the field have attempted to uncover the determinants of capital flows in the medium run. These works mainly centre on macroeconomic factors, such as the existence of a cyclical path of lending and borrowing. Diaz-Alejandro (1984) stresses the importance of the lending cycle in the central economies and its effects on capital flows onto peripheral countries. Similar ideas linking the waves of liquidity fluctuations, lending cycles and sudden reversals are presented in the works by Kindleberger (1984, 1996) and Palma (1998). These two authors attribute the cyclical pattern of flows to fluctuations in liquidity and “irrational behaviour”. However, with respect to our purposes here, none of these pointed out the potential importance of human capital as a crucial medium and long run determinant.

Empirical approaches

Nevertheless, it is noticeable that a few empirical works directly test the hypotheses, with which we are concerned here, namely the relationship between knowledge accumulation and capital flows. We have been able to find a handful of works which address this issue but concentrate on foreign direct investment (FDI). Noorbakhsh et al. (2001) test the conditional relationship between FDI inflows and human capital in a cross-country regression for 36 developing countries. Yussof and Ismail (2002) identify the effect of highly skilled professionals and workers as a key condition for FDI inflows in four Asian countries. Dasgupta et al. (1996) find in a survey of Japanese firms that human capital consideration is a key factor in determining FDI
country choices. In an economic history study, Hanson (1996) finds a significant role for human capital on FDI, but he also suggests that political risk and institutional compatibility across countries are key issues. On the other hand, Schneider and Frey (1985) show that this effect is not consistently significant using a cross-section methodology.

iv. Fourthly, and perhaps more importantly, we are aware of only two contributions that directly address the specific relationship we want to study in this thesis. The paper by Barro et al. (1995) studies international convergence in income levels with a small open economy model which includes human capital and partial physical capital mobility with the rest of the world. In addition, the work by Manzocchi and Martin (1996) presents a small, open economy augmented-Solow model with partial mobility of capital to study long-term determinants of capital flows. Borrowing from abroad can be used to accumulate physical but not human capital, and human capital cannot be used as collateral for external borrowing. Then, as instantaneous convergence is not feasible, capital flows depend on the same determinants as conditional convergence à la Barro. The model was tested econometrically in a cross-section of countries but the results are inconclusive.

We believe, however, that these studies fall short of the one we advance in our thesis, since we fully incorporate the production of knowledge into the models, use as an analytical device a two-country growth model and allow for the full effect of free capital mobility.
Thesis outline

This thesis comprises three main chapters, which broadly include the three main themes or stages discussed in the introduction above.

In Chapter 1 we construct a two-country Solow-Swan growth model with knowledge as human capital, in which physical capital moves freely across borders and human capital is immobile. The interest rate is determined endogenously. The results of this model show that the stock of international assets responds positively to changes in human capital accumulation in the debtor country and to changes in physical capital accumulation in the creditor country. Human capital accumulation also has a positive effect on the interest rate. Both economies reach a unique steady state equilibrium after physical capital markets liberalisation, exhibiting higher levels of economic activity than before. The steady-state pattern of international capital stocks is determined by the relative fraction of income that each country invests in physical capital with respect to its marginal productivity.

In Chapter 2 we develop a two-country endogenous growth model with capital flows, in which knowledge production is achieved by means of a learning-by-doing process in both countries. Knowledge accumulation occurs as a side-effect of world physical capital accumulation. Physical capital accumulates as in the Solow-Swan model, in which saving rates are constant and exogenous. In addition, physical capital is mobile between countries, whilst labour is immobile. The interest rate is determined endogenously. Both countries attain a balanced growth equilibrium in which either a positive or a negative stock of international assets is accumulated. As
in the previous chapter, the steady-state pattern of international capital stocks depends on the savings rates of each country relative to the elasticity of output with respect to physical capital.

Finally, in Chapter 3 we build on the connections between knowledge production and physical capital accumulation explored theoretically in previous chapters. Essentially, we investigate the extent to which human capital differences across countries could account for differences in physical capital inflows, after controlling for other factors. This chapter uses recently released datasets on human capital stocks and a broad measure of capital inflows for a relatively large sample of industrial and developing countries, using panel data estimation techniques. The main result we find is the robust positive effect that the level of human capital stock has on driving capital inflows across sub-samples of countries and for different types of foreign capital inflows, although this effect is larger for industrialised countries than for developing ones.
Chapter 1.

A two-country Solow-Swan growth model with human capital and international assets

1 Introduction

There is a vast literature devoted to the analysis of linkages between international capital movements and economic performance.\textsuperscript{5} Interestingly enough, most of these open economy models have studied the role of capital markets integration without considering simultaneously the role of human capital accumulation and the importance of abandoning the small open economy assumption that relegates the price of capital as a key variable.

The purpose of this chapter is to analyse physical capital, human capital and international asset accumulation in a two-country growth model. We extend the analysis of the basic growth model by Solow (1956) and Swan (1956), including the accumulation of human capital and allowing free mobility of physical capital between the two countries. We restrict the movements of human capital across the two large economies, and allow the endogenous determination of the interest rate through an equilibrium parity condition. Thus this model can be used to examine the interactions between two large economies or groups of countries with different physical-human capital accumulation structures, allowing through the endogeneity of the interest rate for the full effect of physical capital mobility to affect the long run equilibrium.

Another common feature of open economy models is the disregard for the role of external factor remunerations on the accumulation and growth processes. Following Ruffin (1979), we include fully the effect of international physical capital remuneration by founding our analysis on national income and not on domestic production levels alone.

The importance of human capital in relation to the process of growth has been long stressed in the literature. There have been several attempts to model its process of accumulation in growth models. To reconcile the prediction of the Solow-Swan growth model with empirical evidence, Mankiw et al. (1992) augment the traditional version by including human capital accumulation, whereby human capital, like physical capital, is accumulated at a fixed fraction of the income. Barro et al. (1995)
study international convergence using a small, open economy model with human
capital and partial physical capital mobility. We include human capital following
Mankiw et al. (1992) and Barro et al. (1995) by directly including it as an additional
productive factor in a neoclassical growth framework.

In addition to the inclusion of human capital, we use as an analytical device a
two-country growth model. Given its tractability, this framework has been adopted
by several authors to analyse international physical capital and goods transactions.
both in neoclassical and in endogenous growth models.

Regarding neoclassical models, Ruffin (1979) uses a two-country version of
the Solow-Swan model to analyse the effect of free physical capital mobility on
factor remunerations, the balance of payments and growth. Buiter (1981) looks at
capital flows in a two-country neoclassical overlapping-generations model.
Deardorff (1994) uses a two-country neoclassical model with international mobility
of physical capital and diverging populations. Mountford (1998) considers the
dynamic implications of trade in a two-country growth model. A further extension
of this framework, based on Ruffin (1979), is provided by the work of Sorger (2003)
who analyses a multicountry Solow-Swan model in which the depreciation rate is
different between countries. There are several authors that use two-country models
in an endogenous growth framework. We postpone reference to these models until
the next chapter.
As has already been mentioned above, two methodological innovations with respect to the existing literature are included in the model that is presented in this chapter. We include human capital and make the interest rate endogenous. This extension of the literature thus allows us to show the dynamics of the accumulation processes of physical and human capital stocks in both countries. Secondly, this permits the analysis of the effects of physical and human capital accumulation on the stock of international assets, interest rate and foreign and home country income. Finally, we are able to study the existence and nature of the steady state solution of the model.

We find that the stock of international assets responds positively to positive changes in human capital accumulation in the recipient country. This finding we also document empirically in Chapter 3 of the dissertation. A second finding is the positive response of international assets to positive changes in physical capital accumulation in the supplier country. We also find that human capital accumulation has a positive effect on the interest rate. Nevertheless, we are able to pin down two components for this result: there is, on one hand, an increase in the interest rate due to higher physical capital productivity and, on the other, an increase due to a higher relative scarcity of physical capital to human capital. Physical capital accumulation has the expected negative effect on interest rate.

With respect to national income, we find that it is determined in each country by human and physical capital accumulation in both countries. We are also able to uncover the relationship of the processes of capital accumulation for both countries.
The accumulation of human capital in one country is inversely related to the stock of physical capital invested by this country in the other one. In contrast, the accumulation of physical capital in one country is positively related to the size of its investments in the other country.

With respect to the dynamics, we show that the economies reach a unique steady state. In this new steady state both economies enhance their economic activity with respect to their position before the liberalisation of physical capital markets. The positive results of free physical capital markets are robust with regard to the presence of different patterns of human capital accumulation between the two countries. Finally, we find that at the steady state the pattern of international capital stocks is a result of the relative fraction of income that each country invests in physical capital with respect to its marginal productivity.

The remainder of this chapter is organised as follows: the next section describes the model; section 3 presents a sensitivity analysis to describe the effects of changes in physical and human capital on international assets, interest rate and income; section 4 describes the dynamics of the model in the steady state; section 5 analyses two different patterns of human capital accumulation for the general case; section 6 concludes.
2 The model

Consider a two-country Solow-Swan model with human capital. Both economies produce an identical homogeneous good using labour, physical capital and human capital that can be either consumed or invested. For simplicity, label the countries "home" and "foreign" and denote the variables and equations that refer to the foreign country with an asterisk.

2.1 Production of final output and income

Production in both countries occurs in full employment according to a constant returns to scale technology. This assumption, as many others that are introduced below, are put in place in order to isolate the potential effect of human capital on foreign capital. In a closed economies scenario, the output produced at time $t$ for the home and foreign countries, denoted by $Q(t)$ and $Q^*(t)$ respectively, is

1. $Q(t) = F(K(t), H(t), L(t))$,

2. $Q^*(t) = G(K^*(t), H^*(t), L^*(t))$,

where $K(t)$, $H(t)$ and $L(t)$ are the physical capital, human capital and labour employed in production at time $t$ for the home country. The same variables with an asterisk correspond to the foreign country case.
Output per worker produced at time $t$ in the home and foreign countries is

\[ q(t) = f(k(t), h(t)), \]

\[ q^*(t) = g(k^*(t), h^*(t)), \]

where $k(t)$ and $h(t)$ are physical and human capital per unit of labour.

Standard assumptions are made for the production processes: $f(\cdot)$ and $g(\cdot)$ are continuously differentiable, strictly increasing, concave with respect to each input and satisfy the Inada conditions (Inada, 1964). We also introduce the mild assumption that physical and human capitals are complementary in the production process. Complementarity is key in driving the results of the model, as it is precisely the nature of human capital in the recipient and investing economies what will drive the flows across countries. Also, the fact that technologies across countries can be "copied" or is easily applied, simplify the model, but implies that there are no restrictions to the spreading of technological innovations globally. These can be stated formally as\(^6\):

\[
\begin{align*}
f_1(k(t), h(t)) &> 0 & g_1(k^*(t), h^*(t)) &> 0 \\
f_2(k(t), h(t)) &> 0 & g_2(k^*(t), h^*(t)) &> 0 \\
f_{11}(k(t), h(t)) &< 0 & g_{11}(k^*(t), h^*(t)) &< 0
\end{align*}
\]

\(^6\) Bear in mind that, for example, $f_1$ refers to the first derivative of the production function with respect to the first factor, i.e. the stock of physical capital.
\[ f_{22}(k(t), h(t)) < 0 \quad g_{22}(k^*(t), h^*(t)) < 0 \]
\[ f_{12}(k(t), h(t)) > 0 \quad g_{12}(k^*(t), h^*(t)) > 0 \]
\[ f_{12}(k(t), h(t)) = f_{21}(k(t), h(t)) \quad g_{12}(k^*(t), h^*(t)) = g_{21}(k^*(t), h^*(t)) \]
\[ \lim_{k \to 0} f_1(k(t), h(t)) = \infty \quad \lim_{k \to 0} g_1(k^*(t), h^*(t)) = \infty \]
\[ \lim_{k \to \infty} f_1(k(t), h(t)) = 0 \quad \lim_{k \to \infty} g_1(k^*(t), h^*(t)) = 0 \]
\[ \lim_{k \to 0} f_2(k(t), h(t)) = \infty \quad \lim_{k \to 0} g_2(k^*(t), h^*(t)) = \infty \]
\[ \lim_{k \to \infty} f_2(k(t), h(t)) = 0 \quad \lim_{k \to \infty} g_2(k^*(t), h^*(t)) = 0. \]

We allow the two economies to open up. Physical capital moves freely across borders, but human capital is immobile. This assumption captures a stylised fact of economies in which increasingly they are exposed to foreign direct investment but are not willing to receive labour flows. \( Z(t) \), called here international assets, denotes the net stock of physical capital in the foreign country owned by the home country, i.e. a positive \( Z(t) \) implies that the home country has a net positive stock of physical capital in the foreign country; in turn, a negative \( Z(t) \) denotes a net positive stock of physical capital in the home country owned by the foreign country. When \( Z(t) \) is positive there are net home country international assets, and when it is negative there is net home country international debt.

\footnote{Using Young's Theorem.}
It is assumed that both countries exhibit the same rate of population growth $n$.

Again, this is done with the intention to isolate the results of the model from divergent demographic paths across countries.

\[ \frac{\dot{L}}{L} = \frac{\dot{L}^*}{L^*} = n. \]

The home country per capita physical capital stock in the foreign country is $\frac{Z(t)}{L(t)} = z(t)$. The total per capita stock of physical capital in the home country is $k(t) - z(t)$. In turn, the total per capita stock of physical capital in the foreign country is $k^*(t) + bz(t)$, where $b = \frac{L(t)}{L^*(t)}$. Note that from this moment onwards all variables will be defined in per capita terms.

As physical capital is perfectly mobile between these two economies, the marginal product of physical capital is equalised in both countries with interest rate $r(t)$, and this equilibrium parity condition is defined as

\[ f_i(k(t) - z(t), h(t)) = g_i(k^*(t) + bz(t), h^*(t)) = r(t). \]

Equation 6 above captures the idea of a completely free and perfect international capital market, with perfect adjustment and no information imperfections. This supposes that no restrictions are imposed in the recipient or the

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8 The $b$ parameter is just a normalisation device to use the same per capita international investment capital stock in both countries.
investing countries, that there are no tax regime differences, null transactions cost, no risk differentials and no information asymmetries nor agency problems.

In this open economy scenario, the national income in each country must be netted out by the rental payments incurred (or received, respectively) from international debt (international assets). Obviously, foreign assets also directly increase (decrease) the production in the recipient (investor) country. Using output definitions (equations (3) and (4)) to define national income at time \( t \) for the home country and the foreign country, we have

\[
y(t) = f(k(t) - z(t), h(t)) + r(t)z(t),
\]

\[
y^*(t) = g(k^*(t) + bz(t), h^*(t)) - br(t)z(t).
\]

### 2.2 The dynamics of the economies

The relevant processes driving these economies are the accumulation of physical and human capital. National income in each country is spent on consumption or investment in physical or human capital. Physical capital follows an accumulation process as in the traditional Solow-Swan model. The rate of change of the physical capital stock is the difference between two terms. The first one, \( s_k y(t) \), is the fraction of income devoted to physical capital investment (\( s^*_k y^*(t) \) for the foreign country), where \( s_k \) (\( s^*_k \)) is exogenous and constant. The second term is the amount
of investment that must be done to keep $k(t)$ ($k^*(t)$) at the existing per capita level, given that population grows at rate $n$. For simplicity, the rate of depreciation is zero.

Thus the equations for physical capital accumulation are

\[
\dot{k}(t) = s_k y(t) - nk(t) = s_k [f(k(t) - z(t), h(t)) + r(t)z(t)] - nk(t).
\]

\[
\dot{k}^*(t) = s_k^* y^*(t) - nk^*(t) = s_k^* [g(k^*(t) + bz(t), h^*(t)) - br(t)z(t)] - nk^*(t).
\]

where equations (7) and (8) were used to substitute for the national incomes.

It is assumed that human capital is accumulated in the same way as physical capital, as in Mankiw et al. (1992). Each country invests in human capital an exogenous and constant fraction of their national income, denoted by $s_h$ and $s_h^*$. As in the physical capital case, the accumulation of human capital is affected by increasing requirements of human capital, which are proportional to the rate of population growth $n$. The rate of depreciation of human capital is also assumed to be zero. The equations of human capital accumulation are:

\[
\dot{h}(t) = s_h y(t) - nh(t) = s_h [f(k(t) - z(t), h(t)) + r(t)z(t)] - nh(t),
\]

\[
\dot{h}^*(t) = s_h^* y^*(t) - nh^*(t) = s_h^* [g(k^*(t) + bz(t), h^*(t)) - br(t)z(t)] - nh^*(t),
\]

where equations (7) and (8) were used to replace the national incomes.
3 Sensitivity analysis

This section analyses the effect of changes in the accumulation of physical and human capital on international assets, interest rate and national incomes. Table 1 summarises the findings in this section.

3.1 Foreign assets

Using the equilibrium parity condition in (6) and taking its derivative to isolate the effect of changes in the home country physical capital on the stock of international assets, we have

\[
\frac{\partial}{\partial k} z(k(t), k^*(t), h(t), h^*(t)) = \frac{f_{11}(k(t) - z(t), h(t))}{f_{11}(k(t) - z(t), h(t)) + bg_{11}(k^*(t) + bz(t), h^*(t))} > 0.
\]

Changes in the home country stock of physical capital directly affect international assets. Nevertheless, given that both terms in the denominator are unambiguously negative, the fraction is below unity, i.e. the positive response of international assets to increases in the home country stock of physical capital is less than proportional. When \( z(t) > 0 \), the direct positive effect of an increase in the home country capital stock on capital flows (changes in \( z(t) \)) arises from the fall in the home country marginal productivity of total capital stock (negative numerator). This last effect is diluted by the indirect reduction in the other country marginal productivity of physical capital stock.

Using again the equilibrium parity condition in (6), we obtain:
A change in the stock of physical capital of the foreign country has an inverse effect on international assets. This inverse effect is also less than proportional (the absolute value of (14) is less than unity). As the level of physical capital in the foreign country increases, investments in this country become less attractive and international investment falls but in a proportion that is smaller than the increase in the foreign country capital stock.

Following the same process as above, equation (15) shows the interesting effect of changes in the stock of human capital on international assets:

\[
\frac{\partial}{\partial h} z(k(t), k^*(t), h(t), h^*(t)) = \frac{f_{12}(k(t) - z(t), h(t))}{f_{11}(k(t) - z(t), h(t)) + b g_{11}(k^*(t) + b z(t), h^*(t))} < 0.
\]

There is a negative effect of changes in the home country human capital on international assets. The accumulation of human capital in the home country generates a bigger need for physical capital domestically, due to the complementarity between human and physical capital, increasing the return of domestic investment and hence decreasing the attractiveness of investment in the foreign country.

More important, in our view, is the response of international assets to changes in human capital accumulation in the foreign country:

\[
\frac{\partial}{\partial h^*} z(k(t), k^*(t), h(t), h^*(t)) = \frac{-g_{12}(k(t) - z(t), h^*(t))}{f_{11}(k(t) - z(t), h(t)) + b g_{11}(k^*(t) + b z(t), h^*(t))} > 0.
\]
Due to complementarity between human and physical capital, human capital investment efforts in the foreign country will increase the productivity of physical capital, attracting foreign investment from the home country. In itself, this result implies that changes in the stock of human capital in a recipient country will attract further international assets from foreign investors. We explore this result empirically in Chapter 3.

3.2 Interest rate

Taking the partial derivative of the parity condition in (6) with respect to \( k \) and \( k^* \) and substituting \( \partial z(\cdot) / \partial k \) and \( \partial z(\cdot) / \partial k^* \) from equation (13) and (14), we obtain:

\[
\frac{\partial}{\partial k} r(k(t), k^*(t), h(t), h^*(t)) = \frac{bf_{11}(k(t)-z(t), h(t)) \cdot g_{11}(k^*(t)+bz(t), h^*(t))}{f_{11}(k(t)-z(t), h(t)) + bg_{11}(k^*(t)+bz(t), h^*(t))} < 0.
\]

\[
\frac{\partial}{\partial k^*} r(k(t), k^*(t), h(t), h^*(t)) = \frac{f_{11}(k(t)-z(t), h(t)) \cdot g_{11}(k^*(t)+bz(t), h^*(t))}{f_{11}(k(t)-z(t), h(t)) + bg_{11}(k^*(t)+bz(t), h^*(t))} < 0.
\]

The response of the interest rate to changes in physical capital has the sign expected. This is due to diminishing marginal productivity of capital in both countries. Moreover, a change in the stock of physical capital has the same impact on the interest rate regardless of which of the two countries is the owner.
Following the same procedure as before but this time using (15) and (16) to substitute $\frac{\partial z(t)}{\partial h}$ and $\frac{\partial z(t)}{\partial h^*}$, we find a very interesting result in the following two equations:

\begin{align*}
(19) \quad \frac{\partial}{\partial h} r(k(t), k^*(t), h(t), h^*(t)) &= \frac{bf_{12}(k(t) - z(t), h(t)) \cdot g_{11}(k^*(t) + bz(t), h^*(t))}{f_{11}(k(t) - z(t), h(t)) + bg_{11}(k^*(t) + bz(t), h^*(t))} > 0, \\
(20) \quad \frac{\partial}{\partial h} r(k(t), k^*(t), h(t), h^*(t)) &= \frac{f_{11}(k(t) - z(t), h(t)) \cdot g_{12}(k^*(t) + bz(t), h^*(t))}{f_{11}(k(t) - z(t), h(t)) + bg_{11}(k^*(t) + bz(t), h^*(t))} > 0.
\end{align*}

Increases in human capital have a positive effect on the interest rate $r(t)$, given that the complementarity effect dominates the diminishing marginal productivity of human capital. An expansion in the stock of human capital in one country increases the remuneration of physical capital due to complementarity and hence the demand for physical capital in that country.

### 3.3 Home and foreign country incomes

The effect of changes in physical and human capital stocks on the home country income depends, among other things, on the direction of international assets $(z(t) > 0 \text{ or } z(t) < 0)$. Taking the derivative of equation (7) with respect to $k$, using (6) and cancelling terms, we get
\[
\frac{\partial}{\partial k} y(k(t), k^*(t), h(t), h^*(t)) = r(k(t), k^*(t), h(t), h^*(t)) + z(t) \frac{\partial}{\partial k} r(k(t), k^*(t), h(t), h^*(t)),
\]

An expansion in the home country physical capital increases its income, if the foreign country has a positive stock of capital in the home country, i.e. there is home country international debt \((z(t) < 0)\). This result arises from the fact that a debtor country will find it highly profitable to substitute international assets for domestic physical capital accumulation. The country will not only accrue the benefits of the expansion in capital, but will reduce the outlays of its domestic product paid overseas. However, if there is a positive home country international investment \((z(t) > 0)\), the response of home country income to changes in its physical capital is positive if \(r(t) > -z(t) \frac{\partial r(\cdot)}{\partial k}\) and negative if \(r(t) < -z(t) \frac{\partial r(\cdot)}{\partial k}\). In contrast to the unambiguous effect in the case when the home country is a debtor in the international markets \((z(t) < 0)\), an expansion in its own physical capital in the case of a creditor country \((z(t) > 0)\) may or may not increase its income. This arises from the fact that a marginal increase in its own physical capital stock has a direct effect on income, providing a remuneration of \(r(t)\) (interest rate) for each additional unit. However, this effect must be adjusted by the fall in the profitability of capital caused by the marginal increase in home country physical capital. This last effect will have a positive influence on income when the home country accumulates debt. The ambiguous one will depend on the magnitude of the interest rate.
Similarly, the effect of changes in the foreign country physical capital on the home country income is:

\[
\frac{\partial}{\partial k} y(k(t), k^*(t), h(t), h^*(t)) = z(t) \frac{\partial}{\partial k} r(k(t), k^*(t), h(t), h^*(t)).
\]

This effect is positive if the foreign country has a positive stock of physical capital in the home country \((z(t) < 0)\). As the physical capital in the foreign country increases, its remuneration decreases and foreign country investors expand their investments abroad, improving the home country income. However, if the home country has a positive stock of physical capital in the foreign country \((z(t) > 0)\), the increase in foreign physical capital decreases its remuneration in the foreign country negatively affecting home country income.

In turn, the effects of changes in home and foreign country human capital on the home country incomes are:

\[
\frac{\partial}{\partial h} y(k(t), k^*(t), h(t), h^*(t)) = f_z(k(t) - z(t), h(t)) + z(t) \frac{\partial}{\partial h} r(k(t), k^*(t), h(t), h^*(t)) ,
\]

\[
\frac{\partial}{\partial h^*} y(k(t), k^*(t), h(t), h^*(t)) = z(t) \frac{\partial}{\partial h^*} r(k(t), k^*(t), h(t), h^*(t)).
\]

If the home country is an international creditor \((z(t) > 0)\), as \(\partial r(\cdot)/\partial h > 0\), increases in either country stock of human capital have a positive effect on the home country income. The positive effect of human and physical capital complementarity leads to a spillover of human capital investments in either country to the other one.
more than offsetting the negative effect arising from diminishing marginal productivity of human capital. The importance of allowing an endogenous determination of the interest rate is perceived here. The positive effect just described operates in both countries through the international parity condition that allows an indirect transfer of productive improvements embodied in capital accumulation from one country to the other.

If, in turn, the home country international investment is negative ($z(t) < 0$), changes in the foreign country's human capital (equation (24)) unambiguously decrease home country income. If the country is an international debtor and a human capital investment effort takes place in the creditor country, this will induce an increase in the interest rate due to the complementarity with physical capital, thus pushing upwards the cost of servicing debt. Keeping in mind that here $z(t) < 0$, changes in the home country's human capital (equation (23)) have an ambiguous effect on home country income: the effect is negative if $f_2(\cdot) < -z(t) \frac{\partial r(\cdot)}{\partial h}$ and positive if $f_2(\cdot) > -z(t) \frac{\partial r(\cdot)}{\partial h}$. For some intuition see the last case: if the increase in productivity due to human capital accumulation ($f_2(\cdot)$) is smaller than the increase in the cost of servicing foreign debt (due to the increase in the interest rate), the home country income is eroded.

Following the same procedure but using equation (8) to study the effect of physical and human capital stock changes in foreign country national income, symmetric results are found.
\[ \frac{\partial}{\partial k} y^*(k(t), k^*(t), h(t), h^*(t)) = r(k(t), k^*(t), h(t), h^*(t)) \]
\[ -bz(t) \frac{\partial}{\partial k} r(k(t), k^*(t), h(t), h^*(t)), \]

\[ \frac{\partial}{\partial h} y^*(k(t), k^*(t), h(t), h^*(t)) = -bz(t) \frac{\partial}{\partial k} r(k(t), k^*(t), h(t), h^*(t)), \]

\[ \frac{\partial}{\partial h} y^*(k(t), k^*(t), h(t), h^*(t)) = g_2(k^*(t) + bz(t), h^*(t)) - bz(t) \frac{\partial}{\partial h} r(k(t), k^*(t), h(t), h^*(t)). \]

\[ \frac{\partial}{\partial h} y^*(k(t), k^*(t), h(t), h^*(t)) = -bz(t) \frac{\partial}{\partial h} r(k(t), k^*(t), h(t), h^*(t)). \]

Notice that for the foreign national income, we will have a symmetric effect for each one of the cases already explained for the home country national income (Table 1). It is necessary to bear in mind that the role of \( z(t) \) is opposite to its previous role. For example, the positive effect found in \( \partial y^* / \partial k^* \) when \( z(t) < 0 \), corresponds to \( \partial y^* / \partial k \) when \( z(t) > 0 \), or the negative effect found in \( \partial y^* / \partial h^* \) when \( z(t) < 0 \), corresponds to \( \partial y^* / \partial h \) when \( z(t) > 0 \).

To summarise these findings: We show firstly, that an expansion in a debtor country’s physical capital has a positive effect on its own income. If the expansion of physical capital occurs in a creditor country, the effect over its income is ambiguous. Secondly, when the physical capital expansion occurs in the other country, the effect over income is positive for a debtor country and negative for a creditor country. With respect to human capital, we find in the third place that an
expansion in a debtor country's human capital has a positive effect on its income, but if the changes are in a creditor country, the effect is ambiguous. Finally, when there is an increase in the other country's human capital, a creditor country will see an increase in its income, but if the country is a debtor, a negative result is obtained as a debtor country unambiguously sees its income fall.
<table>
<thead>
<tr>
<th>$y'(\cdot)$</th>
<th>$k$</th>
<th>$k'$</th>
<th>$H$</th>
<th>$H'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y(\cdot)$ if $z(t) &gt; 0$</td>
<td>$\frac{\partial}{\partial k} y(\cdot) &gt; 0$</td>
<td>$\frac{\partial}{\partial k'} y(\cdot) &gt; 0$</td>
<td>$\frac{\partial}{\partial H} y(\cdot) &gt; 0$ if $f_1(\cdot) &gt; -z(t) \partial r(\cdot) / \partial k$</td>
<td>$\frac{\partial}{\partial H'} y(\cdot) &gt; 0$ if $g_2(\cdot) &gt; b z(t) \partial r(\cdot) / \partial k^*$</td>
</tr>
<tr>
<td>$y'(\cdot)$ if $z(t) &lt; 0$</td>
<td>$\frac{\partial}{\partial k} y'(\cdot) &lt; 0$</td>
<td>$\frac{\partial}{\partial k'} y'(\cdot) &lt; 0$ if $r(\cdot) &gt; b z(t) \partial r(\cdot) / \partial k^*$</td>
<td>$\frac{\partial}{\partial H} y'(\cdot) &lt; 0$ if $g_2(\cdot) &lt; b z(t) \partial r(\cdot) / \partial k^*$</td>
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</tbody>
</table>
4 Steady state analysis

This section concentrates on the steady state analysis of physical and human capital accumulation, factor payments and equilibrium. We first describe the conditions for the steady state and then proceed to analyse graphically and formally the equilibrium.

4.1 Physical and human capital accumulation

Recall from section 2 the system of equations that define the dynamics. There are two equations for the physical capital accumulation of both home and foreign countries ((9) and (10)), two equations for the human capital accumulation ((11) and (12)) and the parity condition equation ((6)). Since at the steady state the rates of growth of all variables are zero, we obtain equations (9) to (12) in the steady state

\[ s_k\left[f(k(t) - z(t), h(t)) + r(t)z(t)\right] - nk(t) = 0, \]

\[ s_k^*[g(k^*(t) + bz(t), h^*(t)) - br(t)z(t)] - nk^*(t) = 0, \]

\[ s_h\left[f(k(t) - z(t), h(t)) + r(t)z(t)\right] - nh(t) = 0, \]

\[ s_h^*[g(k^*(t) + bz(t), h^*(t)) - br(t)z(t)] - nh^*(t) = 0. \]

Using equations (29) and (31) and reorganising terms, the stock of human capital in the home country in the steady state could be written as
Similarly, using equations (30) and (32), the foreign country stock of human capital could be written as

\[ h^*(t) = \frac{s^*_k}{s_k} k^*(t). \]

The system of four equations (29) to (32) reduces to a system of two equations using (33) and (34):

\[ s_k \left[ f \left( k(t) - z(t), \frac{s_h}{s_k} k(t) \right) + r(t)z(t) \right] - nk(t) = 0, \]

\[ s^*_k \left[ g \left( k^*(t) + bz(t), \frac{s^*_h}{s^*_k} k^*(t) \right) - br(t)z(t) \right] - nk^*(t) = 0. \]

Likewise, including equations (33) and (34) in (6), the steady state interest rate condition becomes

\[ f_1 \left( k(t) - z(t), \frac{s_h}{s_k} k(t) \right) = g_1 \left( k^*(t) + bz(t), \frac{s^*_h}{s^*_k} k^*(t) \right) = r(t). \]

Our former system of four equations and four unknowns is now defined in (35) to (37).
4.2 Factor payments

Given the assumption of linearly homogeneous production functions, Euler’s theorem may be applied. Income is then exhausted by factor remunerations which are equal to the sum of each marginal input product multiplied by its input level. The labour remunerations for the home and the foreign countries are:

\[
\frac{∂}{∂L}(L_y(k(t), k^*(t), h(t), h^*(t))) = y(k(t), k^*(t), h(t), h^*(t))
\]

(38)

\[
-k(t) \frac{∂}{∂k} y(k(t), k^*(t), h(t), h^*(t))
\]

\[
-h(t) \frac{∂}{∂h} y(k(t), k^*(t), h(t), h^*(t))
\]

\[
\frac{∂}{∂L} (L^* y^*(k(t), k^*(t), h(t), h^*(t))) = y^*(k(t), k^*(t), h(t), h^*(t))
\]

(39)

\[
-k^*(t) \frac{∂}{∂k^*} y^*(k(t), k^*(t), h(t), h^*(t))
\]

\[
-h^*(t) \frac{∂}{∂h^*} y^*(k(t), k^*(t), h(t), h^*(t))
\]

We use now (21) and (23) to replace the derivatives on the right-hand side of (38). In (38) we also use (33) to substitute human capital stocks by their steady state equivalent in terms of physical capital. We have then:

\[
\frac{∂}{∂L} (L_y(k(t), k^*(t), h(t), h^*(t))) = y(k(t), k^*(t), h(t), h^*(t))
\]

(40)

\[
-k(t) \left[ r(k(t), k^*(t), h(t), h^*(t)) + z(t) \frac{∂}{∂k} r(k(t), k^*(t), h(t), h^*(t)) \right]
\]

\[
-\frac{s_k}{s_k} k(t) \left[ f_z(k(t) - z(t), h(t)) + z(t) \frac{∂}{∂h} r(k(t), k^*(t), h(t), h^*(t)) \right]
\]
Similarly, replacing the derivatives on the right-hand side of equation (39) with (25) and (27) and human capital stocks by their steady state equivalent in terms of physical capital (equation (34)), the remuneration to labour in the foreign country is:

\[
\frac{\partial}{\partial L^*} (L^* y^*(k(t), k^*(t), h(t), h^*(t))) = y^*(k(t), k^*(t), h(t), h^*(t)) \]

\[
-k^*(t) \left[ r(k(t), k^*(t), h(t), h^*(t)) - bz(t) \frac{\partial}{\partial k^*} r(k(t), k^*(t), h(t), h^*(t)) \right] + \frac{\delta}{\delta h} \left[ g_2(k^*(t) + bz(t), h^*(t)) - bz(t) \frac{\partial}{\partial h} r(k(t), k^*(t), h(t), h^*(t)) \right]
\]

Equations (35) and (36) are rewritten as:

\[
\frac{nk(t)}{s_k} = f \left( k(t) - z(t), \frac{s_k k(t)}{s_k} \right) + r(t) z(t)
\]

\[
\frac{nk^*(t)}{s_k} = g \left( k^*(t) + bz(t), \frac{s_k k^*(t)}{s_k} \right) - br(t) z(t)
\]

Using these two equations to replace national incomes in (40) and (41), labour remuneration in both countries is then:
\[
\frac{\partial}{\partial L} (L_y(k(t), k^*(t), h(t), h^*(t))) =
\]
\[
\begin{align*}
&\frac{nk(t)}{s_k} - k(t) \left[ r(t) + z(t) \frac{\partial}{\partial k} r(k(t), k^*(t), h(t), h^*(t)) \right] \\
&- \frac{s_h}{s_k} k(t) \left[ f_z(k(t) - z(t), h(t)) + z(t) \frac{\partial}{\partial h} r(k(t), k^*(t), h(t), h^*(t)) \right].
\end{align*}
\]

\[
\frac{\partial}{\partial L^*} (L^*_y(k(t), k^*(t), h(t), h^*(t))) =
\]
\[
\begin{align*}
&\frac{nk^*(t)}{s_k^*} - k^*(t) \left[ r(t) - bz(t) \frac{\partial}{\partial k^*} r(k(t), k^*(t), h(t), h^*(t)) \right] \\
&- \frac{s_h^*}{s_k^*} k^*(t) \left[ g_z(k^*(t) + bz(t), h^*(t)) - bz(t) \frac{\partial}{\partial h^*} r(k(t), k^*(t), h(t), h^*(t)) \right].
\end{align*}
\]

Accordingly, a positive labour remuneration (left-hand side of (44) and (45) positive) implies that the right-hand side of these two equations is positive and so the two following inequalities need to hold

\[
\begin{align*}
n &> s_k \left[ r(k(t), k^*(t), h(t), h^*(t)) \right] \\
&+ z(t) \frac{\partial}{\partial k} r(k(t), k^*(t), h(t), h^*(t)) + \frac{s_h}{s_k} f_z(k(t) - z(t), h(t)) \\
&+ \frac{s_h}{s_k} z(t) \frac{\partial}{\partial h} r(k(t), k^*(t), h(t), h^*(t)),
\end{align*}
\]
\[ n > s_k^* \left[ r(k(t), k^*(t), h(t), h^*(t)) \right] \]

\[
(47) \quad -bz(t) \frac{\partial}{\partial k} r(k(t), k^*(t), h(t), h^*(t)) + \frac{s_h^*}{s_k^*} g_z(k^*(t) + bz(t), h^*(t)) \\
- \frac{s_h^*}{s_k^*} bz(t) \frac{\partial}{\partial h^*} r(k(t), k^*(t), h(t), h^*(t))
\]

which completes the definition of factor payments in the steady state.

### 4.3 Equilibrium analysis

We are now ready to obtain the stationary equilibrium. We define the steady state as the pair of domestic and foreign physical capital levels at which there is no further growth in the per capita stock of physical capital; e.g. those levels of \( k \) and \( k^* \) that lead to the conditions \( \dot{k} = 0 \) and \( \dot{k}^* = 0 \) being satisfied simultaneously. The analysis proceeds as follows: firstly, we examine the curve \( z = 0 \) that represents the total combination of home and foreign physical capital in each country consistent with no physical capital movements, even under free capital mobility; secondly, we analyse the \( \dot{k} = 0 \) curve that depicts all the combinations of home and foreign physical capital such that the home country is in steady state equilibrium; and thirdly, we study the curve \( \dot{k}^* = 0 \) that shows all the combinations of home and foreign physical capital under which the foreign country is in steady state.
To examine the curve $z = 0$, we use the steady-state equilibrium parity condition in (37), when $z = 0$. The slope of the curve is obtained by invoking the implicit function theorem for equation (37) as follows:

$$\left.\frac{dk^*}{dk}\right|_{z=0} = -\frac{\partial}{\partial k^*} \left[ f_1 \left( k(t), \frac{s_h}{s_k} k(t) \right) - g_1 \left( k^*(t), \frac{s_h}{s_k} k^*(t) \right) \right]$$

where

$$f_1 \left( k(t), \frac{s_h}{s_k} k(t) \right) - g_1 \left( k^*(t), \frac{s_h}{s_k} k^*(t) \right)$$

and

$$f_{11} \left( k(t), \frac{s_h}{s_k} k(t) \right) + \frac{s_h}{s_k} g_{12} \left( k(t), \frac{s_h}{s_k} k(t) \right)$$

$$g_{11} \left( k^*(t), \frac{s_h}{s_k} k^*(t) \right) + \frac{s_h}{s_k} g_{12} \left( k^*(t), \frac{s_h}{s_k} k^*(t) \right).$$

The sign of $\left.\frac{dk^*}{dk}\right|_{z=0}$ depends on the relative magnitude of the first and second terms in both numerator and denominator of (48). Given the assumption of diminishing marginal productivity of physical capital, $f_{11}(\cdot)$ and $g_{11}(\cdot)$ are always negative. Similarly, given the assumption of complementarity between human and physical capital in each country, $f_{12}(\cdot)$ and $g_{12}(\cdot)$ are always positive. The fractions that relate the savings rates of human and physical capital in each country are also positive. Thus the sign of the fraction will depend on the shape of $f(\cdot)$ and $g(\cdot)$.

The slope is positive in two cases. The first one occurs when the degree of diminishing marginal productivity of physical capital in both countries is greater than the degree of complementarity between human and physical capital adjusted by the
human-to-physical-capital savings ratio. The second case of positive slope occurs when this same difference is negative in both countries.

The slope is negative when in one country the degree of diminishing marginal productivity of physical capital is greater (smaller) than the degree of complementarity between human and physical capital adjusted by the human to physical capital savings ratio, but in the other country the same difference is smaller (greater).

As in this general case we are unable to determine further the sign of the slope of the curve $z = 0$, we concentrate on two particular cases which assume that both countries exhibit constant elasticity of substitution (CES) production functions.

**CES production function**

When both countries have constant elasticity of substitution (CES) production functions the labour intensive production functions with no physical capital movements for the home and the foreign country are

\[
f = \left[ A^\sigma k^{\sigma-1} + B^\sigma h^{\sigma-1} + C^\sigma \right]^{\frac{\sigma-1}{\sigma}}
\]

and

\[
g = \left[ A'^\ast k'^{\sigma-1} + B'h'^{\sigma-1} + C'^\ast \right]^{\frac{\sigma-1}{\sigma}}
\]

respectively.
Where $\sigma$ and $\sigma^*$ are the elasticities of substitution between physical and human capital in each country with $0 < \sigma < \infty$ ($0 < \sigma^* < \infty$), $\sigma \neq 1$ ($\sigma^* \neq 1$). $A$, $B$, $C$, $A^*$, $B^*$, $C^*$ are parameters. Then the slope of the curve $z = 0$ is

$$ \left. \frac{dk^*}{dk} \right|_{z=0} = \frac{AC\left(-\frac{1}{\sigma}\right)\left[A + B\left(\frac{s_h}{s_k}\right)^{\frac{1-\sigma}{\sigma}} + Ck\right]^{\frac{2-\sigma}{\sigma}}}{A^*C^*\left(-\frac{1}{\sigma^*}\right)\left[A^* + B^*\left(\frac{s_{h^*}}{s_{k^*}}\right)^{\frac{1-\sigma^*}{\sigma^*}} + C^*k\right]^{\frac{2-\sigma^*}{\sigma^*}}} \cdot $$

As both terms of the fraction are unambiguously positive, the slope of the curve $z = 0$ is always positive under CES production functions.

As the slope of the curve $z = 0$ is positive for the CES production function, we will assume from this point onwards that this is always the case. Figure 1 shows the curve $z = 0$ with a positive slope in the $k^* - k$ plane. This plane is split in two parts by the curve. Points not belonging to the curve $z = 0$ represent configurations of $k^*$ and $k$ in which there is international physical capital accumulation. Taking the derivative of the steady-state equilibrium parity condition in (37) with respect to $dk^* = 0$, we have:

---

9 In Appendix 1 we present the slope of the curve $z = 0$ for the specific case when both countries exhibit Cobb-Douglas production functions.
\[ \frac{dz}{dk} \bigg|_{\dot{k}^* = 0} = \frac{f_{11}(k(t), \frac{s_h}{s_k} k(t)) + \frac{s_h}{s_k} f_{12}(k(t), \frac{s_h}{s_k} k(t))}{f_{11}(k(t), \frac{s_h}{s_k} k(t)) + b g_{11}(\dot{k}^*(t), \frac{s_h}{s_k} \dot{k}^*(t))}. \]

\[ \frac{dz}{dk} \bigg|_{\dot{k}^* = 0} = \frac{f_{11}(k(t), \frac{s_h}{s_k} k(t)) + \frac{s_h}{s_k} f_{12}(k(t), \frac{s_h}{s_k} k(t))}{f_{11}(k(t), \frac{s_h}{s_k} k(t)) + b g_{11}(\dot{k}^*(t), \frac{s_h}{s_k} \dot{k}^*(t))}. \]

Figure 1

We have assumed that, as in the CES production function case, the numerator of (50) is always negative. As \( f_{11}(\cdot) \) and \( g_{11}(\cdot) \) are always negative due to diminishing marginal productivity of physical capital, the denominator of (50) is always negative. As a result, we have a positive \( \frac{dz}{dk} \bigg|_{\dot{k}^* = 0} \) everywhere, with points to the south-east of the curve \( z = 0 \) showing combinations of \( k \) and \( k^* \) for which the
home country is a creditor \( z > 0 \), and points to the north-west showing combinations of \( k \) and \( k^* \) for which the foreign country is the creditor \( z < 0 \) (see Figure 1).

After having determined the characteristics of \( z = 0 \) in the \( k^* - k \) plane, we turn to the \( \dot{k} = 0 \) curve in the same plane, which depicts all the combinations of home and foreign physical capital such that the home country is in steady-state equilibrium under free physical capital mobility. To determine the slope of the curve \( \dot{k} = 0 \), we make use again of the implicit function theorem:

\[
\frac{dk^*}{dk} \bigg|_{k=0} = -\frac{\frac{\partial}{\partial k} \left( k(t), k^*(t), \frac{s_h}{s_k} k(t), \frac{s_h}{s_k} k^*(t) \right)}{\frac{\partial}{\partial k^*} \left( k(t), k^*(t), \frac{s_h}{s_k} k(t), \frac{s_h}{s_k} k^*(t) \right)}.
\]

Using the home and foreign country physical capital accumulation equation (35), we have:

\[
\frac{dk^*}{dk} \bigg|_{k=0} = -\frac{s_k \left[ r(\cdot) + \frac{s_h}{s_k} f_s(\cdot) + z(t) \left( \frac{\partial}{\partial k} r(\cdot) + \frac{s_h}{s_k} \frac{\partial}{\partial h} r(\cdot) \right) \right] - n}{s_k z(t) \left( \frac{\partial}{\partial k} r(\cdot) + \frac{s_h}{s_k} \frac{\partial}{\partial h} r(\cdot) \right)}.
\]

The numerator of (52) is always negative as it is equivalent in the steady state to the inequality already analysed in (46), guaranteeing a positive remuneration to labour in the home country. The term in parentheses in the denominator is the
derivative of the interest rate with respect to the foreign country physical capital stock in steady state and is negative. In that case, the sign of the denominator depends on the direction of international investment $z$. We have then two cases: if $z < 0$ the denominator is positive, then the slope of the curve $\dot{k} = 0$ is positive: on the other hand, if $z > 0$, the denominator is negative and the slope of the curve is negative.

To summarise, the curve $\dot{k} = 0$ has a positive slope when the stock of international asset in the home country owned by the foreign country is positive, which means that the foreign country is a creditor ($z < 0$). In turn, $\dot{k} = 0$ has a negative slope when the home country is the creditor ($z > 0$). As shown in Figure 2, the curve has a positive slope in the north-west of the curve $z = 0$ and negative slope in the south-east.

Figure 2
Knowing already the shape of \( z = 0 \) and \( \dot{k} = 0 \), we now examine the curve \( \dot{k}^* = 0 \), depicting all the combinations of \( k \) and \( k^* \) when the foreign country physical capital stock is in steady state in conditions of free physical capital mobility. As before, invoking the implicit function theorem, the slope of \( k^* = 0 \) is:

\[
\frac{dk^*}{dk} \bigg|_{k^* = 0} = -\frac{\frac{\partial}{\partial k} k^* \begin{pmatrix} k(t), k^*(t), \frac{S_h}{s_k} k(t), \frac{S^*_h}{s_k} k^*(t) \end{pmatrix}}{\frac{\partial}{\partial k^*} k^* \begin{pmatrix} k(t), k^*(t), \frac{S_h}{s_k} k(t), \frac{S^*_h}{s_k} k^*(t) \end{pmatrix}}
\]

\[= \frac{-s^*_h b z(t) \left( \frac{\partial}{\partial k} r(\cdot) + \frac{s^*_h}{s_k} \frac{\partial}{\partial \hat{k}} r(\cdot) \right)}{s^*_h \left[ r(\cdot) + \frac{s^*_h}{s_k} g_z(\cdot) - b z(t) \left( \frac{\partial}{\partial k} r(\cdot) + \frac{s^*_h}{s_k} \frac{\partial}{\partial \hat{k}} r(\cdot) \right) \right] - n}.
\]

The denominator of (53) is always negative as it is equivalent to the inequality already analysed in (47) that guarantees a positive remuneration to labour in the foreign country. The sign of the numerator depends on the sign of international assets, since the term in parentheses is negative\(^\text{10}\). Hence the curve \( \dot{k}^* = 0 \) has a positive slope when the home country owns physical capital in the foreign country \((z > 0)\), and a negative slope when the foreign country owns physical capital in the home country \((z < 0)\). In Figure 2, the curve \( \dot{k}^* = 0 \) has a positive slope in the south-east of the \( k^*-k \) plane and a negative slope in the north-west.

\(^{10}\) The term in parentheses corresponds to the derivative of the interest rate with respect to the home country physical capital stock in steady state.
Let point $a$ in Figure 2 denote our initial point of analysis under autarky. At $a$ the home country has a higher level of physical capital than the foreign one, but for each country the actual level of physical capital input corresponds to its steady state level. Take the home country at $a$: at this point, the usual steady state condition implies that (35) is equal to zero, i.e. at $a$ the level of $k$ has attained the critical level $k_a$ for the condition (35) to hold. This same point $a$ is a critical $k^*_a$ point in $k^*$ for condition (36). At this autarky level, if capital movements were allowed, capital will flow from the home country to the foreign one. At $a$, in autarky, the slope of both steady-state physical capital schedules is given by $\frac{dk^*}{dk} \bigg|_{k=0, z=0} = \infty$ and

$$\frac{dk^*}{dk} \bigg|_{k^*_a=0, z=0} = 0.$$  

At this same point $a$, both critical levels of physical capital, obviously, coincide with $z = 0$ under autarky.  

Point $b$ on the curve $z = 0$ directly above $a$ must also be a solution to $\dot{k} = 0$, since by uniqueness in the solution of equation (35) both points have a common ordinate on $k$. Likewise the point $c$ on curve $z = 0$ directly to the left of point $a$ in $z = 0$ must be a solution for $\dot{k}^* = 0$.

Until now we have defined the steady-state physical capital levels for each country, examined the shape of the $z = 0$ schedule and determined the characteristics of $\dot{k} = 0$ and $\dot{k}^* = 0$ curves. We are now ready to proceed to the main analytical step.

---

11 This is a result of considering equations (35) and (36) using the implicit function theorem.
12 This can be verified by evaluating equations (52) and (53) under the condition $z = 0$. 

55
which is to obtain the stationary equilibrium under free capital mobility in this two-
country world.

Graphically, as shown in Figure 2, it is evident that the stationary equilibrium
under free capital mobility is unique and stable and corresponds to point e. As the
curves \( \dot{k} = 0 \) and \( \dot{k^*} = 0 \) have opposite slopes in each of the two regions of the plane,
and given that both curves have the shapes illustrated in Figure 2, it is possible to
conclude that there is a unique stationary solution under free capital mobility as the
forces of attraction will lead the accumulation of both foreign and home capital
towards equilibrium. This can be demonstrated formally as follows.

The conditions for uniqueness and stability of this solution result from formally
considering (35) and (36) above. Taking the direct and cross-partial derivatives of
both equations with respect to home and foreign country physical capital stocks we
have:

\[
\begin{align*}
\frac{\partial}{\partial k} k(t), k^*(t), \frac{s_h}{s_k} k(t), \frac{s^*_h}{s_k} k^*(t) &= a_{11} & \frac{\partial}{\partial k} k(t), k^*(t), \frac{s_h}{s_k} k(t), \frac{s^*_h}{s_k} k^*(t) &= a_{12} \\
\frac{\partial}{\partial k^*} k(t), k^*(t), \frac{s_h}{s_k} k(t), \frac{s^*_h}{s_k} k^*(t) &= a_{21} & \frac{\partial}{\partial k^*} k(t), k^*(t), \frac{s_h}{s_k} k(t), \frac{s^*_h}{s_k} k^*(t) &= a_{22}
\end{align*}
\]

Using these definitions, the usual conditions for the stability of the system are:

\[
\begin{align*}
a_{11} + a_{22} &< 0 \\
\Delta &= a_{11}a_{22} - a_{12}a_{21} > 0
\end{align*}
\]
This clearly holds for both the cases of $z > 0$ and $z < 0$. Consider only the case of $z > 0$: $a_{11}$ corresponds to the numerator of (52), and we have already shown that it is negative; $a_{22}$ is the denominator of (53) and it is negative; $a_{12}$ is the denominator of (52) and it is negative; and $a_{21}$ is the numerator of (53) and it is positive. If these signs are known, it is straightforward to verify (55).

A remarkable feature of this stable equilibrium is the fact that both countries are unambiguously better off under physical capital mobility than under autarky. Returning to Figure 2, point $e$ is always to the north-east of the autarky point $a$; still, the home country is a net investor in the foreign one. It is important at this point to emphasise: the fact that both countries are better off occurs even when there is positive cross-country asset ownership in the stable equilibrium, the final result being determined by the initial pattern of asset accumulation previous to the opening up of the capital account. In fact, departing from autarky, capital liberalisation will lead to the capital-abundant country holding a positive stock of foreign capital in equilibrium. Moreover, this condition affects national income equilibrium levels. We turn now to study some relevant configurations of human-physical capital accumulation.

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13 Or the symmetric case if the foreign country is the physical capital abundant one.
5 Some particular cases

To study different possible dynamics in the physical and human capital accumulation processes among different groups of countries or two large economies, we present two particular cases derived from the general model already analysed. In the first one, the foreign country has a negligible accumulation of human capital and in the second one both countries have this characteristic. We also explore what determines the direction of international assets in this two-country model under Cobb-Douglas production functions. These results are nothing more than relatively trivial applications of the general result already shown in the previous section, but they can still be useful for a proper understanding of the results of the model.

5.1 Negligible human capital investment in the foreign country

We explore here the particular cases of a group of countries (or two large countries), which exhibit different patterns of human capital accumulation. The human-capital-rich country devotes a bigger fraction of its national income to human capital than the other does. The income fraction that the human-capital-poor country invests \((s_h^*)\) is so small than can be assumed to be zero. With this assumption the system of equations (35)-(37) becomes:

\[
\begin{align*}
(56) & \quad s_k \left[ f(k(t) - z(t), \frac{S_h}{S_k} k(t)) + r(t) z(t) \right] - nk(t) = 0,
\end{align*}
\]
(57) \[ s_k^*[g(k^*(t) + bz(t)) - br(t)z(t)] - nk^*(t) = 0, \]

(58) \[ f_1(k(t) - z(t), \frac{S_h}{S_k}k(t)) = g_1(k^*(t) + bz(t)) = r(t). \]

Following the same procedure as for the general case, the slope of the curve \( z=0 \) is

\[
\frac{dk^*}{dk} \bigg|_{z=0} = \frac{f_{11}(k(t), \frac{S_h}{S_k}k(t)) + \frac{S_h}{S_k}f_{12}(k(t), \frac{S_h}{S_k}k(t))}{g_{11}(k^*(t))}
\]

which is positive. As in the discussion of the general case in equation (48), the numerator is always negative, and given the assumption of diminishing marginal productivity of physical capital, the denominator is always negative. As in the general case, points to the south-east of \( z=0 \) show combinations of \( k \) and \( k^* \) for which the stock of foreign-country physical capital owned by the home country is positive \( (z > 0) \), and points to the north-west show combination where \( z < 0 \). The slope of the curves \( \dot{k} = 0 \) is the same as in the general case presented in equation (52). The slope of the curve \( k^* = 0 \) is:

\[
\frac{dk^*}{dk} \bigg|_{k^*=0} = \frac{s_k^*bz(t) \left( \frac{\partial}{\partial k} r(t) + \frac{S_h}{S_k} \frac{\partial}{\partial h} r(t) \right)}{s_k^* \left[ r(t) - bz(t) \frac{\partial}{\partial k^*} r(t) \right]} - n
\]

The sign of the numerator in (60) depends on the sign of \( z \) as the term inside the bracket is negative. The denominator is always negative since it is equivalent to
the inequality already analysed in (47) in the case of negligible human capital accumulation in the foreign country. This slope is positive when $z > 0$ and negative when $z < 0$. As in the general case, there is a unique steady-state equilibrium in which, under free physical-capital mobility, both countries are in a better position compared with the autarky steady state. The main point, which can be seen here, is that even in this extreme case of divergent patterns of human capital accumulation in both countries, there are still gains to be reaped from the free capital mobility, in spite of different levels of income at the stable equilibrium.

5.2 Negligible human capital investment in both countries

The model can be simplified to a two-country traditional Solow-Swan model in which we assume that both countries devote a very small fraction of their national incomes to investment in human capital. If the propensities to save in human capital in both countries ($s_h, s^*_h$) are assumed to be close to zero, the slopes of the curves $z = 0, \dot{k} = 0$ and $\dot{k}^* = 0$ are:

$$\left. \frac{dk^*}{dk} \right|_{z=0} = \frac{f_{11}(k(t))}{g_{11}(k^*(t))},$$

$$\left. \frac{dk^*}{dk} \right|_{k=0} = \frac{s_k \left( r(\cdot) + z(t) \frac{\partial}{\partial k} r(\cdot) \right) - n}{s_k z(t) \left( \frac{\partial}{\partial k^2} r(\cdot) \right)},$$
As in the general case, we have a unique state of stationary equilibrium and we have gains due to free mobility of physical capital. This particular model is similar to the model presented in Ruffin (1979).

5.3 International assets in the Cobb-Douglas case

We explore here the determinants of the direction of international assets in assuming that both countries operate under a Cobb-Douglas production function, as presented in Appendix 1. No particular assumption is made regarding the parameters driving the processes of capital accumulation. The labour-intensive output under free physical capital mobility for the home and the foreign country are \( q = (k - z)a h^\alpha \) and \( q^* = (k^* + bz)a h^{\alpha^*} \) respectively. As before, \( \alpha + \beta < 1 \) and \( \alpha^* + \beta^* < 1 \). We can rewrite both outputs in terms of the interest rate as \( q = r(k - z)/\alpha \) and \( q^* = r(k^* + bz)/\alpha^* \).

Replacing national outputs in equations (35) and (36), we have:

\[
\left(64\right) \frac{dk^*}{dk} \bigg|_{k^*} = \frac{s_k b(z(t) \left( \frac{\partial}{\partial k} r(\cdot) \right)}{s_k \left( r(\cdot) - b(z(t) \frac{\partial}{\partial k^*} r(\cdot)) - n \right)}.
\]
Dividing equation (64) by \( rk \) and equation (65) by \( rk^* \), we obtain the following:

\[
\frac{s_k}{\alpha} \left[ 1 - (1 - \alpha) \frac{z}{k} \right] = \frac{n}{r},
\]

\[
\frac{s_k^*}{\alpha} \left[ 1 + b(1 - \alpha^*) \frac{z}{k^*} \right] = \frac{n}{r}.
\]

We can equate equations (66) and (67) to obtain an expression for the international assets:

\[
\frac{s_k}{\alpha} - \frac{s_k^*}{\alpha^*} = \left[ \frac{s_k (1 - \alpha)}{\alpha k} + b \frac{(1 - \alpha^*)}{k^*} \frac{s_k^*}{\alpha^*} \right].
\]

As the term in parenthesis is always positive, the sign of \( z \) depends on the sign of the term on the left-hand side. Thus the home country is a creditor country when

\[
\frac{s_k}{\alpha} > \frac{s_k^*}{\alpha^*}.
\]

It is important to emphasise this result: in the case of this particular functional form of the production function, the key determinant of the direction of international physical capital accumulation, in the absence of other disparities between countries, is driven by the ratio between the share of national income devoted to physical capital accumulation and its productivity. Differences in
physical capital productivity are, on top of investment rates, a determinant of international assets accumulation.

6 Conclusions

This chapter develops a two-country Solow-Swan growth model with human capital in which physical capital is mobile across borders but human capital is immobile. Three innovations are introduced here. Firstly, there is the introduction of human capital that allows us to pin down the positive effects of each country’s human capital accumulation, not only on its own income path but on the trajectory of the other economy. Secondly, the importance of allowing an endogenous determination of the interest rate is perceived when a possible positive effect of human capital accumulation operating through the international parity condition is found. This allows us to show that an indirect transfer of productivity improvements from one country to the other is possible, if capital is allowed to move between countries, even under human mobility restrictions. Finally, the model considers how the stock of international investment affects directly the production and national incomes through the remuneration to foreign capital. The positive effect of allowing the economy to receive foreign capital takes here into account the need to service international assets. Once this effect is included, it is clear that the effect of further domestic physical capital accumulation has an unambiguous effect in those cases in which the country
is substituting international capital for domestic capital through this investment process.

Regarding specific findings, we find that, on one hand, the stock of physical capital that one country invests in the other is positively affected by increases in the stock of the physical capital of the creditor country. On the other hand, an expansion in the stock of physical capital in the debtor country negatively affects the flows of international investment at this country. However, these two effects are less than proportional.

Due to complementarities between human and physical capital in each country, an expansion in the stock of human capital in the creditor decreases the stock of physical capital that this country invests in the other. However, an expansion in the stock of human capital in the debtor country can have the opposite effect, leading to increases in the flow of international investment that it receives from the creditor country. If the expansion in physical capital occurs in a debtor country, the flow of resources that it receives decreases, but if the human capital is the one which is increasing, the flow of physical capital increases.

The model also considers how human capital accumulation positively affects the interest rate, due to the complementarity effect dominating the diminishing marginal productivity of human capital.

Increases in physical capital accumulation have non-trivial results as regards the national income. An expansion in the debtor country’s physical capital has the
expected positive effect on its own national income. However, when the expansion is in the creditor country, the effect on its own national income is ambiguous. In terms of the cross-country effects, an expansion in the stock of physical capital in the creditor country increases the national income of the debtor country, due to the reduction in the cost of debt service. However, if the expansion is in the physical capital of the debtor country, there is a negative effect on the creditor country's national income. In terms of changes in human capital the previous results are somewhat reversed: an expansion in the stock of human capital in the creditor country increases its own income. However, if the increase in human capital occurs in the debtor country the effect on its income is ambiguous. In terms of cross-country effects, human capital accumulation in a creditor country decreases national income in the debtor country. If the expansion in human capital happens in the debtor country it will have a positive effect on the income of the creditor country.

We find a unique and stable equilibrium under free capital mobility, strongly dependent on initial conditions. The different combinations in the same plane of the three steady-state path schedules for international investment, namely home country physical capital and foreign country physical capital, determine the existence of a unique stationary equilibrium. This result gives support to the existence of convergence between two large groups of economies with differences in physical capital, being conditional on the level of human capital accumulation and under free capital mobility.
We also present two particular cases to illustrate the model. In the first one, we mirror the relationship between a group of advanced countries and a group of developing countries, in which the former invest heavily and the latter lag behind in terms of human capital investment. In the second one, we follow two large groups of countries that exhibit a very low level of human capital investment. Despite the divergent patterns of human and physical capital accumulation, which will definitely lead to different levels of income at the stable equilibrium, there are in both cases gains to be reaped from free capital mobility.

Finally, using Cobb-Douglas technologies, we find that differences in physical capital productivity are, on top of investment rates, determinant of international assets accumulation and income levels in the long run.
Appendix 1

When both countries exhibit Cobb-Douglas production functions with non-increasing returns to scale, if the labour intensive outputs under autarky are $q = k^\alpha h^\beta$, $q^* = k^{\alpha^*} h^{\beta^*}$ and $\alpha + \beta < 1$, $\alpha^* + \beta^* < 1$, the slope of the curve $z = 0$ is:

$$\left. \frac{dk^*}{dk} \right|_{z=0} = \frac{\alpha(\alpha - 1) \left( \frac{s_h}{s_k} \right)^\beta (\alpha + \beta - 2) k^{\alpha - 1} + \alpha\beta \left( \frac{s_h}{s_k} \right)^\beta (\alpha + \beta - 2) k^{\alpha - 1}}{\alpha^* (\alpha^* - 1) \left( \frac{s_h}{s_k} \right)^{\beta^* (\alpha^* + \beta^* - 2)} k^{\alpha^* - 1} + \alpha^* \beta^* \left( \frac{s_h}{s_k} \right)^{\beta^* (\alpha^* + \beta^* - 2)} k^{\alpha^* - 1}}$$

$$= \frac{\alpha(\alpha + \beta - 1) \left( \frac{s_h}{s_k} \right)^\beta (\alpha + \beta - 2) k^{\alpha - 1}}{\alpha^* (\alpha^* + \beta^* - 1) \left( \frac{s_h}{s_k} \right)^{\beta^* (\alpha^* + \beta^* - 2)} k^{\alpha^* - 1}}$$

which is unambiguously positive.
Chapter 2. International assets in a two-country learning-by-doing growth model

1 Introduction

During the last thirty years the continuous process of international capital markets integration has made foreign physical capital a determining factor in the performance of open economies.\textsuperscript{14} In addition, a greater mobility of capital has coincided with the growing recognition that factor fundamental to economies is the production and use of knowledge. In Chapter 1, we explored the connections between these two facts by means of a neoclassical two-country growth model with human capital accumulation. In this chapter, we depart from the idea of knowledge as human capital accumulation which was used before. Here, knowledge accumulates endogenously through a learning-by-doing process that generates long-run endogenous growth.

\textsuperscript{14} For bibliographic references that support this claim, please see the ones included in the introduction and in Chapter 1.
The purpose of this chapter is to analyse physical capital and international asset accumulation in a two-country endogenous growth model. We extend the traditional endogenous growth model, with learning-by-doing as the source of technological progress, to a two-country endogenous growth model with free mobility of physical capital between the two countries and an endogenously determined interest rate. In the model presented in this chapter, knowledge is accumulated by a learning-by-doing process in which learning takes place as a side-effect of the world physical capital accumulation. Hence, when physical capital moves across countries, there is a possible positive effect due to a faster rate of learning across economies. This approach builds on the endogenous growth literature relating to open economies.

During the 1980s, the seminal works of Paul Romer (1986) and Robert Lucas (1988) opened up a new avenue of research in the modern theory of endogenous growth. In these two papers, the long run rate of growth is determined endogenously through a technological process without decreasing returns to scale. In Romer's model, the absence of decreasing returns to scale arises from the spread of innovations as a result of research and development activities associated with the investment process. In Lucas's model the externalities associated with human capital accumulation explain the absence of decreasing returns. These two papers were

15 The basic ideas of these two authors have been circulating through the academic community since the early eighties. Paul Romer's (1986) paper is based on his PhD dissertation at the University of Chicago in 1983, and Robert Lucas's (1988) paper was originally written to be delivered during the 1985 Marshall Lectures at Cambridge University.
preceded by the earlier contribution of Arrow’s (1962) learning-by-doing model, which introduced a way of modelling the accumulation of knowledge as a side product of ordinary economic activities, through experience and not as a deliberate process.\textsuperscript{16} By contrast, in the model presented in this chapter, learning occurs as a side-effect of the accumulation of physical capital in the world economy. This is an innovation with respect to the previous literature, as this concept of learning is broader than the notion traditionally used in theoretical models of endogenous growth, in which learning occurs as a side-effect of the build-up of physical or human capital in each country. Knowledge is hence assumed to be a “world” public good; that is, knowledge is worldly \textit{non-rival} and \textit{non-excludable}. Knowledge is universally available to both countries.

In dealing with the issues of international capital mobility and growth, this paper is related to the neoclassical growth models discussed in the previous chapter. More significantly, it is also related to endogenous growth models for open economies using a two-country framework for the analysis. Amongst the authors who resort to the use of this framework, Buiter and Kletzer (1991) study the causes of country differences in average labour productivities within an overlapping generations model. Rivera-Batiz and Romer (1991) examine the scale effects of trade integration on the growth process. Dellas and DeVries (1995) study the effects of the speed of international factor markets integration within a general equilibrium two-country model. Mountford (1999) analyses the dynamic implications of international

\textsuperscript{16} Arrow’s (1962) theoretical formulation was motivated by his empirical observation of a learning curve in the production process of the airframe industry.

We extend this literature with the inclusion of international asset accumulation in an endogenous growth model, in which knowledge is accumulated as a side-effect of the accumulation of world physical capital. This theoretical setting is used firstly, to show the dynamics of the accumulation process of physical capital stock in both countries; secondly, to analyse the dynamics of international asset accumulation under openness; and finally, to study the existence and nature of the steady-state solution of the system.

We carefully consider, as in the previous chapter, the role of international physical capital remuneration in relation to the process of accumulation of physical capital and growth. The interest rate is, as in the previous chapter, endogenously determined through an equilibrium parity condition. Physical capital accumulates as in the traditional Solow-Swan model. Each country’s savings rates are constant and exogenously determined.

The chapter is organised as follows: Section 2 lays out the basic features of the model on which all arguments rely. It describes the production functions,
international assets, the learning-by-doing process and the physical capital accumulation process. Section 3 describes the equilibrium of the model using Cobb-Douglas production functions. Section 4 analyses the general results and discusses the extensions and limitations of the model.

2 Specification of the model

Consider a two-country endogenous growth model. As assumed in Chapter 1, there are two countries: "home" and "foreign". We denote with an asterisk variables and equations that refer to the latter.

2.1 Output, national income and international assets

Both countries produce an identically homogenous good that can be either consumed or invested, but each country has a different production function. Output in each country is represented by a well-behaved neoclassical production function that requires physical capital, raw labour and knowledge, according to a constant returns-to-scale technology. Labour-augmenting technological progress is internationally non-rival: i.e every innovation is quickly learnt worldwide. Rapid technological diffusion will be at the base of the results, as the spread of technological innovations across countries will affect symmetrically the physical-human capital relation in both countries, allowing us to concentrate on the effect of human capital on capital flows.
across countries due to reasons different to protection to innovations. The
population growth is assumed to be constant in both countries. Then, in a closed-
economy situation, the output produced at time $t$ for the home and foreign countries,
denoted by $Q(t)$ and $Q^*(t)$ are:

\begin{align}
(1) \quad Q(t) &= F(K(t), A(t)L(t)), \\
(2) \quad Q^*(t) &= G(K^*(t), A(t)L^*(t)),
\end{align}

where $K(t)$, $A(t)$ and $L(t)$ are physical capital, knowledge and labour
employed in production at time $t$ for the home country, and $K^*(t)$, $A^*(t)$ and $L^*(t)$
are the equivalent variables for the foreign country. The production functions, $F(\cdot)$
and $G(\cdot)$, are twice continuously differentiable, strictly concave with respect to each
input, exhibit constant returns to scale and satisfy the Inada conditions. Formally
these can be stated as$^{17}$:

\begin{align}
F_1(K(t), A(t)L(t)) > 0 & \quad G_1(K^*(t), A(t)L^*(t)) > 0 \\
F_2(K(t), A(t)L(t)) > 0 & \quad G_2(K^*(t), A(t)L^*(t)) > 0 \\
F_{11}(K(t), A(t)L(t)) < 0 & \quad G_{11}(K^*(t), A(t)L^*(t)) < 0 \\
F_{22}(K(t), A(t)L(t)) < 0 & \quad G_{22}(K^*(t), A(t)L^*(t)) < 0
\end{align}

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$^{17}$ Recall that $F_1$ refers to the first derivative of the production function with respect to the first factor,
i.e. the stock of physical capital.
\[ F_{12}(K(t), A(t)L(t)) > 0 \quad \quad G_{12}(K^*(t), A(t)L^*(t)) > 0 \]

\[ F_{12}(K(t), A(t)L(t)) = F_{21}(K(t), A(t)L(t)) \quad 18 \]

\[ G_{12}(K^*(t), A(t)L^*(t)) = G_{21}(K^*(t), A(t)L^*(t)) \]

\[ \lim_{K \to 0} F_1(K(t), A(t)L(t)) = \infty \quad \lim_{K^* \to 0} G_1(K^*(t), A(t)L^*(t)) = \infty \]

\[ \lim_{K \to \infty} F_1(K(t), A(t)L(t)) = 0 \quad \lim_{K^* \to \infty} G_1(K^*(t), A(t)L^*(t)) = 0 \]

\[ \lim_{L \to 0} F_2(K(t), A(t)L(t)) = \infty \quad \lim_{L \to 0} G_2(K^*(t), A(t)L^*(t)) = \infty \]

\[ \lim_{L \to \infty} F_2(K(t), A(t)L(t)) = 0 \quad \lim_{L \to \infty} G_2(K^*(t), A(t)L^*(t)) = 0 \]

We allow the economies to open up and for physical capital to be completely mobile between the two countries. Physical capital mobility will determine total physical capital availability and national income in each country. As in Chapter 1, let \( Z(t) \) be the net stock of physical capital in the foreign country owned by the home country and call it international assets. A positive \( Z(t) \) means that the home country has a net positive stock of physical capital in the foreign country, and a negative \( Z(t) \) denotes a net positive stock of physical capital in the home country owned by the foreign country. Then the total stock of physical capital that enters

\[ ^{18} \text{Using Young's Theorem.} \]
into the production process in the home country is $K(t) - Z(t)$, and in the foreign
country is $K^*(t) + Z(t)$.

To isolate from the effect of demographic differentials, we assume that raw
labour is constant in both countries, hence the stock of labour in each country can be
normalised to unity. This assumption allows us to write:

\begin{align}
Q(t) &= F(K(t) - Z(t), A(t)), \\
Q^*(t) &= G(K^*(t) + Z(t), A(t)).
\end{align}

Interest rate is determined endogenously through the following equilibrium
parity condition:

\begin{equation}
F_1(K(t) - Z(t), A(t)) = G_1(K^*(t) + Z(t), A(t)) = r(t),
\end{equation}

where $F_1(\cdot)$ and $G_1(\cdot)$ are the first partial derivatives of each production function
with respect to the total level of capital in each country.

The national income in each country must take into account the rental
payments incurred from international debt or the rental payments received from
international assets. Then national incomes at time $t$ for the home and foreign
country are:

---

19 Observe that in Chapter 1, we used per capita notation. In this chapter we only use notation in
levels.

20 This assumption implies the population size of the two countries is taken as irrelevant to the
analysis. For a good study of the size effects on growth models, see Young (1998).
(6) \( Y(t) = F(K(t) - Z(t), A(t)) + r(t)Z(t) , \)

(7) \( Y^*(t) = G(K^*(t) + Z(t), A(t)) - r(t)Z(t) . \)

**Learning-by-doing**

Learning-by-doing is the source of knowledge accumulation. Learning occurs as a side-effect of worldwide physical capital accumulation: i.e. the sum of the accumulation of physical capital in both the home and the foreign countries. As the accumulation of knowledge is a function of the investment process, the stock of knowledge is also a function of the stock of worldwide physical capital. As we mentioned before, knowledge is not rival and freely and immediately available worldwide. This assumption will drive some of the results of the model: indeed, the idea is to explore what would be the effect to international physical capital movements without considering the effect of proprietary innovations in one of the countries. Here, results not necessarily depend on the degree of protection of technological innovations, but as the process of innovation is a result of the process of investment, most of these advances are assumed to spread freely and rapidly across countries. Then we have:

(8) \( A(t) = B(K(t) + K^*(t)) , \)

where \( B \) is a positive constant.
Using the definition of the learning-by-doing knowledge-accumulation process from equation (8) to replace in the equations of national income for both countries and the equilibrium parity condition we obtain:

\[ Y(t) = F(K(t) - Z(t), B(K(t) + K^*(t))) + r(t)Z(t), \]

\[ Y^*(t) = G(K^*(t) + Z(t), B(K(t) + K^*(t))) - r(t)Z(t), \]

\[ F(K(t) - Z(t), B(K(t) + K^*(t))) = G(K^*(t) + Z(t), B(K(t) + K^*(t))) = r(t). \]

2.2 The dynamics of the economies

The accumulation of physical capital is the fundamental process that drives the growth process in each country. As is standard in the literature, it is in the spirit of the Solow-Swan neoclassical growth model. The saving rates, \( s \) and \( s^* \) for the home and foreign countries respectively are constant and exogenously given. Depreciation is set to zero for simplicity. Physical capital is accumulated in each country as in the following two equations:

\[ \dot{K}(t) = s\left[F(K(t) - Z(t), B(K(t) + K^*(t))) + r(t)Z(t)\right], \]

\[ \dot{K^*}(t) = s^*\left[G(K^*(t) + Z(t), B(K(t) + K^*(t))) - r(t)Z(t)\right]. \]
The rates of growth of physical capital in both countries, denoted by $g_k$ and $g_{K^*}$, are:

$$g_k = \frac{\dot{K}(t)}{K(t)} = s \left[ F \left( 1 - \frac{Z(t)}{K(t)}, B \left( 1 + \frac{K^*(t)}{K(t)} \right) \right) + r(t) \frac{Z(t)}{K(t)} \right],$$

$$g_{K^*} = \frac{\dot{K}^*(t)}{K^*(t)} = s \left[ G \left( 1 + \frac{Z(t)}{K^*(t)}, B \left( \frac{K(t)}{K^*(t)} + 1 \right) \right) - r(t) \frac{Z(t)}{K^*(t)} \right].$$

By means of equations (14) and (15), we define the ratio of international assets to the stock of physical capital in the home and foreign countries respectively as:

$$M(t) = \frac{Z(t)}{K(t)},$$

$$M^*(t) = \frac{Z(t)}{K^*(t)}.$$

It is interesting to note the properties of $M(t)$ and $M^*(t)$:

**REMARK** The sign of $M$ and $M^*$ depends on the ownership of net international assets. In all cases, they are less than or equal to unity, since international assets could not exceed the stock of physical capital of any country.
Replacing $M(t)$ and $M^*(t)$ in equations (14) and (15), the rates of growth of physical capital in the home and foreign countries can be rewritten as:

\begin{align*}
(18) \quad g_K &= \frac{\dot{K}(t)}{K(t)} = s \left[ F \left( 1 - M(t), B \left( 1 + \frac{M(t)}{M^*(t)} \right) \right) + r(t)M(t) \right], \\
(19) \quad g_{K^*} &= \frac{\dot{K}^*(t)}{K^*(t)} = s' \left[ G \left( 1 + M^*(t), B \left( 1 + \frac{M^*(t)}{M(t)} \right) \right) - r(t)M^*(t) \right].
\end{align*}

In turn, the equilibrium parity condition, using $M(t)$ and $M^*(t)$, is:

\begin{align*}
(20) \quad F \left( 1 - M(t), B \left( 1 + \frac{M(t)}{M^*(t)} \right) \right) = G \left( 1 + M^*(t), B \left( 1 + \frac{M^*(t)}{M(t)} \right) \right).
\end{align*}

Equations (18), (19) and (20) give a complete description of the general model. The first two equations describe the growth rates of physical capital in both countries and the other one gives the equilibrium parity condition. The model has two stock variables whose behaviour is endogenous, $M(t)$ and $M^*(t)$, which show the ratio of international assets to the stock of physical capital in the home and foreign countries respectively.
3 Balanced growth

Cobb-Douglas technologies

Using the general form described in the previous section and to keep the analysis tractable, we assume Cobb-Douglas production functions with constant returns to scale for both countries. The Cobb-Douglas form is a reasonable description of actual production processes and satisfies the properties of a neoclassical production function. Output for the home and foreign country under Cobb-Douglas production functions are:

\[
\frac{Q}{K} = (1 - M)^\alpha \left( B \frac{M + M^*}{M^*} \right)^{\beta}
\]

\[
\frac{Q^*}{K^*} = (1 + M^*)^{\alpha^*} \left( B \frac{M + M^*}{M^*} \right)^{\beta^*}
\]

where \( \alpha, \beta, \alpha^*, \) and \( \beta^* \) are input shares.\(^{21}\) Also, \( \alpha + \beta = 1 \) and \( \alpha^* + \beta^* = 1 \) need to hold for constant returns to scale.

Equations (23) and (24) are the growth rates of physical capital for both countries, while equation (25) is the equilibrium parity condition, all of them under Cobb-Douglas production functions:

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\(^{21}\) From this point onwards, time indicators are suppressed for ease of notation.
Replacing outputs $Q$ and $Q^*$ as defined in equations (21) and (22), in the growth rates and the equilibrium parity condition [equations (23) to (25)] we obtain:

(26) $g_k = \frac{\dot{K}}{K} = s \left[ \frac{Q}{K} + rM \right]$.

(27) $g_{k^*} = \frac{\dot{K}^*}{K^*} = s \left[ \frac{Q^*}{K^*} - rM^* \right]$.

(28) $\alpha \frac{Q}{K(1-M)} = \alpha^* \frac{Q^*}{K^*(1+M^*)} = r$.

Equations (26) to (28) constitute a complete description of the model for the Cobb-Douglas production functions. However, it is possible to reduce the model because, as we demonstrate in the following Lemma, the physical capital growth rates equalise amongst countries.
LEMMA 1 In the balanced-growth path, the physical capital growth rates for the home and foreign countries are equal. This is: \( g_K = g_{K^*} \).

PROOF

Step 1. Define the balanced-growth path as a solution along which \( K, K^* \), and \( Z \) grow at constant rates.

Step 2. Assume, for the moment, that \( g_K > g_{K^*} \), and recall that, according to the remark made before, \( Z < K \) and \( Z < K^* \), it follows that \( g_K \geq g_{K^*} \geq g_Z \).

Step 3. Using the definitions of \( M \) and \( M^* \) from equations (16) and (17) and step 2, we have: \( M = \frac{Z}{K} \to 0 \), \( \frac{M}{M^*} = \frac{Z}{K^*} = K^* \to 0 \), and \( \frac{M^*}{M} = \frac{Z}{K} \to \infty \).

Step 4. Using the left-hand side of the equilibrium parity condition (equation (20)) and the previous step, we find that the interest rate is finite:

\[
F_i \left[ 1 - M, B \left( 1 + \frac{M}{M^*} \right) \right] \to F_i(1, B).
\]

Step 5. Nevertheless, if we use the right-hand side of the same equilibrium parity condition, we will find that the interest rate is infinite:

\[
22 \text{ Where } g_z \text{ is equivalent to the growth rate of } Z.
\]
\[ G_i \left(1 + M^*, B \left(1 + \frac{M^*}{M} \right) \right) \rightarrow \infty, \] which is contrary to what we just found in Step 4. For the equilibrium parity condition to hold, \( g_k = g_k'. \)

Lemma 1 states that, under free capital mobility, the rate of growth of physical capital in both countries equalises even after allowing for learning-by-doing. As corollary of this result we can equate the right-hand side of (26) and (27):

\[
(29) \quad s \left[ \frac{Q}{K} + rM \right] = s^* \left[ \frac{Q^*}{K'} - rM^* \right].
\]

At this point, we have been able to reduce the model to three equations with three unknowns, \( M, M^* \) and \( r \). We proceed now to determine the existence of equilibrium for this system.

**Characterization of the balanced growth path**

Firstly, to reduce the system to two equations in the variables \( M \) and \( M^* \). We rewrite the equilibrium parity condition from equation (28) as the fraction that relates home and foreign country outputs:

\[
(30) \quad \frac{Q}{Q^*} = \frac{(1 - M) \alpha^*}{(1 + M^*) \alpha}.
\]
Subsequently, rewrite equation (29) in terms of the same fraction of outputs, and substitute \( r \) from equation (28) to obtain:

\[
\frac{Q/K}{Q^*/K^*} = \frac{1 - \alpha^*}{1 + M^*} \frac{M^*}{1 + \alpha \frac{M}{1 - M}} \frac{s^*}{s}.
\]

Replacing equations (30) into (31) and rearranging it, we obtain a linear relation between the two variables, \( M \) and \( M^* \):

\[
M^* = \frac{s \alpha^* - s^* \alpha}{s^* \alpha (1 - \alpha^*)} + \frac{s \alpha^* (\alpha - 1)}{s^* \alpha (1 - \alpha^*)} M.
\]

This is a linear relation of possible values of \( M \) and \( M^* \) along the balanced-growth path equation (32). The shape of this relation is a function of the input shares and saving rates for the home and foreign countries. As we will see, equation (32) can be depicted in the \((M^*, M)\) plane as a downward-sloping line. Since both variables need to have the same sign (this follows from equations (16) and (17) and the non-negativity of the capital stocks), the only part of the downward-sloping line that is relevant is the one contained in either the first or the third quadrant of the \((M^*, M)\) plane. In particular, the location of the function depends on the sign of international assets \((Z)\) as the stock of physical capital is always positive. If international assets are positive, both \( M \) and \( M^* \) are positive and the line will be located in the first quadrant. If international assets are negative, the line will be located in the third quadrant. As we will see now, the direction of international
assets will be determined, as expected, by a combination of the level of savings rates and the productivity of capital.

Regarding the particulars of the linear relation (32), it is clear that the slope (given by \( s\alpha^*(\alpha - 1)/s^*\alpha(1 - \alpha^*) \)) is always negative, and that the intercept (given, in turn, by \( (s\alpha^* - s^*\alpha)/s^*\alpha(1 - \alpha^*) \)) can be positive or negative. On one hand, if the intercept is positive (\( M^* > 0 \)), the stock of net international assets \( Z \) need to be positive and the linear relation will be in the first quadrant of the \((M^*, M)\) plane. On the other hand, if the intercept is negative (\( M^* < 0 \)), the stock of net international assets is negative and the linear relation will be in the third quadrant. As the denominator of the intercept is always positive, the sign of the intercept depends on the sign of the numerator that in turn depends on the relative values of the savings rates, \( s \) and \( s^* \), and of the productivity of capital (physical capital shares on income), \( \alpha \) and \( \alpha^* \).

In particular, if \( s\alpha^* > s^*\alpha \), the intercept is positive and if \( s\alpha^* < s^*\alpha \), the intercept is negative. The home country is a creditor (\( Z \) is positive) when \( \frac{s}{\alpha} > \frac{s^*}{\alpha^*} \). In turn, the home country is a debtor if \( \frac{s}{\alpha} < \frac{s^*}{\alpha^*} \). This result shows that the direction of international assets, in the absence of other disparities between both countries, is driven by the difference in the ratio between the share of national income devoted to physical capital accumulation and its productivity. This result is consistent with the
one found for the Cobb-Douglas case of the two-country Solow-Swan growth model introduced in the previous chapter.\textsuperscript{23}

More meaningfully, we may assume for the moment that the two countries may have similar levels of productivity of capital (and hence similar shares of capital-related remuneration on domestic product). In this case, the investor country will be the one that has the largest saving rates, quite an intuitive result. But if we assume, momentarily, that saving rates are similar, the investor country will be the one with the lowest productivity of capital, as it will find its domestic capital “pulled” to the other country.

To pin down the values of $M$ and $M^*$ on the balanced growth path equation (32) is not sufficient; we need a second equation relating $M$ and $M^*$. As this second equation we chose the first equation in (25) in which we replace the linear relation (32). To simplify we denote equation (32) as $M^* = a - cM$ where $a$ and $c$ are the intercept and the slope of the line respectively, being non-trivial combinations of the savings rates and the parameters of the production functions. Then, now we reduce the system of equations to a single equation $h(M) = 0$ in the single variable $M$:

\begin{equation}
(33) \quad h(M) = \alpha (1 - M)^{a-1} \left( B \frac{M + a - cM}{a - cM} \right)^\beta - \alpha^* (1 + a - cM)^{a^*-1} \left( B \frac{M + a - cM}{M} \right)^{\beta^*} = 0
\end{equation}

\textsuperscript{23} See in particular, section 5.3.
This equation is non-linear and continuous. Its non-linearity is apparent and its degree depends on the production function parameters. The continuity is guaranteed by the assumptions of the production functions.

To pin down the solution for this equation, and for the system, we distinguish between the two cases we already presented when we referred to equation (32). In the first case $\frac{s}{\alpha} > \frac{s^*}{\alpha}$ the intercept of the linear relation in equation (32) is bigger than zero, $a > 0$. As we know from the Remark and from the non-negativity of capital, the capital stocks $M$ and $M^*$ are positive and less than or equal to unity. Then, as we use equation (32) ($M^* = a - cM$), $M$ needs to be less than $\frac{a}{c}$ to preserve the non-negativity of $M^*$. Then, we find that $M$ must be in the interval $\left[0, \min\left\{\frac{a}{c}, 1\right\}\right]$. In turn, $\lim_{M \to 0} h(M) = -\infty$ and $\lim_{M \to \min\left\{\frac{a}{c}, 1\right\}} h(M) = +\infty$. These limits together with the continuity of $h$ in the open interval $\left(0, \min\left\{\frac{a}{c}, 1\right\}\right)$ prove that there exists at least one value $M$ that satisfies $h(M) = 0$.

In the second case $\frac{s}{\alpha} < \frac{s^*}{\alpha}$, then the intercept of the linear relation in equation (32) is less than zero, $a < 0$. As we know from the Remark and the non-negativity of capital, capital stocks $M$ and $M^*$ are negative and less than or equal to minus...
one. Then, as we use equation (32) \( M^* = a - cM \), \( M \) needs to be less than \( \frac{1 + a}{c} \) to preserve the conditions for \( M^* \). Then, we find that \( M \) must be in the interval \( \left[ \frac{a}{c}, \min \left\{ 0, \frac{1 + a}{c} \right\} \right] \). In turn, \( \lim_{M \to a^c} h(M) = +\infty \) and \( \lim_{M \to \min \left\{ 0, \frac{1 + a}{c} \right\}} h(M) = -\infty \). The limits together with the continuity of \( h \) in the open interval \( \left( \frac{a}{c}, \min \left\{ 0, \frac{1 + a}{c} \right\} \right) \) prove that there exists at least one value \( M \) that satisfying \( h(M) = 0 \) in this second case.

For the two possible cases there exists values of \( M \) and \( M^* \) satisfying the system of equations from which we departed. The existence and localization of the equilibrium is stated in Lemma 2.

**LEMMA 2** There is an equilibrium either at the first or the third quadrant of the \((M^*, M)\) plane.

**PROOF**

We have already established that the linear relationship given by (32) is decreasing in the \((M^*, M)\) plane and the intercept of this line is positive if

\[
\left( \begin{array}{c} s \\ \alpha \\ s^* \\ \alpha^* \end{array} \right) > 0
\]

and negative otherwise. Secondly, we prove that there exists at least one solution for \( h(M) = 0 \) for each of the two cases of the ratio between the share of national income devoted to physical capital accumulation and its productivity in each
country. Then, the equilibrium point is either in the first quadrant $\left( \frac{s}{\alpha} > \frac{s^*}{\alpha^*} \right)$ or the third one $\left( \frac{s}{\alpha} < \frac{s^*}{\alpha^*} \right)$.

From Lemma 2 we know that the model has an equilibrium point in which the net stock of international assets is either positive or negative, i.e. the home country is a creditor or a debtor country. This is a significant result. There are two sources of country differences in the model in the presence of long-term diffusion of technological innovations: productivity differences and savings differences. The fact that a balanced-growth path equilibrium exists, means that, despite those differences, capital movements under openness will operate in order for investment to occur in one of the two countries.

More importantly, this foreign investment will lead, in equilibrium, to the home and foreign country physical capital growth rates to be equal: that is, $g_K = g_{K^*}$. This result means that, even in presence of the technological innovations due to the learning-by-doing process, and the differences in the parameters driving the accumulation process of the two countries, capital movements will make the physical capital growth rates to converge in the long-run. Obviously, production and income growth rates may be different outside the balanced-growth path and income levels can diverge. What is important here is that physical capital movements will drive the system to equilibrium along the balanced growth path of the two
economies. This equilibrium is characterised by the equality of the growth rates of the capital stock in the two countries.

In this equilibrium, the ratio between the share of national income devoted to physical capital accumulation and its productivity in each country determines the localization of the equilibrium point. If the share of national income devoted to physical capital accumulation and its productivity in the home country is bigger than that for the foreign country, \( \frac{s}{\alpha} > \frac{s^*}{\alpha} \), the equilibrium point is located in the first quadrant and the home country is the investor one. In turn, if the share of national income devoted to physical capital accumulation and its productivity in the home country is smaller than that for the foreign country, \( \frac{s}{\alpha} < \frac{s^*}{\alpha} \), the equilibrium point is located in the third quadrant and the foreign country is the investor one.

4 Conclusions

This paper develops a two-country endogenous growth model in which learning-by-doing is the source of knowledge accumulation. Physical capital is mobile across borders, knowledge is a side-effect of worldwide physical capital accumulation and there is an endogenous determination of the interest rate. The model also considers the effects of the stock of international investment in the production and national incomes of both countries.
We find that despite the endogeneity of the growth process, under physical
capital mobility the physical capital growth rates equalise along the balanced growth
path. This result is not necessarily trivial. It is physical capital mobility and the
diffusion of knowledge that comes with it what will lead to the growth rates of
capital accumulation to converge in the long run. As a corollary, the rate of growth in
both countries will also equalise in the long run.

The direction of international assets, that do have an effect on national
incomes, is determined by the size of the ratio of the savings rates in each country to
the productivity of capital. In a way, this can shed light on the push and pull debate
that has pervaded the empirical literature on capital flows. Theoretically, savings
rates are important, as a saver country will "push" its capital to the rest of the world
if there are no significant differences in productivity. Yet under equality of savings
rates, is productivity what will explain why a less productive country will chase
higher returns; indeed more productive and profitable economies will "pull" capital.
But in the end, what determines for the direction of international physical capital
accumulation is the difference in the ratio of savings rates to productivity of capital
between countries. Higher profitability of capital and rapid technology adoption are
complementary attractors of foreign capital under openness. Higher savings rates will
reduce the impact that "serving" foreign capital will have on income, but will not
impede a country profiting from world availability of knowledge production. Non-
proprietary knowledge production is a requirement for this process to exist.
We also demonstrate the existence of equilibrium for the system analysed here in which the net stock of international assets is either positive or negative. In equilibrium we will find that capital movements will occur and one country will accumulate physical capital abroad. Even when there are relative differences in savings rates and productivity and free technological diffusion, international physical capital movements will take place. This process is what produces the equalization of physical capital and the economies' growth rates in equilibrium.
Chapter 3. The role of human capital in attracting capital inflows: an empirical exploration

1 Introduction

One of the crucial issues in international economics and economic history is how to explain the low level of physical capital mobility across countries relative to what investment opportunities would indicate. As the theoretical literature has shown convincingly, the connection between capital flows and economic performance is a positive one.\(^{24}\) Even in a standard neoclassical growth model, external capital would be attracted by higher profitability to a capital-poor country until factor returns were equal, thereby creating higher levels of national income for both countries. We have explored earlier this connection theoretically in Chapter 1 when considering the role

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of human capital interacting with physical capital in an open economy growth framework. Our results show that in these conditions and after a liberalisation of physical capital markets, both economies enhance their economic activity.

We will explore here the extent to which human capital differences across countries can indeed account for differences in physical capital inflows. This is a natural step forward. Having demonstrated the potential positive effects of capital liberalisation, after accounting for human capital stock differentials and asymmetries in initial conditions, it is interesting to see whether these differences in human capital play a role in determining the flow of physical capital across countries. This is probably the fundamental factor that the theory has put forward to explain the shortfall in capital flows. In his celebrated 1990 paper, Lucas offered, what he termed, "non-exclusive solutions" to the puzzle of why physical capital does not flow from capital-abundant to capital-scarce countries, pointing to the fact that capital would be either less productive than expected or would face market or institutional failures. Differences in human capital may explain, in part, the low levels of capital flows, as lack of skills will make that capital relatively unproductive. In addition, capital market imperfections, macroeconomic instability and political risks, mostly related to the protection of property rights, may deter mobility.

Several papers have concentrated on gauging the negative impact of political risk issues and capital market imperfections on capital flows\textsuperscript{25}. Nevertheless, it is surprising to realise that few empirical works have explored the connection.

\textsuperscript{25} See section 2 below for a brief account of recent works concentrating on this area.
suggested by Lucas himself, between capital flows and human capital accumulation. This, most likely, is due to the scarcity of datasets on human capital stocks for a sufficiently large sample of countries. Our aim in this paper is to make a first attempt to fill this gap by exploiting recently released datasets on human capital stocks by means of sound econometric techniques and using a broad measure of capital inflows.

The specific objective of this paper is to provide a long-term empirical characterization of the role of human capital in attracting different types of capital inflows for a relatively large sample of industrial and developing countries. We perform our empirical exercises, using both a broad measure of total foreign capital inflows (FCI) and a series of foreign direct investment inflows (FDI) and foreign portfolio inflows (FPI). Human capital is considered as a stock that is idiosyncratic to each country. We use a panel of data identifying different results across industrial and developing countries. Our dataset covers a large and heterogeneous group of countries (21 industrial and 39 developing) over a long time-span (1976-2000).

The next section of the paper presents some theoretical underpinnings of our empirical exercise. In section 3, we detail some data issues and methodology, before continuing in sections 4 and 5 with our main results. Section 6 presents a variety of robustness test for the main results discussed in sections 5. Section 7 concludes.
2 Theoretical issues

We concentrate here on the empirical relationship between the processes of foreign physical capital movements and human capital accumulation across economies. No single theoretical model can encompass the entire range of short-term and long-term theoretical relationships that we would like to include in order to isolate the relationship on which we want to focus on.

As it will become apparent in the following subsections, the literature on capital flow determinants has emphasized several theoretical relationships and many channels through which these determinants can potentially affect foreign capital inflows. In this section, we refer in detail to the theoretical underpinnings of the main matter, namely the effect of changing levels of human capital in determining physical capital inflows. We also briefly address other determinants mentioned in the literature.

In a standard neoclassical growth model, external capital would be attracted by its higher profitability to capital-poor countries until factor returns were equal, thus creating higher levels of national income in both countries. We have explained this theoretical connection in Chapter 1, taking into account the role of human capital and

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26 We have already referred to the theoretical and empirical literature on the strong connection involving physical capital flows and economic outcomes. There is also a large body of studies on the relationship linking human capital accumulation and economic growth (see, for example, Mankiw et al. (1992), Benhabib and Spiegel (1994), Islam (1995), Caselli et al. (1996), Pritchett (2001), Temple (1999, 2001), Storesletten and Zilibotti (2000), Bassanini and Scarpetta (2002), McDonald and Roberts (2002)), and Hojo (2003). What we are concentrating on here, nevertheless, is the intermediate link between human capital accumulation and international physical capital movements.
its interaction with physical capital in an open economy growth framework. After assuming endogenous determination of the interest rate, we found a potentially positive effect of human capital accumulation operating through international financial markets that allows an indirect transfer of productivity improvements from one country to the other. Our results show that in these conditions and after a liberalisation of physical capital markets, both economies experience an increase in their economic activity. The degree of physical capital mobility is determined not only by initial conditions in terms of physical capital, but also by the process of human capital accumulation operating in a non-trivial manner. Yet from our theoretical results, it is clear that an expansion in the stock of human capital in a debtor country can lead to increases in the flow of international investment that it receives from a creditor.

This theoretical argument is part of an interesting discussion regarding the possible set of relevant influences affecting capital movements and economic outcomes. As mentioned in section I, the work by Lucas (1990) introduces a distinction between the notion of unproductive capital and the idea of market-institutional failures to explain the relative lack of capital movements.27

The first view identifies a third, previously overlooked, factor that causes deterioration of the foreign-capital potential profitability, even in the case in which foreign capital is allowed to migrate. This condition, in itself, explains why capital

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27 See Clemens and Williamson (2000) for a presentation of this view, with particular application to the case of British foreign capital during the 19th century.
movements are so rare compared to what is expected. Human capital is the main “third factor” candidate, and the one we would like to isolate here.

There are few previous attempts to isolate this relationship empirically. Noorbakhsh et al. (2001) measured the conditional relationship between FDI inflows and human capital for a sample of 36 developing countries, after controlling for other determinants. Despite some unresolved econometric issues in their work and the fact that the period of observation is restricted to 1983–1994, they managed to find a sizeable and significantly positive relationship.28 Yussof and Ismail (2002) identify the production of highly skilled professionals and workers as the key condition for attracting FDI inflows into four ASEAN developing countries (Malaysia, Thailand, Indonesia and the Philippines), through parallels with other countries' experiences. Dasgupta et al. (1996) find, in a survey of Japanese firms, that human capital consideration is a crucial factor in determining FDI country choices. In an economic history study, Hanson (1996) finds a significant role for human capital in FDI, but he also suggests that political risk and institutional compatibility across countries are key issues. In his study, the author uses data for developing countries during the 1960s and opinion surveys. On the other hand, Schneider and Frey (1985) using a cross-section methodology show that this effect is not consistently significant. It is

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28 They focus on a pooled OLS regression as the canonical model for their results, without following a testing procedure to select this model as the preferred one. A lagged change in the dependent variable is included, creating all sorts of issues in this dynamic regression, some of which are not addressed. Both issues question the consistency and inference of their point estimates.
most likely that the lack of good quality data on human capital and capital inflows is what explains the lack of empirical results in this area. We aim to fill this vacuum.\textsuperscript{29}

As suggested before, other “third factors” have been mentioned in the literature taking the “unproductive capital” view. Some of them are not directly linked with capital flows, but, in general, put forward issues affecting economic outcomes. Putnam (1993), for example, suggests that several institutional factors related to the intensity of trustworthy-generating group interactions are inherently correlated with economic outcomes. Temple and Johnson (1998) show indeed that social capabilities have a strong predictive power of future economic performance. Mellinger et al. (1999) and Sachs (2000) have stressed the role of geography in hindering economic outcomes. Sokoloff and Engerman (2000) and Acemoglu et al. (2001) have shown the historic role of wealth and income distribution in determining economic outcomes through the role of institutions. Finally, Higgins and Williamson (1997) and Bloom and Williamson (1998) emphasize the effect of the demographic structure on productivity and capital accumulation patterns. Interestingly, in most of these works human capital is mentioned in passing as one factor that will affect economic outcomes in the long run, but in contrast to others, we would be able to measure its changes across time during a relatively short time-span.

The second view focuses on market failures or institutional inadequacies that increase the user’s cost of capital and hence prevent factor price equalisation.

\textsuperscript{29} A related literature is the one that concentrates on the determinants of FDI going to developing countries. For an early survey see Agarwal (1980) and for a more recent work, see Dunning (2002).
possibly restricting capital inflows. Amongst these factors we can mention discretionary tariffs, herding behaviour, unenforceable property rights and lack of a capital-protective legal framework.

Thus we should have two sets of factors to control in order to obtain the conditional effect of human capital on capital flows. In the first set we have those variables that are time-variant and differ across countries; they could well be a proxy for a "market failure" effect or have an "unproductive capital" effect. The second set of factors includes all those time-invariant idiosyncratic effects that account for different potential capital profitability (e.g. geographical, distance and size effects) across countries; this will be a proxy for most "unproductive capital" differences across countries. In terms of econometric methodology, these time-invariant idiosyncratic characteristics blend into a time-invariant unobserved effect, the existence of which implies the use of an unobserved-components model for the estimation of our conditional relationship (Wooldridge, 2002, p 248). This procedure will allow us to focus on the common thread of this dissertation: the direct link connecting human capital and physical capital accumulation processes across countries. As we are primarily concerned with obtaining a precise estimate of the influence of human capital on capital inflows, it is not our purpose here to find other significant relationships involving different variables. We detail now the different
variables for the set of controls used at different stages of the econometric procedure.\textsuperscript{30}

It is particularly difficult to construct indicators of the quality of institutions and the degree of market failures. One of the most common indexes used in the empirical literature to control for the risk of expropriation and political instability affecting foreign capital are the indexes of civil liberties and political rights from the Freedom House Survey. Considering that these measures could be a proxy for the riskiness of investment and the standard of rule-of-law in a country, a positive estimate would mean that a higher-profitability effect associated with large risk is dominant over a negative risk-aversion effect (in a simple mean variance framework). A negative estimate would show that political risk or lack of property-rights protection is effectively deterring inflows, despite higher expected profitability.\textsuperscript{31}

An indicator of openness in trade measures the level of exposure to foreign competition. In our view, this could also be an indicator of the degree to which the economy is open to receive capital inflows (in many cases complementary to trade) as the pattern of openness of the capital account usually follows closely the degree of

\textsuperscript{30} We also considered other alternative variables mentioned in the theoretical literature, which are not reported in our final regressions as they did not offer significant results or affect our main findings. Amongst those are: indicators of relative development, which are constructed using a ratio of the GDP of each country with respect to the GDP of the United States and dependency ratios for the young and the old.

\textsuperscript{31} Bilson et al. (2002) have found that political risk is important in explaining return variation in individual emerging markets but not in developed markets, and that there is a positive relation between political risk and ex-post return in emerging markets at the aggregate level. This does not necessarily mean a deterrent effect on capital inflows, as the final result will depend on the degree of risk aversion of investors and alternative investments available. Wei (2000) shows that bilateral FDI
openness of the trade account.\textsuperscript{32} Lane (2003, p.4) refers to this measure as a proxy for the degree of creditworthiness of the economy, since "...the more open is an economy, the more costly is the loss of opportunities to engage in international trade; the more open is an economy, the easier is it to disrupt trade and seize tradable goods and assets from the offending country".\textsuperscript{33} In both interpretations of this variable, we would expect to obtain a positive estimated coefficient.

A set of macroeconomic variables is tested in order to control for the dynamics of the recipient economy. Lack of dynamism of the economy would signal lower potential profitability and creditworthiness to prospective investors. We expect countries with sustained economic growth and lower macroeconomic volatility to attract higher inflows. We use real GDP growth rate as a measure of dynamics. As a proxy for macroeconomic volatility, we use the annual inflation rate of the economy.

3 Data and empirical framework

The benchmark sample covers the period 1976-2000 and includes 60 countries, of which 21 are classified as industrialised economies and 39 as developing\textsuperscript{34}. The inclusion criterion was determined by information availability, capital inflows being the more stringent restriction. Nevertheless, only three countries of those that have inflows are significantly related to a corruption measure. Globerman and Shapiro (2002) find a positive effect of legal and competition framework on FDI for developing and transition economies.\textsuperscript{32} Lane (2001) offers a theoretical growth model in which traded goods serve as collateral for international borrowing, traces out the evolution of output and debt during the convergence process and reports a positive empirical relation between net capital flows and trade openness.\textsuperscript{33} This follows the argument of Bulow and Rogoff (1989) regarding sovereign debt.
complete information for capital inflows are not included in the set of human capital
information. We are reasonably confident that those countries included in the
sample account for the largest part of the total amount of capital inflows during the
period of study. The most important omission would be that of post-communist
transition countries, including China. Apart from the case of China, we do not expect
this to be a large omission, since for these cases we would only be able to observe
capital flows for recent years.

As our interest is in medium-term rather than short-term relationships and to
avoid potentially significant measurement errors common in annual data for
developing countries, we construct a panel dataset over non-overlapping five-year
periods. Starting with 25 annual observations for each particular country over the
period 1976-2000, we obtain five observations as five-year averages of each
variable. Due to data availability, we measure the stock of human capital at the end
of each 5-year period rather than as an average over the period. This procedure
applies a filter to the yearly observations, allowing us to capture the desired long-
term relationship and to smooth-out idiosyncratic variations in the annual data. Our
panel data is balanced, which allows us to use the full set of tools available for
estimation and inference for panel-data procedures and unobserved component
models (Greene, 2000). It is also important to mention that all of our variables are

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34 See Appendix 1 for the countries included in each of the groups.
35 These are the cases of Morocco, Côte d'Ivoire and Oman, which are not included in the Barro-Lee
(2001) dataset.
time-changing ones. This is useful as it implies that, in those exercises in which we estimate unobserved effects, we do not have to omit known explanatory variables.

We detail now the different sets of variables that are included in our exercise and compare them with other datasets previously used in related literature.

3.1 Capital inflows data

We detail here the main dependent variable together with its decomposition. We apply a concept of foreign capital inflows that includes foreign direct investment inflows (FDI) and portfolio inflows (FPI). This distinction is useful for identifying the differential effect of human capital on each type of capital inflow that, in turn, has distinct effects on the recipient economies.38

We construct the series of FDI and FPI for each of the countries included in our sample, based on the data included in the balance of payments statistics as registered by the IMF’s International Financial Statistics. We complement this data with other sources in order to fill the missing observations in the IMF data.39

37 This methodological practice is already common for empirical studies using economic panel datasets; see e.g. Blanchard and Wolfers (2000), Phelps and Zoega (2001), Mody et al. (2003), Chinn and Prasad (2003).
38 Bosworth and Collins (1999) and Razin (2002) provide evidence that FDI inflows have a larger impact on domestic investment than portfolio inflows, in the case of developing countries. Razin and Sadka (2002) show that, in certain conditions on the production function, the size of the aggregate stock of capital is larger in FDI than in the case of portfolio equity inflows.
39 See Appendix 2 for a complete description of the other sources.
The IMF's balance of payments statistics distinguish four types of capital inflows: FDI, portfolio investment, financial derivatives and other investment. As financial derivatives and other investment (primarily bank loans) are financial transactions not linked with capital investment transfers, we exclude them from our analysis. Our measure of capital inflows (TCI) is equal then to the sum of FDI and FPI. FDI inflows represent the flows of direct investment capital into the respective countries. Direct investment, as defined by the IMF, includes equity capital, reinvested earnings, other capital, and certain kinds of financial derivatives, and excludes certain types of "exceptional financing" such as debt-for-equity swaps. FPI includes transactions with no residents in financial securities of any maturity, such as corporate securities, bonds, notes and money-market instruments different from those included in FDI, exceptional financing and reserve assets.

We calculate these three (FCI, FDI and FPI) series as a ratio with respect to the Gross Domestic Product. A negative value for each of these variables represents an outflow of the specific type of physical capital from each respective country.

The resulting panel data of capital inflows has several advantages over data used in previous literature. In the first place, it properly measures the two main components of capital inflows, portfolio and direct investment inflows. It includes data up to the year 2000, thus providing an ample sample of industrial and developing countries (60 in total). Capital inflows have been measured in other studies as bilateral flows, financial short-term transactions or by means of proxy
variables. Here, in contrast, we present and use up-to-date data that include direct measures of inflows for a multiplicity of countries over a long time-span.

3.2 Human capital data

The most widely accepted measures of human capital are based on education standards and show strong correlation with social and economic outcomes. Education is also highly correlated with other dimensions of human capital stock like health and political participation. According to Barro and Lee (2001), "An abundance of well-educated human resources also helps to facilitate the absorption of advanced technologies for developed countries. In addition, the level and distribution of education attainment has a strong impact on social outcomes, such as child mortality, fertility, education of children and income distribution." (p.541) Of course, education is not only relevant in terms of improving productive conditions, but we will not refer to these connections here.

Several authors employ basic educational measures as proxy variables for overall human capital. The indicators most commonly used are school enrolment ratios or adult literacy rates. School enrolment ratios represent investment levels in

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40 For example, Chuhan et al. (1998) use bilateral data of US equity and bond flows to developing countries for 1988-1992; Calvo et al. (1993) use data on changes in international reserves to proxy capital inflows to developing countries; Noorbakhsh et al. (2001) restrict themselves to FDI for developing countries for 1980-1994.

41 Some authors argue that special attention should be given to health when human capital is analysed: see e.g. Mushkin (1962), Knowles and Owen (1995), McDonald and Roberts (2002).

42 For example, Mankiw et al. (1992) use the percentage of the working age population that is in secondary school.
human capital but are a poor proxy for investment in human capital, as they do not take into account completion rates or attrition in the educational system. Literacy is a stock variable, but its use as a proxy for human capital has empirical problems due, firstly, to the large variations in the quality of measurement across countries and, secondly, to the fact that literacy rate has an upper bound which could be attained quite rapidly and has, indeed, been attained by most industrial countries. Note that more accurate measures of human capital stock, like international comparable test scores of educational achievement or the International Adult Literacy Survey (IALS), are still in the early stages and cover a reduced sample of mostly industrial countries\(^4\).

We use the most recent update of the stock of human capital as educational attainment, as estimated by Barro and Lee (2001). In our view, this is not only the most complete and up-to-date measure of human capital, but also the most precise estimate available. In particular, we use the average number of years of schooling of the population aged 25 and over, as this variable measures directly the education stock embodied in the adult population. This dataset provides complete information for 107 countries at five-year intervals from 1960 to 2000.

The Barro and Lee dataset has several advantages that make it the preferred choice for practitioners of empirical economic literature (see, amongst others, Hall and Jones (1999), Barro (1999), Islam (1995) and Sachs and Warner (1995)). Firstly, the fact that it is the result of a stock calculation provides a precise measure of the

\(^{43}\) For a discussion regarding these indicators, see Barro and Lee (2001).
actual level of education of the population available for productive purposes. Secondly, it includes updated data with high periodicity for a large number of countries during a long period, making it valuable for panel data studies like the one we attempt here. Thirdly, the fact that the stock is calculated using the same type of source data for all countries makes its methodology uniform and thus allows cross-country comparability.

The level of educational attainment is calculated by means of the method of perpetual inventory using census or survey information on educational attainment as a benchmark, and gross enrolment rates, adjusted for repeaters, as flows that are added to stocks at different periods in time. The average number of years of schooling are calculated taking into account the changes in school duration over time within each country.\textsuperscript{44}

Early attempts to calculate educational attainment for a group of countries are those by Psacharopoulos and Ariagada (1986), using census information, and Lau et al. (1991) and Nehru et al. (1995), using school enrolment rates. The first one has only one observation per country in most cases, while the other two suffer from potentially large measurement errors. In all three cases the datasets have not been updated.

Recently, the OECD compiled educational statistics for the population aged 15 to 64 for a sample of 32 OECD member and non-member countries starting in the

\textsuperscript{44} The data set we use here (Barro and Lee, 2001) includes all these methodological characteristics, while previous versions of the dataset (Barro and Lee, 1993 and Barro and Lee, 1996) do not.
1990s. This sample has been used to construct two new datasets. Cohen and Soto (2001) put together a database for 95 industrial and developing countries for each decade, starting in 1960 and continuing until 2000, using data from the OECD education database combined with national censuses, school enrolment rates and surveys from UNESCO and national statistics agencies’ web pages. In turn, De la Fuente and Doménech (2002) constructed a dataset on educational attainment for a sample of 21 OECD countries using all the census and survey information available for each country from international or national sources, without making use of flow estimates (school enrolment rates). This database is available for the period 1960 to 1995 at five-year intervals and covers only the industrial country members of the OECD. The fact that these two databases use multiple sources implies that they can be subject to inconsistencies. They also have limited cross-country coverage and few time-data points.

3.3 Other explanatory variables

We referred in section 2 to the different theoretical underpinnings of including control variables for our empirical set-up. We now mention here the data used to capture each one of these effects. A detailed table presenting the source of each variable and its definitions is in Appendix 1.
We include Freedom House indexes of civil liberties and political rights as proxy variables for property rights protection and political risk. The Freedom House survey provides an annual evaluation of political rights and civil liberties according to a single standard throughout the world. The index of political rights measures the capacity of people to participate freely in the political process; this represents the right of all adults to vote and compete for public office, and for elected representatives to have a decisive vote on public policies. Civil liberties include the freedom to develop views, institutions and personal autonomy apart from the state. Both series are measured on a one-to-seven scale, with one representing the highest level of political rights or civil liberties and seven, the lowest.

The indicator of openness in trade is a measure of the sum of exports and imports as a ratio of the GDP of the country. We also use real GDP growth rate as a measure of the dynamics of the economy.\(^{45}\) As a proxy for macroeconomic volatility we used the annual inflation rate of the economy.\(^ {46}\) Finally, we use sets of dummy variables for African countries, Latin American countries, oil-exporting countries and time dummies.

\(^{45}\) To capture the dynamics of the economy, we alternatively use the rates of growth of GDP per capita, population growth, and labour force growth, without obtaining significantly different results. We also construct a panel of real deposit interest rate in order to capture the effect of interest rate differentials across countries without results varying significantly.

\(^{46}\) Inflation rate is measured as the change in the logarithm of the consumer price index.
3.4 Variance decomposition

We turn now to the analysis of the panel dataset. Table 1 presents a variance decomposition for the data that indicates how much of the variation in the variables is attributable to variation across countries and over time. Certain variables, such as FCI, FDI, FPI and inflation, vary substantially across countries and within each country, over time. In contrast, other variables, including human capital and the openness indicator, vary markedly across countries but are relatively more stable over time within countries. There are some differences in the contribution across countries and -within countries- over time for the industrial and developing country samples, but the relative importance of these two effects for the total variation in each variable is quite similar across samples, except for the index of political rights. This index shows a larger variation across countries for developing nations in contrast with a larger variation over time for the subset of industrial countries. The main result to be taken from this table is that many of the dependent and independent variables of this study vary quite markedly across countries and over time, and that provides validity for the empirical exercise presented here.
### Table 1
Variance decomposition into cross-section and time-series components (in percentage terms)

<table>
<thead>
<tr>
<th></th>
<th>Industrial countries</th>
<th></th>
<th>Developing countries</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Across Countries</td>
<td>Over time</td>
<td>Across Countries</td>
<td>Over time</td>
</tr>
<tr>
<td>Capital inflows</td>
<td>20,93</td>
<td>79,07</td>
<td>39,93</td>
<td>60,07</td>
</tr>
<tr>
<td>to GDP ratio (FCI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign direct investment inflows to GDP ratio (FDI)</td>
<td>22,28</td>
<td>77,72</td>
<td>47,31</td>
<td>52,69</td>
</tr>
<tr>
<td>Portfolio inflows to GDP ratio (FPI)</td>
<td>21,12</td>
<td>78,88</td>
<td>25,98</td>
<td>74,02</td>
</tr>
<tr>
<td>Human capital</td>
<td>89,40</td>
<td>10,60</td>
<td>82,66</td>
<td>17,34</td>
</tr>
<tr>
<td>GDP growth</td>
<td>28,51</td>
<td>71,49</td>
<td>39,62</td>
<td>60,38</td>
</tr>
<tr>
<td>Openness indicator</td>
<td>94,50</td>
<td>5,50</td>
<td>95,91</td>
<td>4,09</td>
</tr>
<tr>
<td>Political rights</td>
<td>28,70</td>
<td>71,30</td>
<td>67,63</td>
<td>32,37</td>
</tr>
<tr>
<td>Inflation</td>
<td>41,47</td>
<td>58,53</td>
<td>25,35</td>
<td>74,65</td>
</tr>
</tbody>
</table>

Notes: This table shows the proportion of the total variance (of five-year non-overlapping averages) of each variable that is attributable to variation across countries and over time respectively.

## 4 Cross-section and pooled specifications

The first step of our empirical analysis is to examine the results from the cross-section ordinary least squares (OLS) regressions using the full-sample 25-year averages of the dependent and independent variables for each country. The table shows White’s Heteroscedasticity Consistent standard errors. As expected in this type of applications, a range of tests indicated heteroscedastic disturbances.
shows the results for each one of the three dependent variables: FCI, FDI and FPI. The first column of the table shows the results for the benchmark sample including 60 countries, while the remaining columns show the results of the regressions run separately for the sub-samples of industrial and developing countries. Since many of our results are sensitive to the inclusion of the African countries, we report independent results for the samples excluding these countries. Apart from the human capital stock measure, we include a set of control variables comprising the rate of growth of GDP, an indicator of openness in trade, an index of political rights and changes in the consumer price index. This same set of variables would be maintained throughout the whole exercise.

We find that human capital is significant and positively related to FCI for the full sample and the sample excluding Africa. Also, in the case of FPI, human capital is significant and positive. These are interesting results since, as we will see in the next sections, they point to the robustness of the human capital effect in driving flows. Yet, since the variation in capital inflows is large over time (within countries)

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48 Notice that as FCI is the arithmetical sum of FDI and FPI, the coefficient results for FCI are the arithmetical sum of the other two.
49 This is a fairly common finding in empirical applications (for the African experience see, for example, Easterly and Levine (1997) and Sachs and Warner (1997)). The countries excluded are sub-Saharan countries: Botswana, Kenya, Mauritius, Senegal, South Africa, Swaziland and Togo. There were no significant differences if we excluded the Latin American or Asian countries from the benchmark sample or from the sample of developing countries.
50 In some cases we had two or more candidate variables to serve as a proxy for the same effect. This was the case of political rights and civil liberties indicators. We keep the one that performed better in the preferred specification and did not create significant changes in other specifications. This was also the case for indicators of the dynamics of the economy in which GDP growth rate performed better than labour force growth, population growth or GDP per capita growth. We have excluded from our analysis the indicators of relative development and demography, since both variables were insignificant in all our specifications.
it is necessary to explore the panel in detail, as we are losing a large amount of information here.
Table 2
Cross-section regressions

<table>
<thead>
<tr>
<th></th>
<th>Full sample</th>
<th>Full sample, excluding Africa</th>
<th>Industrial countries</th>
<th>Developing countries</th>
<th>Developing countries, excluding Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependent variable: capital inflows to GDP ratio (FCI)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human Capital</td>
<td>0.236 *</td>
<td>0.174 *</td>
<td>-0.019</td>
<td>0.101</td>
<td>0.043</td>
</tr>
<tr>
<td></td>
<td>(0.092)</td>
<td>(0.095)</td>
<td>(0.228)</td>
<td>(0.083)</td>
<td>(0.094)</td>
</tr>
<tr>
<td>GDP growth</td>
<td>-0.142</td>
<td>-0.028</td>
<td>0.664</td>
<td>0.087</td>
<td>0.098</td>
</tr>
<tr>
<td></td>
<td>(0.251)</td>
<td>(0.371)</td>
<td>(0.636)</td>
<td>(0.080)</td>
<td>(0.098)</td>
</tr>
<tr>
<td>Openness indicator</td>
<td>0.030 *</td>
<td>0.030 *</td>
<td>0.115 *</td>
<td>0.018 *</td>
<td>0.019 *</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
<td>(0.012)</td>
<td>(0.040)</td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Political rights</td>
<td>-0.401</td>
<td>-0.604 *</td>
<td>1.052</td>
<td>0.126</td>
<td>0.067</td>
</tr>
<tr>
<td></td>
<td>(0.248)</td>
<td>(0.355)</td>
<td>(1.913)</td>
<td>(0.125)</td>
<td>(0.128)</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.002 *</td>
<td>0.002 *</td>
<td>-0.173 *</td>
<td>0.003 *</td>
<td>0.003 *</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.064)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.345</td>
<td>0.346</td>
<td>0.720</td>
<td>0.655</td>
<td>0.674</td>
</tr>
<tr>
<td><strong>Dependent variable: foreign direct investment inflows to GDP ratio (FDI)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human Capital</td>
<td>0.081</td>
<td>0.064</td>
<td>0.177</td>
<td>-0.029</td>
<td>-0.068</td>
</tr>
<tr>
<td></td>
<td>(0.059)</td>
<td>(0.057)</td>
<td>(0.148)</td>
<td>(0.089)</td>
<td>(0.097)</td>
</tr>
<tr>
<td>GDP growth</td>
<td>-0.040</td>
<td>-0.098</td>
<td>-0.528</td>
<td>0.106</td>
<td>0.071</td>
</tr>
<tr>
<td></td>
<td>(0.113)</td>
<td>(0.140)</td>
<td>(0.314)</td>
<td>(0.067)</td>
<td>(0.089)</td>
</tr>
<tr>
<td>Openness indicator</td>
<td>0.023 *</td>
<td>0.024 *</td>
<td>0.054</td>
<td>0.020 *</td>
<td>0.020 *</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.005)</td>
<td>(0.019)</td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Political rights</td>
<td>-0.016</td>
<td>0.015</td>
<td>1.297</td>
<td>0.080</td>
<td>0.070</td>
</tr>
<tr>
<td></td>
<td>(0.113)</td>
<td>(0.111)</td>
<td>(1.715)</td>
<td>(0.111)</td>
<td>(0.133)</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.002 *</td>
<td>0.002 *</td>
<td>-0.033</td>
<td>0.003 *</td>
<td>0.003 *</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.001)</td>
<td>(0.044)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.535</td>
<td>0.537</td>
<td>0.643</td>
<td>0.742</td>
<td>0.763</td>
</tr>
<tr>
<td><strong>Dependent variable: portfolio inflows to GDP ratio (FPI)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human Capital</td>
<td>0.155 *</td>
<td>0.110</td>
<td>-0.196</td>
<td>0.130 *</td>
<td>0.111 *</td>
</tr>
<tr>
<td></td>
<td>(0.073)</td>
<td>(0.085)</td>
<td>(0.188)</td>
<td>(0.045)</td>
<td>(0.050)</td>
</tr>
<tr>
<td>GDP growth</td>
<td>-0.102</td>
<td>0.069</td>
<td>1.192 *</td>
<td>-0.019</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td>(0.172)</td>
<td>(0.278)</td>
<td>(0.381)</td>
<td>(0.052)</td>
<td>(0.070)</td>
</tr>
<tr>
<td>Openness indicator</td>
<td>0.007</td>
<td>0.006</td>
<td>0.061</td>
<td>-0.001</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.007)</td>
<td>(0.021)</td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Political rights</td>
<td>-0.384 *</td>
<td>-0.619 *</td>
<td>-0.246</td>
<td>0.046</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.188)</td>
<td>(0.319)</td>
<td>(1.149)</td>
<td>(0.065)</td>
<td>(0.091)</td>
</tr>
<tr>
<td>Inflation</td>
<td>-0.001</td>
<td>0.0001</td>
<td>-0.141 *</td>
<td>0.0001</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.034)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.248</td>
<td>0.255</td>
<td>0.758</td>
<td>0.128</td>
<td>0.096</td>
</tr>
<tr>
<td><strong>Number of observations</strong></td>
<td>60</td>
<td>53</td>
<td>21</td>
<td>39</td>
<td>32</td>
</tr>
</tbody>
</table>

Notes: The dependent and independent variables are the full sample averages of the corresponding five-year variables for each country. Heteroscedasticity-consistent standard errors and probability values are reported in parentheses, in that order, below the estimated coefficient. The symbol * indicates statistical significance at least at 10 per cent level or a P-value of less than 0.1.
In Table 3 we present the results using the entire panel of data, without taking crude averages of the variables. This allows us to characterise higher frequency variations in capital flows. In section 5 we test the robustness of our results by this compression of the data and by the choice of empirical specification to obtain our preferred specification. As mentioned earlier, the panel contains non-overlapping five-year averages of the variables for each country, except for human capital that is a stock which is taken every five years. The right-hand side variables are the same as in Table 2. The method of estimation is OLS regression applied to the pool of the data. As in the previous case, we include five columns, presenting the results for the benchmark sample, for industrial countries, for developing countries and for the last two categories excluding Africa.

The main result here, which carries over from the cross-section results, is the significance of human capital. This result appears to be relatively robust not only for the benchmark sample, but also across country groupings and for almost all types of capital flows (except for FCI in industrial countries). We observe, though, that the parameter estimates for human capital change from the cross-section estimates to the pooled ones, but this is not surprising, given the large compression of information in the former.

Using these pooled OLS estimates requires the assumption that the error term is uncorrelated with the set of explanatory variables, otherwise we would be

---

51 In the benchmark sample we included dummy variables for Latin American countries, African countries and oil-exporting countries with no significant result.
obtaining biased and inconsistent estimates. In this case the potential inconsistency arises from an omitted variable bias or "heterogeneity bias". The omission of a time-invariant unobserved effect (the existence of which we confidently establish in the following section) renders the pooled OLS estimates biased and inconsistent, as it is likely that the set of explanatory variables appears to be correlated with the unobserved effect (see Wooldridge, 2002, p.249). A Ramsey Reset test that was performed on the benchmark sample supports this fact. In order to solve this inconsistency problem and exploit the richness of the panel, we turn now to the estimation of models including an unobserved component.

---

52 Many empirical applications assume this rather implausible assumption of uncorrelatedness of the explanatory variables and the error term, and present inconsistent estimates due to data restrictions i.e. there are not enough time-variant explanatory variables or other data available that allow the use of alternative specifications. Another rationale for the use of pooled-OLS estimates has been the particular interest of the researcher in a cross-country variation of a given estimate. Quah (1995), Lane (2001) and Chinn and Prasad (2003) all use pooled-OLS estimates on these grounds. Noorbakhsh, et al. (2001) prefer pooled-OLS estimates after asserting that estimates with Least Squares Dummy Variable regression were "poor".
<table>
<thead>
<tr>
<th>Dependent variable: capital inflows to GDP ratio (FCI)</th>
<th>Full sample</th>
<th>Full sample, excluding Africa</th>
<th>Industrial countries</th>
<th>Developing countries</th>
<th>Developing countries, excluding Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Capital</td>
<td>0.380 *</td>
<td>0.247 *</td>
<td>0.272</td>
<td>0.187 *</td>
<td>0.171 *</td>
</tr>
<tr>
<td></td>
<td>(0.090)</td>
<td>(0.087)</td>
<td>(0.209)</td>
<td>(0.082)</td>
<td>(0.090)</td>
</tr>
<tr>
<td>GDP growth</td>
<td>0.144</td>
<td>0.176</td>
<td>1.341</td>
<td>0.062</td>
<td>0.033</td>
</tr>
<tr>
<td></td>
<td>(0.167)</td>
<td>(0.210)</td>
<td>(0.885)</td>
<td>(0.049)</td>
<td>(0.056)</td>
</tr>
<tr>
<td>Openness indicator</td>
<td>0.029 *</td>
<td>0.030 *</td>
<td>0.141 *</td>
<td>0.017 *</td>
<td>0.017 *</td>
</tr>
<tr>
<td></td>
<td>(0.009)</td>
<td>(0.010)</td>
<td>(0.067)</td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Political rights</td>
<td>-0.395 *</td>
<td>-0.533 *</td>
<td>0.876</td>
<td>-0.104</td>
<td>-0.147</td>
</tr>
<tr>
<td></td>
<td>(0.173)</td>
<td>(0.232)</td>
<td>(1.466)</td>
<td>(0.098)</td>
<td>(0.118)</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.0001</td>
<td>0.0002</td>
<td>-0.238 *</td>
<td>-0.0001</td>
<td>-0.0002</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.078)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.135</td>
<td>0.134</td>
<td>0.331</td>
<td>0.275</td>
<td>0.284</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent variable: foreign direct investment inflows to GDP ratio (FDI)</th>
<th>Full sample</th>
<th>Full sample, excluding Africa</th>
<th>Industrial countries</th>
<th>Developing countries</th>
<th>Developing countries, excluding Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Capital</td>
<td>0.131 *</td>
<td>0.117 *</td>
<td>0.265 *</td>
<td>0.072</td>
<td>0.074</td>
</tr>
<tr>
<td></td>
<td>(0.049)</td>
<td>(0.051)</td>
<td>(0.094)</td>
<td>(0.070)</td>
<td>(0.078)</td>
</tr>
<tr>
<td>GDP growth</td>
<td>0.060</td>
<td>0.033</td>
<td>0.256</td>
<td>0.045</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>(0.053)</td>
<td>(0.060)</td>
<td>(0.172)</td>
<td>(0.042)</td>
<td>(0.046)</td>
</tr>
<tr>
<td>Openness ratio</td>
<td>0.023 *</td>
<td>0.023 *</td>
<td>0.060 *</td>
<td>0.018 *</td>
<td>0.018 *</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.032)</td>
<td>(0.002)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Political rights</td>
<td>-0.059</td>
<td>-0.081</td>
<td>0.753</td>
<td>-0.050</td>
<td>-0.080</td>
</tr>
<tr>
<td></td>
<td>(0.089)</td>
<td>(0.104)</td>
<td>(0.673)</td>
<td>(0.083)</td>
<td>(0.101)</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.0002</td>
<td>0.0001</td>
<td>-0.068 *</td>
<td>0.00004</td>
<td>-0.0001</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.031)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.198</td>
<td>0.190</td>
<td>0.248</td>
<td>0.338</td>
<td>0.341</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent variable: portfolio inflows to GDP ratio (FPI)</th>
<th>Full sample</th>
<th>Full sample, excluding Africa</th>
<th>Industrial countries</th>
<th>Developing countries</th>
<th>Developing countries, excluding Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Capital</td>
<td>0.249 *</td>
<td>0.229 *</td>
<td>0.007</td>
<td>0.115 *</td>
<td>0.096 *</td>
</tr>
<tr>
<td></td>
<td>(0.065)</td>
<td>(0.061)</td>
<td>(0.166)</td>
<td>(0.042)</td>
<td>(0.046)</td>
</tr>
<tr>
<td>GDP growth</td>
<td>0.064</td>
<td>0.143</td>
<td>0.085</td>
<td>0.017</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>(0.131)</td>
<td>(0.167)</td>
<td>(0.763)</td>
<td>(0.029)</td>
<td>(0.035)</td>
</tr>
<tr>
<td>Openness ratio</td>
<td>-0.536</td>
<td>-0.451 *</td>
<td>0.123</td>
<td>-0.054</td>
<td>-0.067</td>
</tr>
<tr>
<td></td>
<td>(0.521)</td>
<td>(0.392)</td>
<td>(0.158)</td>
<td>(0.541)</td>
<td>(0.359)</td>
</tr>
<tr>
<td>Political rights</td>
<td>-0.007</td>
<td>-0.007</td>
<td>0.080 *</td>
<td>-0.002</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.006)</td>
<td>(0.037)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.005</td>
<td>0.005</td>
<td>-0.170 *</td>
<td>-0.0001</td>
<td>-0.0001</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.051)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.095</td>
<td>0.095</td>
<td>0.347</td>
<td>0.051</td>
<td>0.038</td>
</tr>
</tbody>
</table>

Number of observations | 300 | 265 | 105 | 195 | 160

Notes: Pooled OLS regressions. Heteroscedasticity-consistent standard errors and probability values are reported in parentheses, in that order, below the estimated coefficient. The symbol * indicates statistical significance at least at the 10 per cent level or a $p$-value of less than 0.1.
5 Fixed-effect panel estimates

The nature of our panel data and the question we are pursuing here indicate that there is an important distinctive time-constant unobserved effect across countries. As we briefly mentioned in section 2, a series of unobserved country-specific "third factors" can be instrumental in explaining a reduced potential profitability and how this could affect, positively or negatively, the inflow of foreign capital. It is not only that these unobserved effects have been stressed by theory, but also that these are country-specific and have a constant partial effect over time. To be specific, some of these unobserved or difficult-to-measure characteristics (like geography, the degree of social cohesion, the legal and institutional frameworks) are structural as they are roughly constant over time and are country defined. The use of panel data allows us to find the common effect that the main one of these "third factors", namely human capital stock, has on driving physical capital inflows, after considering the structural unobserved effects for each country.

These time-invariant idiosyncratic characteristics blend into a time-invariant unobserved effect, the existence of which implies the use of an unobserved components model for the estimation of our conditional relationship (Wooldridge, 2002, p 248). As we have emphasized before, the cross-section and pooled estimates just presented are likely to suffer from omitted variable problems leading to inconsistent results. This fact alone calls for an improvement in the estimation procedure to take into account possible omitted variables. We thus proceed to apply random-effects and fixed-effects methods of estimation to the panel data. As in the
previous section, the dependent variable is capital inflows (FDI or FPI or its sum FCI) and the explanatory variables are human capital and a set of control-explanatory variables. These include GDP growth rate, the openness indicator, an index of political rights and the inflation rate.53

We first test for the presence of unobserved effects by means of a specification test. As expected, in every sub-sample and for each type of capital inflow (FCI, FDI, and FPI) we confidently reject the non-existence of unobserved effects, in line with the test results of section 4 showing the existence of an omitted variable problem.

Assured of the need to include unobserved effects, we test for the nature of the unobserved component term by means of the Hausman test for fixed or random effects based on the difference between the two estimates. Choosing between the two types of estimation rests on whether or not the explanatory variables are correlated with the unobserved component.54 As expected, we reject with a per cent of confidence the test of a random-effects model in favour of a fixed-effects specification in almost every sub-sample and for each type of capital inflows (see Table 4).55

53 For a detailed description of each variable, please refer to section 3. These variables were the ones that performed better in those cases in which there were alternatives across the different types of controls. In addition, we tested a set of time-specific dummy variables without them being significant.
54 A rejection of the random-effects estimation means not only that random-effects estimates would be inconsistent, but also that the pooled OLS estimates previously presented would be inconsistent as well.
55 For the FPI in the developing countries sample and developing countries excluding Africa, we could not reject the null hypothesis that the random-effects specification is the appropriate one. In both cases the random-effects model was also estimated. We show the fixed-effects estimates of these two cases in Table 4 to maintain consistency in the presentation and also report the two random-effects estimations in Appendix 3.
Table 4
Panel regressions, fixed-effects specification

<table>
<thead>
<tr>
<th>Dependent variable: capital inflows to GDP ratio (FCI)</th>
<th>Full sample</th>
<th>Full sample, excluding Africa</th>
<th>Industrial countries</th>
<th>Developing countries</th>
<th>Developing countries, excluding Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Capital</td>
<td>1.328 *</td>
<td>1.459 *</td>
<td>2.303 *</td>
<td>0.581 *</td>
<td>0.715 *</td>
</tr>
<tr>
<td></td>
<td>(0.245)</td>
<td>(0.257)</td>
<td>(0.635)</td>
<td>(0.142)</td>
<td>(0.148)</td>
</tr>
<tr>
<td>GDP growth</td>
<td>0.350 *</td>
<td>0.321 *</td>
<td>0.836 *</td>
<td>0.040 *</td>
<td>0.016 *</td>
</tr>
<tr>
<td></td>
<td>(0.146)</td>
<td>(0.167)</td>
<td>(0.476)</td>
<td>(0.047)</td>
<td>(0.049)</td>
</tr>
<tr>
<td>Openness indicator</td>
<td>0.104 *</td>
<td>0.110 *</td>
<td>0.625 *</td>
<td>0.017 *</td>
<td>0.011 *</td>
</tr>
<tr>
<td></td>
<td>(0.025)</td>
<td>(0.056)</td>
<td>(0.065)</td>
<td>(0.103)</td>
<td>(0.705)</td>
</tr>
<tr>
<td>Political rights</td>
<td>-0.322</td>
<td>-0.247</td>
<td>3.064 *</td>
<td>-0.526 *</td>
<td>-0.458 *</td>
</tr>
<tr>
<td></td>
<td>(0.208)</td>
<td>(0.217)</td>
<td>(1.512)</td>
<td>(0.161)</td>
<td>(0.168)</td>
</tr>
<tr>
<td>Inflation</td>
<td>-0.0003</td>
<td>-0.0002</td>
<td>-0.078</td>
<td>-0.001 *</td>
<td>-0.001 *</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.000)</td>
<td>(0.060)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.361</td>
<td>0.358</td>
<td>0.553</td>
<td>0.544</td>
<td>0.557</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent variable: foreign direct investment inflows to GDP ratio (FDI)</th>
<th>Full sample</th>
<th>Full sample, excluding Africa</th>
<th>Industrial countries</th>
<th>Developing countries</th>
<th>Developing countries, excluding Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Capital</td>
<td>0.691 *</td>
<td>0.837 *</td>
<td>1.141 *</td>
<td>0.472 *</td>
<td>0.674 *</td>
</tr>
<tr>
<td></td>
<td>(0.134)</td>
<td>(0.141)</td>
<td>(0.254)</td>
<td>(0.128)</td>
<td>(0.136)</td>
</tr>
<tr>
<td>GDP growth</td>
<td>0.128 *</td>
<td>0.098 *</td>
<td>0.303 *</td>
<td>0.044</td>
<td>-0.007</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td>(0.048)</td>
<td>(0.173)</td>
<td>(0.038)</td>
<td>(0.039)</td>
</tr>
<tr>
<td>Openness ratio</td>
<td>0.050 *</td>
<td>0.049 *</td>
<td>0.234 *</td>
<td>0.020 *</td>
<td>0.013 *</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.019)</td>
<td>(0.090)</td>
<td>(0.007)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>Political rights</td>
<td>-0.207</td>
<td>-0.213</td>
<td>1.316 *</td>
<td>-0.290 *</td>
<td>-0.295 *</td>
</tr>
<tr>
<td></td>
<td>(0.142)</td>
<td>(0.154)</td>
<td>(0.631)</td>
<td>(0.141)</td>
<td>(0.152)</td>
</tr>
<tr>
<td>Inflation</td>
<td>-0.0005</td>
<td>-0.0001</td>
<td>-0.006</td>
<td>-0.001 *</td>
<td>-0.001 *</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.022)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.403</td>
<td>0.401</td>
<td>0.473</td>
<td>0.576</td>
<td>0.601</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dependent variable: portfolio inflows to GDP ratio (FPI)</th>
<th>Full sample</th>
<th>Full sample, excluding Africa</th>
<th>Industrial countries</th>
<th>Developing countries</th>
<th>Developing countries, excluding Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Capital</td>
<td>0.637 *</td>
<td>0.622 *</td>
<td>1.162 *</td>
<td>0.199</td>
<td>0.041</td>
</tr>
<tr>
<td></td>
<td>(0.159)</td>
<td>(0.164)</td>
<td>(0.478)</td>
<td>(0.078)</td>
<td>(0.041)</td>
</tr>
<tr>
<td>GDP growth</td>
<td>0.202 *</td>
<td>0.223 *</td>
<td>0.584</td>
<td>0.032</td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>(0.116)</td>
<td>(0.133)</td>
<td>(0.375)</td>
<td>(0.030)</td>
<td>(0.034)</td>
</tr>
<tr>
<td>Openness ratio</td>
<td>0.054</td>
<td>0.062</td>
<td>0.391 *</td>
<td>-0.003</td>
<td>-0.002</td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td>(0.038)</td>
<td>(0.133)</td>
<td>(0.006)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>Political rights</td>
<td>-0.115</td>
<td>-0.034</td>
<td>1.748 *</td>
<td>-0.236 *</td>
<td>-0.163 *</td>
</tr>
<tr>
<td></td>
<td>(0.128)</td>
<td>(0.131)</td>
<td>(1.033)</td>
<td>(0.102)</td>
<td>(0.087)</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.0003</td>
<td>0.0003</td>
<td>-0.084 *</td>
<td>-0.0002</td>
<td>-0.0002</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.042)</td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>R squared</td>
<td>0.352</td>
<td>0.350</td>
<td>0.562</td>
<td>0.309</td>
<td>0.290</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.020)</td>
<td>(0.009)</td>
<td>(0.025)</td>
<td>(0.094)</td>
</tr>
</tbody>
</table>

| Number of observations                                   | 300         | 265                            | 105                  | 195                 | 160                                  |

Notes: Heteroscedasticity-consistent standard errors and probability values are reported in parentheses, in that order, below the estimated coefficient. The symbol * indicates statistical significance at least at the 10 per cent level or a P-value of less than 0.1.
For the benchmark full sample, the parameter estimate for capital inflows shows that, on average, one year more of schooling in the labour force leads to a shift of 1.33 percentage points in the ratio of capital inflows over GDP, after controlling for unobserved effects and a set of control variables. In other words, after controlling for economic idiosyncratic differences and other factors influencing capital inflows, we find that across countries and specifications the capital inflows tend to respond positively to changes in human capital, both within countries (across time) and between countries. For the benchmark sample we find that human capital has a similar effect on both FDI and FPI, the parameters estimates being 0.691 and 0.637 points of GDP respectively (for each additional year of schooling of the labour force).

Despite having positive and consistent effects of human capital across samples, we do find that this effect is substantially larger for industrialised countries than for developing ones. The parameter estimate for FCI as a dependent variable reaches 2.303 percentage points of GDP associated with each additional year of schooling in industrial countries, while it only reaches 0.581 percentage points of GDP in developing countries. In the case of FDI we also find a gap between industrial and developing countries, but not as large as in the case of total capital inflows.

As mentioned, we still find a positive and significant human capital effect on inflows across samples for total FCI and FDI. When the dependent variable is FPI, human capital is insignificant for developing countries and developing countries excluding Africa. However, in these two cases the Hausman test favours random-
effects estimation over that for fixed effects. When random-effects estimation is used human capital becomes highly significant for developing countries and significant at the 15 per cent level of the test for developing countries excluding Africa (see Appendix 3).

Regarding the Africa effect we consistently find a variation in parameter estimates after excluding the African countries, which is in line with other empirical applications ranging from growth to current account determinants (Easterly and Levine (1997), Chinn and Prasad (2003), for example). In general, the large differences existing between industrial and developing countries' parameter estimates ease slightly when the African countries are excluded from the sample. This in turn points to lower profitability of human capital investment in African countries compared with other developing nations.  

Regarding our control variables, we find an expected positive and significant effect of the dynamics of the economy, measured by the rate of growth of GDP, except for the sub-sample of developing countries. The openness indicator is significant and positive in determining FDI and FCI across sub-samples, although the parameter estimate is rather small for developing countries. Another interesting result is that the index of political rights, which has the expected negative sign in all three cases for the developing countries and the parameter estimate, is relatively large. The inflation rate appears as significant and with the expected negative sign for developing countries, but its magnitude is almost negligible. It seems that political

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56 We also tried the exclusion of Latin American countries but did not find any significant difference.
instability has a much greater negative effect on conditions for foreign investment than price instability.

6 Robustness tests

After considering the robustness of results across different econometric models and across regional sub samples, in this section we present additional robustness checks. The following results are performed on the full sample of countries.

Inclusion of initial income per capita levels

We initially included the natural logarithm of the per capita GDP level measured at the start of the analysis period in US dollar nominal and purchasing power parity (PPP) terms. In the pooled OLS regression, this variable appeared to be non significant and substantially reduced the significance of our variable of interest, human capital. A similar result was obtained when the natural logarithm of the per capita GDP level in nominal terms at the start of the analysis period was used. This result is not surprising as the two variables, human capital and initial GDP are strongly correlated. Indeed, human capital levels show a significant positive correlation (p-value lower than 0.001%) with the logarithm of the initial GDP level in PPP terms (0.7778) and with the logarithm of the initial per capita GDP level in nominal terms (0.7704). This correlation is robust to the exclusion of outliers: the Spearman rank correlation coefficient for the first one is 0.7783 and for the latter
variable is 0.7942. Figure 1 shows the scatter plot of the logarithm of the initial GDP per capita level in PPP terms and the human capital level for that initial year. A test of the null hypothesis of independence for the two variables is strongly rejected.

We also ran the random effects model estimates introducing the two measures of initial income per capita to capture the effect of including it into the model. As in the previous case (see section 5 above) the Hausman specification test signals the rejection of this model. Nevertheless, we report here the results obtained. Introducing initial income per capita as a dependent variable in the random effects panel data model shows that the variable is not significant and that human capital remains significant, although the parameter value changes slightly (its value increases) and the p-value decreases.
In the fixed effects model it is evidently not possible to include the initial level of income per capita as this variable will be collinear with the fixed effects slopes.

These three results taken together lead us to maintain our preference for the model presented in section 5 above as that results permits the proper assessment of the effect of the time-changing level of human capital on capital inflows after taking into account the "idiosyncratic" effect of each country.

A similar result is found in the case of the FDI: the initial income variable introduced is not significant while the independent variable of interest reduces its significance and presents a slight change in the parameter. In the case of FPI the introduction of the income variable reduces the significance of the variable of interest. We have to be aware that in these two cases, the result of the introduction of this variable in a model which is clearly rejected by the Hausman test as not consistent is done as a robustness exercise and that in all cases the fixed effects model is the one preferred.

**Time dummies**

We introduced a further robustness check by the use of time dummies. In general we found that time dummies were not significant, except for the case of the time dummy correspondent to the year 2000. When this time dummy was introduced alone or as part of a full set of time dummies our variable of interest lost significance and its estimated parameter changed. We interpret this result given the nature of the
econometric model used. Indeed, when an econometric model using fixed effects is used in the presence of time-varying explanatory variables that fluctuate at a constant rate across time, the introduction of those variables will render the parameter estimates for those variables insignificant if time dummies are introduced (see Wooldridge (2002, p.464) and Wooldridge (2003). A similar result obtains when a time trend is introduced in the presence of a variable that has a time-varying structure which displays such a constant-growth dynamics. This is the case of the present exercise, in which the variable of interest, human capital, shows continuous growth in most of the countries studied over the period of interest. Still, it is important to notice that these time dummies or the interaction of those with other explanatory variables appear to be non-significant in the current framework.

**Outliers and further robustness checks.**

We proceed to identify the nature of the distribution of the three dependent variables used in the econometric exercise (FCI, FDI, FPI) in order to test sample variation and outliers. We performed a variety of experiments of which we summarise the main results here.

We tested our favoured model for the full sample of countries in those cases in which capital flows are positive (FCI>0). The estimated coefficient of the level of human capital is now higher (1.39, compared with 1.328 before) and its significance only falls marginally.
When we limit the regression to exclude negative values of FCI and outliers for higher values of FCI (i.e. including only those cases where capital flows are lower than 15% of GDP and positive) the estimated parameter of HK falls to 1.08 from the 1.328 in the preferred model, but remains highly significant.

When performed similar exercises using as the dependent variable foreign direct investment, limiting the sample for those cases in which FDI is positive, we find an increase in the point estimate of the overall effect of human capital (to 0.738 from 0.691). Only when we exclude outliers (limiting the sample to those cases in which foreign direct investment is positive but it does not surpass 10% of GDP) we see the parameter fall (to 0.588 from the reported 0.691), although it remains highly significant.

A surprising result appears when we limit the sample for those cases when portfolio flows (FPI) are positive. The point estimate for the effect of human capital on capital flows increases substantially from 0.637 to 1.004, maintaining a high level of significance. This result, nevertheless, reverses when we include only in the sample those cases of positive portfolio flows but lower than 8% of GDP. In this case the highly significant point estimate for the effect of human capital on capital flows falls back to 0.587, compared with the 0.637 of the full sample.

When we reduce the sample to exclude those extreme cases for the independent variable of interest, human capital, we find generally that previous results maintain. When we reduced the sample to include only levels of human capital higher than 2 years of average education no perceivable change was observed. Only when we
excluded from the sample those countries with lower levels than 4 years of average schooling for each inhabitant we found a change. Indeed, for the subsample of more than four years of average schooling the parameter estimate reaches 1.7. When we further exclude those countries with population that have less than 6 years of average education the parameter estimate shoots up and reaches a staggering 3.2. This is evidence of a non-linear effect of human capital on capital flows. When the sample is further reduced to those countries with more than 10 years of schooling, we find that the parameter falls back to 1.29, confirming the previous result.

All these changes are robust also to the exclusion of groups of countries. These results maintains even after accounting for regional differences in subsamples, despite continuous reductions in the number of countries included.

7 Conclusions

The aim of this chapter was to investigate empirically the potential effect that human capital accumulation has in driving foreign capital in the medium term. We built a panel dataset using recently released data on human capital stocks, different types of capital inflows and control variables for a sample of 60 heterogeneous countries over the period 1976-2000. We applied fixed-effects estimation in an unobserved components model in order to take into account time-constant country-specific heterogeneity and obtain consistent estimators.
We find a robust positive effect of the level of human capital stocks on driving capital inflows across sub-samples of countries and for different types of foreign capital inflows. The fact of a country having an average of one more year of schooling in the labour force leads to a shift in the ratio of capital inflows over GDP of 1.33 percentage points, after controlling for unobserved effects and a set of control variables. Human capital has a similar effect on both FDI and FPI.

We also find that the effect of human capital on FCI is substantially larger for industrialised countries than for developing ones, while this gap is slightly smaller in the case of FDI. This point to the fact that industrial countries have already attained stocks of human capital which are much more productive than those in developing nations, even after controlling for the idiosyncratic country effects.

Another interesting result appears when African countries are excluded from the sample, leading consistently to higher estimates. This corroborates the existence of a relatively large “Africa effect” that points to a lower profitability of human capital investments in terms of attracting foreign capital inflows.

These strong results showing the importance of human capital in attracting inflows are found not only in our preferred specification, but also using cross-section and pooled-OLS results estimations.

To conclude, investment in education is not only related to the beneficial effect that it can have on society, but also plays a key role in creating the conditions for the economy to overcome country-specific disadvantages and to attract foreign capital.
Appendix 1

Industrial Countries

Australia, Austria, Belgium\(^{57}\), Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, United Kingdom, United States.

Developing Countries

Argentina, Barbados, Bolivia, Botswana, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Guatemala, India, Israel, Jamaica, Jordan, Kenya, South Korea, Malaysia, Malta, Mauritius, Mexico, Pakistan, Panama, Paraguay, Peru, Philippines, Senegal, Singapore, South Africa, Sri Lanka, Swaziland, Thailand, Togo, Tunisia, Turkey, Uruguay, Bolivarian Republic of Venezuela.

\(^{57}\) Data include Luxembourg for the following categories: capital inflows and trade openness.
### Appendix 2

The data used in this paper were built drawing information from a number of different sources. Here we provide a list of the variables, the source used to construct them and their definition.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source*</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI</td>
<td>IFS, WDI, LM, Data</td>
<td>Foreign direct investment inflows to GDP ratio. IFS code 78bed.</td>
</tr>
<tr>
<td>FPI</td>
<td>IFS, JSA, Data</td>
<td>Portfolio investment liabilities to GDP ratio. IFS code 78bgd.</td>
</tr>
<tr>
<td>GDP</td>
<td>WDI, IFS</td>
<td>Gross domestic product (millions US dollars).</td>
</tr>
<tr>
<td>GDPG</td>
<td>WDI, IFS</td>
<td>Growth of real GDP.</td>
</tr>
<tr>
<td>GDPPG</td>
<td>WDI</td>
<td>Growth of real per capita GDP</td>
</tr>
<tr>
<td>GDPI</td>
<td>IFS, WDI</td>
<td>Initial gross domestic product per capita in US dollars (logarithm)</td>
</tr>
<tr>
<td>GDPPPI</td>
<td>WDI</td>
<td>Initial gross domestic product per capita in PPP (logarithm)</td>
</tr>
<tr>
<td>Human capital</td>
<td>Barro-Lee</td>
<td>Average years of school of the total population aged 25 and over.</td>
</tr>
<tr>
<td>Openness</td>
<td>WDI, IFS, ES</td>
<td>Openness indicator: ratio of trade (exports plus imports) to GDP.</td>
</tr>
<tr>
<td>Political rights</td>
<td>FH</td>
<td>Political rights. Measured on a one-to-seven scale, with one representing the highest level of political rights and seven, the lowest one. The data for Germany corresponds to West Germany from 1974-75 to 1989-90 and then to reunified Germany.</td>
</tr>
<tr>
<td>Civil liberties</td>
<td>FH</td>
<td>Civil liberties rights. Measured on a one-to-seven scale, with one representing the highest degree of civil liberties and seven, the lowest one. The data for Germany corresponds to West Germany from 1974-75 to 1989-90 and then to reunified Germany.</td>
</tr>
<tr>
<td>Inflation</td>
<td>IFS, ERS, ES</td>
<td>Changes in the consumer price index.</td>
</tr>
<tr>
<td>LFG</td>
<td>WDI</td>
<td>Growth of total labour force.</td>
</tr>
<tr>
<td>POPG</td>
<td>WDI</td>
<td>Growth of total population.</td>
</tr>
<tr>
<td>Interest</td>
<td>IFS, ERS</td>
<td>Real deposit interest rate (per cent). Excluding Dominican Republic, El Salvador, Israel, Panama and Paraguay</td>
</tr>
<tr>
<td>DIFI</td>
<td>IFS, ERS</td>
<td>Differential of real interest rate with respect to the U.S. Treasury Bill Rate.</td>
</tr>
<tr>
<td>RELGDP</td>
<td>WDI</td>
<td>Relative per capita income, adjusted by PPP exchange rates (measured relative to the U.S.)</td>
</tr>
<tr>
<td>RELDEPO</td>
<td>WDI</td>
<td>Old dependency ratio (relative to mean across countries), population over 65/ population between 15 and 65.</td>
</tr>
<tr>
<td>RELDEY</td>
<td>WDI</td>
<td>Youth dependency ratio (relative to mean across countries), population under 15/population between 15 and 65.</td>
</tr>
<tr>
<td>OIL</td>
<td>WDI</td>
<td>Dummy for fuel exporting countries that takes the value of 1 when average fuel exports as percentage of merchandise exports is bigger that 20 per cent over the period 1975-2000.</td>
</tr>
</tbody>
</table>

Appendix 3

Panel regressions, random-effects specification

<table>
<thead>
<tr>
<th></th>
<th>Developing countries</th>
<th>Developing countries, excluding Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable: portfolio inflows to GDP ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Human Capital</strong></td>
<td>0.111 *</td>
<td>0.090</td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td>(0.063)</td>
</tr>
<tr>
<td></td>
<td>(0.039)</td>
<td>(0.155)</td>
</tr>
<tr>
<td>GDP growth</td>
<td>0.021</td>
<td>0.032</td>
</tr>
<tr>
<td></td>
<td>(0.031)</td>
<td>(0.035)</td>
</tr>
<tr>
<td></td>
<td>(0.489)</td>
<td>(0.364)</td>
</tr>
<tr>
<td>Openness ratio</td>
<td>-0.002</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td></td>
<td>(0.360)</td>
<td>(0.506)</td>
</tr>
<tr>
<td>Political rights</td>
<td>-0.080</td>
<td>-0.085</td>
</tr>
<tr>
<td></td>
<td>(0.060)</td>
<td>(0.071)</td>
</tr>
<tr>
<td></td>
<td>(0.185)</td>
<td>(0.236)</td>
</tr>
<tr>
<td>Inflation</td>
<td>-0.0001</td>
<td>-0.0001</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
</tr>
<tr>
<td></td>
<td>(0.638)</td>
<td>(0.747)</td>
</tr>
<tr>
<td>Hausman test statistic</td>
<td>6.60</td>
<td>1.66</td>
</tr>
<tr>
<td></td>
<td>(0.252)</td>
<td>(0.894)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>195</td>
<td>160</td>
</tr>
</tbody>
</table>

Notes: Heteroscedasticity-consistent standard errors and probability values are reported in parentheses, in that order, below the estimated coefficient. The symbol * indicates statistical significance at least at the 10 per cent level or a $P$-value of less than 0.1.
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