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ABSTRACT

According to the consensus view in growth and development economics, cross country differences in per-capita income largely reflect differences in countries' total factor productivity. We argue that this view has powerful implications for patterns of capital flows: everything else equal, countries with faster productivity growth should invest more, and attract more foreign capital. We then show that the pattern of net capital flows across developing countries is not consistent with this prediction. If anything, capital seems to flow more to countries that invest and grow less. We argue that this result -- which we call the allocation puzzle -- constitutes an important challenge for economic research, and discuss some possible research avenues to solve the puzzle.

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1 Introduction

Between the years 1980 and 2000, the investment to GDP ratio averaged 32 percent in Korea and only 2.8 percent in Madagascar. Over the same period, Korea experienced an economic miracle, with a growth rate of output per worker of 5.4 percent per year, whereas Madagascar was less successful—output per worker declined by 1.3 percent per year. By 2000, PPP-adjusted output per worker reached $22,022 in Korea and only $1,599 in Madagascar. Modern growth theory teaches us how to interpret such enormous differences in economic performance. Hall and Jones (1999) and the subsequent literature on development accounting (see Caselli (2004)) argue conclusively that a substantial share of the differences in output per worker can be attributed to productivity. Indeed, standard growth decomposition exercises tell us that total factor productivity grew by 4.5 percent per year in Korea between 1980 and 2000, whereas it fell by 1.1 percent per year in Madagascar.

What does this imply for international capital flows? The standard growth model delivers an unambiguous answer to this question. High productivity growth in countries like Korea increases the marginal product of capital, which stimulates investment. Korea should have financed a share of its rapidly growing capital stock with foreign capital. Madagascar, facing no or little upward growth prospects, should have attracted much less foreign capital. Consider what happened instead. Between 1980 and 2000, both countries relaxed restrictions on international financial transactions.[1] Yet Korea received almost no net capital inflows. In Madagascar, by contrast, net capital inflows averaged 6 percent of output.

Figure 1 documents the same pattern across a large number of developing countries. It shows that the average share of net capital inflows in GDP between 1980 and 2000 (on the vertical axis) is negatively correlated with the investment-to-GDP ratio (on the horizontal axis). Far from being outliers, Korea and Madagascar are typical of the cross-country correlation between investment and capital inflows shown in Figure 1. Both countries are close to the regression line. If investment and capital flows were driven primarily by changes in

[1] Chinn and Ito's (2007) index of financial openness between 1970 and 1989 was 22 in Korea (resp. 15.4 in Madagascar), and 31.6 (resp. 28.6) between 1989 and 2005. The index runs from 0 (less open) to 100 (more open).

domestic productivity, as suggested by the development accounting literature, countries that invest more should receive more capital from abroad. We observe the exact opposite.

Patterns such as Figure 1 are just one illustration of a range of results that point in the same direction: standard models do not account for the *allocation* of international capital flows across developing countries. Capital flows from rich to poor countries are not only low (as argued by Lucas (1990)), but their allocation across developing countries is the opposite of the predictions of standard textbook models: capital does not flow more to the countries that have a higher marginal product of capital. We argue that the pattern of capital flows across developing countries constitutes a major puzzle and its resolution is a challenge for international economics. We call it the *allocation* puzzle.

The allocation puzzle is different from the Lucas puzzle, which is about the small size of capital flows from rich to poor countries (Lucas (1990)). In terms of Figure 1, the Lucas puzzle is that capital inflows amount to a relatively small share of GDP on average (3.9 percent in our sample). We will show, in the context of our calibrated model, that the small size of aggregate capital flows toward developing countries as a whole is not especially puzzling given the relatively low rate of productivity growth in these countries. This explanation is consistent with Lucas' original hypothesis: capital flows to poor countries are low because these countries are not very productive and face domestic distortions in the return to capital.

Our puzzle is related to the *allocation* of the capital flows across developing countries rather than their overall level. Our calibrated open economy growth model predicts large capital inflows to Asia and large capital outflows from Latin America and Africa. This rather provocative result reflects a straightforward implication of a standard open economy growth model: the countries whose productivity declines relative to the rest of the world should export, not import capital. By contrast, in the data, we observe that capital has flowed to all three regions, and more so (in proportion of investment or GDP) to Africa and Latin America than to Asia.

Section 2 presents the model that we use to predict the volume and allocation of capital flows to developing countries. We use, as a starting point, a simple frictionless small open economy model in the tradition of Ramsey, Cass and Koopmans. The model assumes that countries start at some distance of the world technology frontier, and may—for reasons that are outside of the model—catch up or fall behind relative to the frontier. We derive a closed-form expression showing how the volume of net capital inflows toward a given country depends on the country's exogenous characteristics (initial debt, capital scarcity, and productivity). The model predicts that capital should flow more toward the countries with higher productivity growth to finance both investment and consumption.

Section 3 then calibrates the model using Penn World Table (PWT) data on investment and output for 69 developing countries over 1980-2000, a period that is long enough to look at long-run differences in growth, and during which there was a fair degree of capital mobility. We find that the average developing country was not very capital scarce in 1980, and did not catch up relative to the world technology fontier, potentially explaining the small observed size of capital flows from rich to poor countries. We also find that the cross-country allocation of capital flows is always the opposite of that predicted by the model: countries with faster productivity growth attract *less* capital. This is the *allocation* puzzle.

Although there are various ways to make the basic model more realistic, we argue in section 4 that many of these changes do not help explain the allocation puzzle. Lack of perfect foresight or international financial frictions may mute the volume of international capital flows, but should not change their direction or their allocation across countries. Our results are also robust to the introduction of non-reproducible capital (land) into the model, an extension which Caselli and Feyrer (2007) have shown to be potentially important in estimating international differences in the return to capital. Finally, we show that the allocation puzzle is not accounted for by aid flows, whose behavior may not be appropriately captured by the basic neoclassical model.

What can, then, explain the puzzling allocation of capital flows across developing countries? Although the main purpose of this paper is to establish a puzzle rather than solve it, we offer in section 5 some thoughts on possible explanations. We distinguish three possible approaches, which put the spotlight respectively on the link between savings and growth, the link between trade and growth, and the link between financial development and growth.

No attempt is made to discriminate empirically between these explanations—the objective of that section being merely to propose a roadmap to think about future research rather than establishing new results.

This paper lies at the confluence of different lines of literature. First, it contributes to the literature on the determinants of capital inflows to developing countries, and on the role of capital flows in economic development. Aizenman, Pinto and Radziwill (2004) construct a self-financing ratio indicating what would have been the counterfactual stock of capital in the absence of capital inflows. They find that 90 percent of the stock of capital in developing countries is self-financed, and that countries with higher self-financing ratios grew faster in the 1990s. Prasad, Rajan and Subramanian (2007) also document a negative cross-country correlation between the ratio of capital inflows to GDP and growth, and discuss possible explanations for this finding. Manzocchi and Martin (1997) empirically test an equation for capital inflows derived from an open-economy growth model on cross-section data for 33 developing countries—and find relatively weak support.

This paper is related to the literature on relationship between growth and the current account in developing countries. Emerging market business cycles exhibit countercyclical current accounts, i.e., the current account balance tends to decrease when growth picks up (see Aguiar and Gopinath (2007)). We show in this paper that the correlation between growth and the current account is the opposite when it is considered across countries and over a long time period. Because of the very low frequency at which we look at the data, a more natural benchmark of comparison is the literature on transitional growth dynamics pioneered by Mankiw, Romer and Weil (1992). King and Rebelo (1993) also examine transition dynamics in a variety of neoclassical growth model. Unlike these papers, we allow countries to catch up or fall behind relative to the world frontier and focus on the implications of the theory for international capital flows.

The paper is also related to the literature on savings, growth, and investment. The literature on savings and growth has established a positive correlation between these variables, which is puzzling from the point of view of the permanent income hypothesis since high-growth countries should borrow abroad against future income to finance a higher level of consumption (Carroll and Summers (1991), Carroll and Weil (1994)). Starting with Feldstein and Horioka (1980), the literature has also established a stronly positive correlation between savings and investment, which seems difficult to reconcile with free capital mobility. The allocation puzzle presented in this paper is related to both puzzles, but it is stronger. Our finding is that the *difference between savings and investment* (capital outflows) is positively correlated with productivity growth, which means that savings not only has to be positively correlated with productivity growth, but the correlation must be stronger than that between investment and productivity growth.

Finally this paper belongs to a small set of contributions that look at the implications of the recent "development accounting" literature for international economics. Our model and calibration methods are closely related to that literature—although in this paper we do not consider human capital explicitly—which has emphasized productivity growth as the main proximate cause of economic development. This view has implications for the behavior of capital flows that have not been systematically explored in the literature (by contrast with investment, whose relationship with productivity is well understood and documented). In a related contribution that is discussed in more detail in section 4, Caselli and Feyrer (2007) show that the return to capital, once properly measured in a development accounting framework, is very similar in advanced and developing countries, which might explain why we observe so little capital flow from the former to the latter. In Gourinchas and Jeanne (2006) we use a development accounting framework similar to that in this paper to quantify the welfare gains from capital mobility—and find them to be relatively small. In this paper, by contrast, we look at the positive implications of development accounting for the direction of capital flows. Our paper is the first, to our knowledge, to quantify the level of capital flows to developing countries in a calibrated open economy growth model and compare it to the data.

2 Capital Flows in the Neoclassical Growth Model

The neoclassical growth framework postulates that the dynamics of growth are driven by an exogenous productivity path. In this section we derive the implications of this view for capital flows, i.e., we show how the capital flows to developing countries are determined by their productivity paths relative to the world technology frontier. For simplicity, we abstract from global general equilibrium effects and assume that each developing country can be viewed as a small open economy taking the world interest rate as given. Thus, the model features only one country, and the rest of the world.

2.1 The model

Consider a small open economy that can borrow and lend at an exogenously given world gross real interest rate R^*. Time is discrete and, for the time being, there is no uncertainty. The population N_t grows at an exogenous rate n: $N_t = n^t N_0$. Like in Barro and Sala-i-Martin (1995) the population can be viewed as a continuum of identical families whose representative member maximizes the welfare function:

$$U_t = \sum_{s=0}^{\infty} \beta^s \; N_{t+s} \; u\left(c_{t+s}\right), \tag{1}$$

where c_t denotes consumption *per capita* (more generally, lower case variables are normalized by population) and $u\left(c\right) \equiv \left(c^{1-\gamma} - 1\right) / \left(1 - \gamma\right)$ is a constant relative risk aversion (CRRA) utility function with coefficient $\gamma > 0$. The number of families is normalized to 1, so that per family and aggregate variables are the same.

The economy produces a single homogeneous good using two inputs, capital and labor, according to a Cobb-Douglas production function:

$$Y_t = K_t^{\alpha} \left(A_t L_t\right)^{1-\alpha}, \; 0 < \alpha < 1, \tag{2}$$

where K_t is the stock of domestic physical capital, L_t the labor supply, and A_t the level of productivity. The labor supply is exogenous and equal to the population ($L_t = N_t$). Factor markets are perfectly competitive so each factor is paid its marginal product.

Denote by R_t the marginal product of capital, net of depreciation:

$$R_t = \alpha \left(k_t / A_t \right)^{\alpha - 1} + 1 - \delta. \tag{3}$$

In order to account for long-run cross country differences in investment rates, we assume a distortion τ in the return to capital. Specifically, we assume that investors receive only a fraction $(1 - \tau)$ of the gross return on capital R_t. We call τ the '*capital wedge*'. It is a short hand for the gap between the gross social return to capital R_t and the private return. One can interpret τ as a tax on gross capital income, or as the result of other distortions—credit market imperfections, expropriation risk, bureaucracy, bribery, and corruption—that would also introduce a 'wedge' between social and private returns. In order to focus on the distortive aspects, the revenue per capita $z_t = \tau R_t k_t$ generated by this wedge are rebated in a lump sum fashion.

The representative resident issues external debt d_t and owns all the domestic capital k_t. We assume perfect financial integration, i.e., the representative resident can borrow and lend at the world interest rate R^*. Given our assumptions, the budget constraint of the representative family is:

$$N_t c_t + N_{t+1} k_{t+1} + R^* N_t d_t = (1 - \tau) R_t N_t k_t + N_{t+1} d_{t+1} + N_t w_t + N_t z_t, \tag{4}$$

where w_t is the wage, equal to the marginal product of labor $(1 - \alpha)\, k_t^{\alpha} A_t^{1-\alpha}$.

The representative resident maximizes the welfare function (1) under the budget constraint (4). The Euler equation,

$$c_t^{-\gamma} = \beta R^* c_{t+1}^{-\gamma}, \tag{5}$$

implies that consumption per capita grows at the constant rate $(\beta R^*)^{1/\gamma}$. In addition, capital mobility implies that the private return on domestic capital and the world real interest rate are equal:

$$(1 - \tau)\, R_t = R^*. \tag{6}$$

Substituting this into the expression for the gross return on capital (3), we obtain that the capital stock per efficient unit of labor $\tilde{k} = k/A$ is constant and equal to:

$$\tilde{k}_{t+1} = \tilde{k}^* \equiv \left(\frac{\alpha}{R^* / (1-\tau) + \delta - 1} \right)^{1/1-\alpha}, \tag{7}$$

('tilde-variables' will denote per capita variables in efficiency units: $\tilde{x} = X/AN$).

Equation (7) makes clear that the capital wedge τ is the only source of variation in the steady state capital stock per efficient unit of labor across countries. A higher wedge, equivalent to a higher implicit tax on capital, depresses domestic capital accumulation and lowers $\tilde{k}^*$.

The country has an exogenous, deterministic productivity path $(A_t)_{t=0,..,+\infty}$, which is bounded from above by the world productivity frontier,

$$A_t \leq A_t^* = A_0^* g^{*t}.$$

The world productivity frontier reflects the advancement of knowledge, which is not country specific, and is assumed to grow at a constant rate g^*.

Domestic productivity could grow at a rate that is higher or lower than g^*. In order to describe how domestic productivity evolves relative to the world frontier, it is convenient to define the difference between domestic productivity and the productivity conditional on no technological catch-up,

$$\pi_t = \frac{A_t}{A_0 g^{*t}} - 1.$$

We assume that $\pi = \lim_{t \to \infty} \pi_t$ is well defined. The limit π measures the country's long run technological catch-up relative to the world frontier. If $\pi = 0$, the country's productivity remains unchanged relative to the world frontier. When $\pi > 0$, the country catches up relative to the frontier. When $\pi < 0$, the country falls further behind. Domestic productivity converges to a fraction $(1 + \pi) A_0 / A_0^*$ of the world frontier, and the growth rate of domestic productivity converges to g^*.[2]

[2] That countries have the same long-run growth rate is a standard assumption. Models of idea flows such as Parente and Prescott (2000) or Eaton and Kortum (1999) imply a common long-run growth rate of productivity.

Finally, we assume that the world interest rate is given by,

$$R^* = g^{*\gamma}/\beta. \tag{8}$$

This, together with the Euler equation (5), implies that domestic consumption per capita grows at rate $g^* : c_{t+1} = g^* c_t$. Although not crucial for our results, this assumption simplifies the analysis by ensuring that the domestic economy converges toward a steady growth path in which consumption and output per capita grow at the same rate. Equation (8) holds if the rest of the world is composed of advanced economies that have the same preferences as the small economy under consideration, but have already achieved their steady state. This is a natural assumption to make, given that we explain capital flows by cross-country differences in productivity, rather than preferences.

A country is characterized by an initial capital stock per capita k_0, debt d_0, population growth rate n, a productivity path $\{A_t\}_0^\infty$, and a capital wedge τ. We assume that all countries are financially open at time $t = 0$ and use the model to estimate the size and the direction of capital flows from $t = 0$ onward.

2.2 Productivity and capital flows

We will compare the predictions of the model with the data observed over a finite period of time $[0, T]$. Thus it makes sense to focus on cross-country differences in the determinants of capital flows that are observable in the time interval $[0, T]$. We abstract from unobserved future developments in productivity by assuming that all countries have the same productivity growth rate, g^*, after time T.

Assumption 1 *(finite-time productivity catch-up)* $\pi_t = \pi$ *for* $t \geq T$.

Next, we need to define an appropriate measure of capital inflows during the time interval $[0, T]$. A natural measure, in our model, is the change in external debt between 0 and T normalized by initial GDP,

$$\frac{\Delta D}{Y_0} = \frac{D_T - D_0}{Y_0}. \tag{9}$$

The normalization by initial GDP ensures that the measure is comparable across countries of different sizes.[3]

We obtain the following proposition.

Proposition 1 *Under assumption 1, the ratio of cumulated capital inflows to initial output is given by:*

$$\frac{\Delta D}{Y_0} = \frac{\tilde{k}^* - \tilde{k}_0}{\tilde{k}_0^\alpha} (ng^*)^T + \frac{\tilde{d}_0}{\tilde{k}_0^\alpha} \left[(ng^*)^T - 1 \right] + \pi \left[\tilde{k}^* + \frac{\tilde{w} + \tilde{z}}{R^*} \sum_{t=0}^{T} \left(\frac{ng^*}{R^*} \right)^t (1 - \pi_t/\pi) \right] \frac{(ng^*)^T}{\tilde{k}_0^\alpha} \tag{10}$$

where $\tilde{w} = (1-\alpha)\,\tilde{k}^{*\alpha}$ *and* $\tilde{z} = \tau/\left(1-\tau\right) R^* \tilde{k}^*$.

Proof. See appendix A ■

Equation (10) implies that a country without capital scarcity ($\tilde{k}_0 = \tilde{k}^*$), without initial debt ($\tilde{d}_0 = 0$) and without productivity catch-up ($\pi_t = \pi = 0$) has zero capital flows. The first term on the right-hand side of (10),

$$\frac{\Delta D^c}{Y_0} = \frac{\tilde{k}^* - \tilde{k}_0}{\tilde{y}_0} (ng^*)^T, \tag{11}$$

results from the initial capital scarcity $\tilde{k}^* - \tilde{k}_0$. Under financial integration, and in the absence of financial frictions or adjustment cost of capital, the country instantly borrows and invests precisely the amount $\tilde{k}^* - \tilde{k}_0$. We call this term the *convergence* term.

The second term,

$$\frac{\Delta D^t}{Y_0} = \frac{\tilde{d}_0}{\tilde{y}_0} \left[(ng^*)^T - 1 \right], \tag{12}$$

reflects the impact of initial debt in the presence of *trend* growth ($ng^* > 1$). In the absence of productivity catch-up the economy follows a steady growth path in which external debt remains a constant fraction of output. Expression (12) corresponds to the cumulated debt inflows that are required to keep the debt-to-output ratio constant.

[3] Our conclusions are robust to using alternate measures of foreign borrowing. For example, capital inflows could be measured as the average ratio of net capital inflows to GDP or as the change in the ratio of net foreign liabilities to GDP. Appendix A.2 shows that the predictions of the model are qualitatively the same for the three measures of capital flows. Moreover, we show in the appendix that if the allocation puzzle is observed with measure (9) then it must also hold with the two other measures. This is another reason to use measure (9) as a benchmark when we look at the data.

Finally, the third term in (10) reflects the impact of the productivity catch-up. It can be decomposed into two terms, each with an intuitive interpretation. The first term,

$$\frac{\Delta D^i}{Y_0} = \pi \frac{\tilde{k}^*}{\tilde{y}_0} (ng^*)^T , \tag{13}$$

represents the external borrowing that goes toward financing *domestic investment*. To see this, observe that since capital per efficient unit of labor remains constant at $\tilde{k}^*$, capital *per capita* needs to increase more when there is a productivity catch-up. Without productivity catch-up, capital at time T would be $\tilde{k}^* N_T A_0 g^{*T}$. Instead, it is $\tilde{k}^* N_T A_T$. The difference, $\pi \tilde{k}^* N_T A_0 g^{*T}$, normalized by output $\tilde{y}_0 A_0 N_0$, is equal to the right-hand side of (13).

The second term,

$$\frac{\Delta D^s}{Y_0} = \pi \frac{\tilde{w} + \tilde{z}}{R^* \tilde{y}_0} (ng^*)^T \sum_{t=0}^{T} \left(\frac{ng^*}{R^*} \right)^t \left(1 - \frac{\pi_t}{\pi} \right), \tag{14}$$

represents the change in external debt brought about by changes in *domestic saving*. It is tied to the time path of disposable income $w_t + z_t$. In general, this term depends on the productivity path $\pi_1, \pi_2, ..., \pi_T$. For simplicity we assume that the path for the ratio π_t / π is the same for all countries and satisfies $\pi_t \leq \pi$.

Assumption 2 *(common relative convergence paths)* $\pi_t = \pi f(t)$ *where* $f(\cdot)$ *is common across countries and satisfies* $f(t) \leq 1$ *and* $\lim_{t \to \infty} f(t) = 1$.

Under assumption 2, we can rewrite equation (14) as,

$$\frac{\Delta D^s}{Y_0} = \pi \frac{\tilde{w} + \tilde{z}}{R^* \tilde{y}_0} (ng^*)^T \sum_{t=0}^{T} \left(\frac{ng^*}{R^*} \right)^t (1 - f(t)),$$

which is proportional to the long-run productivity catch-up π. Faster relative productivity growth implies higher future income, leading to an increase in consumption and a decrease in savings.[4] Since current income is unchanged, the representative domestic consumer borrows on the international markets.

[4]Obviously, savings can decrease at the same time as investment increases because of capital inflows. The Fisherian separation of savings and investment is at the core of the economics of capital flows in the neoclassical growth model. By contrast, in a closed economy, faster productivity growth leads to additional

This results in the following corollary.

Corollary 1 *Consider two countries A and B, identical except for their long-run productivity catch-up: $\pi^A < \pi^B$. Under assumptions 1 and 2, country A receives strictly less capital inflows than country B :*

$$\frac{\Delta D^A}{Y_0} < \frac{\Delta D^B}{Y_0}$$

To summarize, the investment and consumption channels lead to the same prediction—that countries growing faster should borrow more.

The simplicity of the relationship between productivity and capital flows is in part driven by the assumptions of the model. First, we assume perfect international financial integration. In reality, financial frictions may limit severely—perhaps eliminate altogether—the ability of developing countries to borrow in order to smooth consumption profiles. Yet, we would argue that, while international financial frictions may be important, they are unlikely to reverse the direction of capital flows, or the sign of their correlation with productivity growth. In the presence of international financial frictions, countries will be able to borrow less. But countries with higher productivity growth should still be willing to borrow *more*, not *less*, than countries with lower productivity growth. International financial frictions can reduce the predicted size of capital inflows, but cannot make capital flow more towards the countries that invest less—or flow less toward the countries that invest more.

Second, equation (14) assumes perfect foresight: the path of future productivity is known with certainty as of time $t = 0$. Uncertainty about the future path of productivity would dampen the willingness of the domestic household to borrow against future income. We will consider a variant of the model with stochastic productivity in section 4.1. Again, while this may affect the magnitude of capital flows, it should still be the case that countries that grow more should borrow more.

Lastly, the assumption that the economy is populated by infinitely-lived consumers removes demographic effects from the model. Models with overlapping generations could

investment only if it successfully mobilizes national savings through higher interest rates. This is the main reason our results are different from Chen, Imrohoroglu and Imrohoroglu (2006) who study the Japanese saving rate from the perspective of a closed economy.

deliver different predictions for the aggregate relationship between saving and growth, and thus modify the implications of the model for capital flows. For instance, in Modigliani's original life cycle model, faster growth may increase aggregate savings by raising the saving of richer young cohorts relative to the dissaving of poorer older cohorts. As we have mentioned in the introduction, other models have been developed to explain the positive association between faster growth and national saving that is observed in the data. We will discuss that literature in section 5. Let us simply note, for now, that when looking at the quantitative predictions of the model, we should take the investment component (13) more seriously than the savings component (14).

3 Capital Flow Accounting and Calibration

We look in this section whether the data support the model's prediction concerning capital flows. To be more specific, we investigate whether developing countries with faster productivity growth and larger initial capital scarcity receive more capital inflows. This requires, for each country, estimates for the levels of initial capital scarcity and for productivity growth.

We focus on the period 1980-2000. This choice of period is motivated by two considerations. First, we cannot start too early because countries need to be financially open over most of the period under study. Indicators of financial openness indicate a sharp increase starting in the late 1980s and early 1990s. For instance, the Chinn and Ito (2007) index indicates an average increase in financial openness from 31.3 in 1980 to 42.5 in 2000 for the countries in our sample.[5] Second, we want as long a sample as possible, since the focus is on long-term capital flows. Results over shorter periods may be disproportionately affected by financial crisis or by fluctuations in the world business cycle. Our final sample consists of 69 developing countries: 66 non-OECD countries, as well as Korea, Mexico and Turkey.[6]

A certain number of model parameters are common across countries. We assume that a period is a year. We adopt logarithmic preferences ($\gamma = 1$) and set the discount factor β

[5] The index is normalized to run from 0 (most closed) to 100 (most open).

[6] We will sometimes refer to the countries in our sample simply as non-OECD countries. For a small set of countries, the sample period starts later and/or end earlier, due to data availability. The list of countries and sample period are reported in appendix C.

to 0.96.[7] Next, we set the depreciation rate δ to 6 percent, and the capital share of output α equal to 0.3.[8] Lastly, the growth rate of world productivity g^* is set to 1.017, the annual multifactor productivity growth observed on average in the U.S. between 1980 and 2000. Given these parameter values, the world real interest rate is equal to $R^* - 1 = 5.94$ percent per year.

The country-specific data are the paths for output, capital and productivity. Those data come from Version 6.1 of the Penn World Tables (Heston, Summers and Aten (2004)). The capital stock K_t is constructed with the perpetual inventory method from time series data on real investment (also from the PWT).[9] From (2), we obtain the level of productivity A_t as $(y_t/k_t^\alpha)^{1/(1-\alpha)}$ and the level of capital stock per efficient unit of labor $\tilde{k}_t$ as $(k_t/y_t)^{1/(1-\alpha)}$.[10]

We measure n as the annual growth rate of the working-age population. Under assumption 1, we can measure π as $\bar{A}_{2000}/(g^{*20}\bar{A}_{1980}) - 1$, where $\bar{A}_t$ is obtained as the trend component of the Hodrick-Prescott filter of A_t. This detrending removes short term fluctuations in productivity due to mismeasurement or business cycle factors.[11]

The next step consists in constructing the steady state capital level $\tilde{k}^*$. From equation (7), this is equivalent to constructing the capital wedge τ. Our approach is to calibrate the capital wedge so as to match exactly investment rates in the data. The next proposition characterizes the average investment rate between 1980 and 2000.

Proposition 2 *Given an initial capital stock $\tilde{k}_0$, productivity catch-up π, and capital wedge τ, the average investment-output ratio between $t = 0$ and $t = T - 1$ can be decomposed into*

[7] The value of γ matters only for the level of R^*, given in equation (8). Conditional on R^*, γ does not matter for the direction and size of capital flows.

[8] This assumption will be relaxed in section 4. Recent estimates by Gollin (2002) suggest that the capital share is roughly constant within countries, and varies between 0.2 and 0.4.

[9] See Caselli (2004) for details. Following standard practice, we set initial capital to $I/(g_i + \delta)$ where I is the initial investment level from the PWT and g_i is the rate of growth of real investment for the first 10 years of available data.

[10] We measure output and capital per working-age capita using data on the fraction of the population of working age (typically ages 15 to 64) from the World Bank.

[11] Consistent with this approach, g^* is equal to $\left(\bar{A}_{2000}^{US}/\bar{A}_{1980}^{US}\right)^{1/20}$. To set the coefficient of the HP filter, we impose that the frequency gain of the filter be equal to 70 percent at the frequency corresponding to an eight-year cycle. This choice mitigates end-point problems and concentrates on long run productivity growth.

the following three terms:

$$\bar{s}_k = \frac{1}{T}\frac{\tilde{k}^*(\tau) - \tilde{k}_0}{\tilde{k}_0^\alpha} + \frac{\pi}{T}\tilde{k}^*(\tau)^{1-\alpha} g^* n + \tilde{k}^*(\tau)^{1-\alpha}(g^* n + \delta - 1). \tag{15}$$

Proof. See appendix A. ■

Equation (15) has a simple interpretation. The first term on the right-hand side corresponds to the investment at time $t = 0$ that is required to put capital at its equilibrium level. This is the *convergence* component. The second term reflects the additional investment required by the productivity catch-up. The last term is simply the usual formula for the investment rate in steady state, with productivity growth g^*. It corresponds to the investment required to offset capital depreciation, adjusted for productivity and population growth.[12]

Solving numerically (15), we obtain the capital wedge τ as a function of the observed average investment rate $\bar{s}_k$, productivity catch-up π and population growth n. Appendix C reports the values of $\bar{s}_k$, π, n and τ for each country in our sample. Everything else equal, our calibration approach assigns a high capital wedge to countries with low average investment rate.

Our approach to constructing τ assumes that countries are perfectly integrated. Although international financial frictions could bias our estimates of τ, this bias should not affect the model's predictions for the direction of capital flows. In the case of a capital-scarce country where financial frictions maintain the domestic interest rate above the world level, the observed investment rate will be lower than under perfect financial integration, leading us to overestimate the capital wedge τ and thus underestimate the level of capital inflows needed to equalize returns. Symmetrically, in the case of a capital abundant country the bias induced by financial frictions should lead us to underestimate the capital outflows. The important point is that while there is a downward bias in the *size* of capital flows, the model still predicts accurately their direction and relative magnitude.

[12] Observe that when $g^* = n = 1$, this last term simplifies to $\delta\tilde{k}^{*(1-\alpha)} = \delta\tilde{k}^*/\tilde{y}^*$.

3.1 Capital accumulation

With these caveats in mind, Table 1 decomposes the observed investment rate $\bar{s}_k$ into the three components of equation (15). This decomposition yields a number of interesting results. First, as is well known, investment rates vary widely across regions. They also vary with income levels, increasing from 8.6 percent for low income countries to 28.5 percent for high-income non-OECD countries. By construction, the model accounts exactly for observed differences in average investment rates. We view this as a strength of our approach: since the model is designed to reproduce the change in the capital stock over the long run for a large number of countries, we can assess precisely whether the drivers of capital accumulation are also the drivers of observed capital flows.

Table 1 also contains interesting information on the factors driving capital accumulation across countries. First, the table indicates that most of the variation in the investment rate is accounted for by the trend component, which itself is strongly correlated with the capital wedge τ (reported in column 5). The average capital wedge is relatively large, at 11.6 percent, and decreases with income levels from 18.8 percent to 1.6 percent. To a first order of approximation, the countries with a high investment rate are those that maintain a high capital-to-output ratio because of a low capital wedge.

The convergence and productivity growth components (columns 2 and 3) account for a relatively small share of the investment rates on average. The small contribution of the convergence component is explained by the fact that the initial capital gap was relatively small on average at the beginning of the sample period ($k_0/k^* = 0.98$). But this average masks significant regional disparities between Asia and Latin America, which were capital scarce ($k_0/k^* = 0.87$ and 0.94 respectively), and Africa, which was capital abundant ($k_0/k^* = 1.07$). Because the countries that were capital-scarce in 1980 also tended to have a higher productivity growth rate in the following two decades, the cumulated contribution of the productivity and convergence components can be significant. This is most apparent if one compares Asia and Africa—the productivity and convergence components explain more than half of the difference in the investment rate between the two regions.

Finally, the estimates of π reported in column 6 show that there is no overall productivity catch-up with advanced countries (π is negative on average). Yet, closer inspection reveals an interesting geographical pattern. There is some productivity catch-up in Asia, with $\pi = 0.19$, while Latin America and Africa fell behind.[13] Accordingly, the contribution of productivity to investment is positive for Asia (1.6 percent), but negative for Africa and Latin America (-1.2 percent and -2.7 percent respectively).

3.2 Capital flows

We now compute, for each country, the level of capital inflows predicted by the model—the right-hand side of equation (10)—and compare the model predictions with the data. There is one measurement difficulty to solve, however, before we can proceed with this comparison. The Penn-World Tables do not not provide PPP-adjusted estimates of capital flows and external liabilities that are comparable to the output and capital data that we have used to calibrate the model.

The reader is referred to Appendix B for a detailed explanation of how we constructed PPP-adjusted measures of capital flows. We measure net capital inflows in current US dollars using International Financial Statistics data on current account deficits, keeping with the usual practice that considers errors and omissions as unreported capital flows. The main point is the choice of an appropriate price index to convert this measure into constant international dollars, the unit used in the Penn World Tables for real variables. In principle, the trade and current account balances should be deflated by the price of traded goods, but the Penn World Tables do not report such price indices. We chose instead the price of investment goods reported in the Penn World Tables. This seems to be a good proxy because investment goods are mostly tradable—as suggested by the fact that their price vary less across countries than that of consumption goods. The PPP adjustment will tend to reduce the estimated size of capital flows relative to output in poor countries, because those countries have a lower price of output (see Hsieh and Klenow (2007)).

[13]There are exceptions to this pattern. For instance, we find $\pi = -0.34$ for the Philippines, 0.28 for Chile and 0.47 for Botswana. See appendix C.

One advantage of our PPP-adjusted estimates of cumulated capital flows is that they can be compared to the measures of output or capital accumulation used in the development accounting literature. The allocation puzzle, however, does not hinge on the particular assumptions that we make in constructing those estimates. The deflator chosen for the PPP-adjustment of capital flows affects the volume but not the direction of capital flows.[14] The theory can be tested using various measures of capital flows, which all deliver the same broad message as the results presented in this section.

We present our estimates of observed and predicted net capital inflows in Table 2. The estimates for the predicted capital flows are constructed under the assumption that the productivity catch-up follows the linear process: $f(t) = \min(t/T, 1)$. Column 1 reports observed net capital inflows, as a fraction of initial output, $\Delta D/Y_0$. The size of cumulated capital inflows is small, around 33 percent of 1980 output.

Column 2 reports the total predicted net capital inflows based on equation (10). Predicted capital flows are often an order of magnitude larger than realized flows. More importantly, they often have the wrong sign. For instance, the model predicts that the average developing country in our sample should have *exported* a quantity of capital amounting to 2.5 times its initial output. While Lucas (1990) argued that the volume of capital flowing from rich to poor countries seemed puzzingly low, our results rather suggest that given the absence of productivity catch-up and high level of distortions, capital should have flown *out* of the average developing country in our sample.[15]

Why is there such a discrepancy between the model and the data? The answer lies in columns 3-6, which report the various components of (10). Column 3 indicates that developing countries should have borrowed 7 percent of initial output on average to equate domestic and foreign private returns on capital at the beginning of the sample period. This is a small amount, less than one fourth of the observed capital inflows. Likewise, the trend

[14] We used the price of output as a deflator for current account balances in a previous version of this paper, and obtained similar results.

[15] The results for average cumulated capital flows are different if the cross-country averages are weighted by GDP or population. Then, we find that the average developing country should receive capital inflows, because of the large weights of China and India. Whereas the predictions of the model for average capital flows are sensitive to outliers, we found that the allocation puzzle is robust to the different weighting schemes. The results are also qualitatively unchanged if we use the median instead of weighted averages.

component reported in column 6 is also relatively small and similar in magnitude to observed flows.

Most of the difference between the model-predicted and the observed capital flows come from the investment and savings components reported in columns 4 and 5. As discussed earlier, both terms increase with the productivity catch-up parameter π. The model implies that, everything else equal, capital should flow to the countries that catch up relative to the world technology frontier ($\pi > 0$), and flow out of the countries that fall behind ($\pi < 0$). The average developing country in our sample falls in the second category ($\pi = -0.1$) and thus should have *exported* capital. The capital outflows coming from lower investment are sizeable (29 percent of initial output) and those that come from lower savings are very large (2.6 times initial output), reflecting the high sensitivity of consumption-savings choices to future income in a perfect foresight model.

For reasons discussed earlier, we should not expect the model to predict very precisely the volume of capital flows to specific countries. Sovereign risk, financial frictions or uncertainty about future productivity will limit the extent to which countries rely on foreign capital. However, the neoclassical growth model should do a good job of predicting the broad *direction* of capital flows. This is where the model fails in a systematic and interesting way. The observed allocation of capital flows *across developing countries* is the opposite of the one predicted by the model. Consider first the allocation of capital across regions. We would expect net capital inflows to Asia, the only region that catches up in terms of productivity. Indeed, Table 2 reports that the investment component of capital inflows to the average Asian developing country should represent 81 percent of its initial output. Yet Asia borrowed, over that period, only 12.5 percent of its initial output (col. 1).

By contrast, consider Africa. With an initial abundance of capital and a relative productivity decline, the model predicts large capital outflows. Indeed, Table 2 indicates that the outflows related to the investment and convergence components amount to 42 percent and 28 percent of initial output respectively (columns 4 and 3). Yet Africa received more than 40 percent of its initial output in capital flows. Similarly, capital flows to Latin America amounted to 37 percent of its initial output, in spite of a significant relative productivity decline.

The same pattern is evident if we group countries by income levels rather than regions. According to Table 1, poorer countries experienced lower productivity growth and so should export more capital. Indeed, Table 2 shows that predicted capital inflows increase with income level from -492 percent of output for low income countries to 828 percent of output for high-income non-OECD countries. Observed capital inflows run in the exact opposite direction: actual capital flows *decrease* with income per capita, from 58 percent of output for low income countries to -54 percent for high-income non-OECD countries.

Figure 2 summarizes the puzzle. It reports actual against predicted capital flows. One observes immediately that most countries are located in the 'wrong' quadrants of the figure, with predicted capital outflows and observed capital inflows, or vice versa. Figure 3 plots observed capital flows against the three determinants identified in Proposition 1: the capital gap $(k^* - k_0)/k_0$, initial debt d_0/y_0, and productivity catch-up π. While observed capital flows are positively (although weakly) correlated with the first two components, we find strong evidence against the predictions of the model regarding productivity: countries with faster productivity growth attract less capital inflows.[16] This is the *allocation puzzle*.

We ran a number of straightforward robustness checks.[17] First, we checked that our results were robust to the exclusion of African countries (which arguably may be too poor to export capital while maintaining subsistence levels of consumption). Second, we started the analysis in 1970 instead of 1980. The sample is much smaller (30 countries), but the pattern of capital flows is very similar. Third, we split the sample according to whether Chinn and Ito's (2007) index of financial account openness is above or below the sample median. One would a priori expect a better fit between the model and the data for more financially open countries. Yet the results are similar for both groups of countries.[18]

[16]The figure reports the fitted values from an OLS regression. The regression coefficients are significantly negative for the productivity catch-up. They are not significant for the capital gap or the initial debt.

[17]Results are available upon request. The following section presents additional robustness checks.

[18]The index of Chinn and Ito (2007) does not differentiate between inflows and outflows. Hence it is possible that it is too crude a measure of capital market liberalization. As pointed out to us by Peter Henry, financial frictions can account for our results if countries with $\pi > 0$ face restrictions on inflows, whereas countries with $\pi < 0$ face restrictions on outflows.

To summarize, standard growth theory can account for cross-country differences in capital accumulation, once we take into account cross-country differences in productivity and capital markets distortions. The same theory makes a strong and counterfactual prediction about the direction of capital flows: the countries that grow faster should rely more on foreign financing. In fact, the countries that grow faster tend to receive less capital flows. The puzzle here is not that developing countries receive little capital from advanced countries, as Lucas argued. Rather, it is the *allocation of capital across developing countries* that contradicts the theory in a fundamental way.

4 Robustness

Can the textbook model be rescued in a simple way? This section explore some alternatives: introducing uncertainty about future productivity or non-reproducible capital in the model, and controlling for international aid flows. The upshot is that our central result is robust to these extensions.

4.1 Uncertainty and permanent productivity shocks

We emphasized earlier the importance of the assumption of perfect foresight for the saving side of the model. Under perfect foresight, agents tend to borrow or lend heavily against a certain future income. Uncertainty about the path of future productivity should dampen the willingness of the domestic representative agent to borrow or lend.

We now consider what happens when agents expect future productivity growth to remain constant and equal to g^*. This is a reasonable approximation, in light of Easterly, Kremer, Pritchett and Summers (1993) finding that output growth rates are unpredictable, and uncorrelated across decades. In order to abstract from the complications associated with precautionary savings, we solve the model under certainty equivalence and assume that agents always expect productivity to grow at rate g^* with certainty. Under this assumption we obtain the following result.

Proposition 3 *If agents always expect productivity to grow at rate* g^* *the ratio of cumulated capital inflows to initial output,* $\Delta D^n / Y_0 = [D_T - D_0] / Y_0$, *is given by:*

$$\frac{\Delta D^n}{Y_0} = \frac{\tilde{k}^* - \tilde{k}_0}{\tilde{k}_0^\alpha} (g^* n)^T + \frac{\tilde{d}_0}{\tilde{k}_0^\alpha} \left[(ng^*)^T - 1 \right] + \pi \tilde{k}^* \frac{(g^* n)^T}{\tilde{k}_0^\alpha}. \tag{16}$$

Proof. See appendix A. ■

The only difference between (16) and (10) is that the consumption smoothing term has disappeared. The intuition is straightforward: when productivity is expected to grow at rate g^*, the consumption-savings choices are the same as in the steady growth path with no productivity catch-up. Productivity influences capital flows only through the investment term.

Column 7 in Table 2 reports estimates of $\Delta D^n / Y_0$, as the sum of columns 3, 4 and 6. The orders of magnitude are closer to the data. Another difference with our previous results is that the average developing country is now predicted to receive capital inflows (although significantly less than the actual amount). However, the allocation puzzle still stands. As shown in Figure 4, the predicted and actual net capital inflows remain negatively correlated.

4.2 Non-reproducible capital

In a recent paper, Caselli and Feyrer (2007) argue that, while naive estimates of the marginal product of capital vary enormously across countries, the returns to capital are essentially the same once the estimates are adjusted for cross country differences in non-reproducible capital and in the relative price of investment and consumption goods. This adjustment is especially important for developing countries that have a larger share of natural capital (in particular land) in total capital. Their result offers another resolution to the Lucas puzzle: if substantial differences in capital-output ratio coexist with marginal product equalization, then we should expect little, if any, capital flows between countries.

This paper adopts a different approach, based on the wedge between the private and social marginal returns to capital. The cross country distribution of the private marginal return to capital is compressed by the wedge τ. To illustrate, the top panels of Figure 5 report the naive estimate of private returns (left), defined as $RN = \alpha Y/K - \delta$, and the wedge-adjusted return (right), $RW = (1-\tau)(1+RN)-1$, against 2000 income per capita. The left-hand side top panel indicates enormous variation in the naive estimate, between 3.6 percent (Singapore) and 104 percent (Uganda), with a mean of 17.5 percent. By contrast, the wedge-adjusted return varies between -2.5 percent (Nigeria) and 14 percent (Malawi) with a mean of 4.7 percent. The amount of compression is remarkable, given that the capital wedge is not calibrated to ensure private returns equalization. Our results thus parallel those of Caselli and Feyrer (2007): private returns to capital appear remarkably similar. This result explains why there is no Lucas puzzle according to our estimates.

We now check the robustness of our results to allowing for non-reproducible capital.[19] We start by modifying the production function (2) as follows:

$$Y_t = K_t^{\alpha_k} X^{\alpha_l} L^{1-\alpha_k-\alpha_l} A_t^{1-\alpha_k},$$

where X represents non-reproducible capital (assumed to be constant) and α_l denotes the share of non-reproducible capital in output. Notice that this production technology is isomorphic to (2) if we define a composite factor $Z_t = \left(X^{\alpha_l} L_t^{1-\alpha_k-\alpha_l}\right)^{1/(1-\alpha_k)}$ and write output as $Y_t = K_t^{\alpha_k}\left(A_t Z_t\right)^{1-\alpha_k}$. Non-reproducible capital matters, however, for estimating the capital share α_k.

The production function is calibrated as follows. Like Caselli and Feyrer (2007), we obtain an estimate of $\alpha_w = \alpha_k + \alpha_l$, the total share of capital (reproducible and non-reproducible), from Gollin (2002) supplemented by Bernanke and Gürkaynak (2001), as one minus the labor share. The private return to reproducible capital is $(1-\tau)(1+\alpha_k Y_t/K_t - \delta)$ while the private return to non-reproducible capital is $(1-\tau)\left(\alpha_l Y_t/X_t + P_t^x\right)/P_{t-1}^x$ where P_t^x denotes the price of non-reproducible capital in terms of the final good.[20]

In steady state, both returns must be equal and the rate of price appreciation must equal

[19] In this paper, we do not consider systematic variation across countries in the price of investment goods. See Chatterjee and Naknoi (2007) for an analysis of capital flows along this line.

[20] We assume that the capital wedge applies equally to all forms of capital and that non-reproducible capital does not depreciate.

the rate of growth of real output: $P_t^x/P_{t-1}^x = g_y$. Solving for α_k, we obtain:

$$\alpha_k = \left[\alpha_w - (1 - g_y - \delta)\frac{P^x X}{Y}\right].\frac{K}{W}, \tag{17}$$

where $W = P^x X + K$ denotes total wealth (natural and reproducible). This formula has a simple interpretation. If there is no natural capital ($X = 0$ and $W = K$), it boils down to $\alpha_k = \alpha_w$. With non-reproducible capital, two adjustments take place. First, only a fraction K/W of total capital income $\alpha_w Y$ goes to reproducible capital. This is the first term in brackets. Second, a faster growth rate g_y or higher depreciation rate δ mean a faster price appreciation and a larger private return on non-reproducible capital relative to reproducible capital. In both cases, returns on both types of capital can only be equated if the reproducible capital share α_k increases. This is the second term in brackets.[21] We follow Caselli and Feyrer (2007) and obtain estimates of $P^x X$ from World Bank (2006). Our estimated adjusted capital shares are reported in appendix C.

The bottom two panels of Figure 5 report the estimate of private returns to capital once we adjust the share of reproducible capital. The bottom left panel reports estimates of private returns without the capital wedge. We find returns varying between 4.4 percent (Thailand) and 29.5 percent (El Salvador), with a mean of 10.08 percent. Once we take into account the capital wedge, the returns are further compressed.[22] We find returns varying between 0.7 percent (Nigeria) and 11.5 percent (Malawi), with a mean of 4.9 percent.

Adjusting for non-reproducible capital does not change the essence of our results. Table 3 reports the predicted and actual capital flows in the adjusted model.[23] The predicted capital inflows remain negative on average, and the model predictions for the allocation of capital flows by income levels or by regions remain at odds with the data. Figure 6 shows the same variables as Figure 3 for the model with non-reproducible capital. Again, predicted capital flows are negatively correlated with productivity growth.

[21] These last two corrections are absent in Caselli and Feyrer (2007) who assume a common depreciation rate and price appreciation for reproducible and non-reproducible capital.

[22] The capital wedges are recomputed for the model with non-reproducible capital to match the observed investment rates. The adjustment for natural capital reduces the average level and variance of our capital wedge estimates. The mean capital wedge is now only 4.5 percent.

[23] The actual capital flows are not the same as in 2, because the sample of countries is slightly smaller.

4.3 Official aid

The basic neoclassical framework may not be appropriate to predict official aid flows because aid is not necessarily allocated to the countries with the highest expected returns on capital. On the one hand, if aid has any effectiveness the flows of development aid should be positively correlated with productivity growth. On the other hand, there is a selection bias, as the countries that have received aid flows over long period of time are often those that have failed to develop. In addition, the components of aid that are justified by humanitarian reasons should be negatively correlated with growth. The large literature on development aid has generally failed to find a significant relationship between aid and growth (see Rajan and Subramanian (2005)).

That the neoclassical growth model does not capture well the determinants of aid flows does not necessarily invalidate its predictions for net capital flows. If we modeled aid as a lump-sum transfer to the representative agent in the model of section 2, then aid would immediately leave the country, as the representative agent would find it optimal to invest it abroad given the lack of domestic investment opportunities. Because of the fungibility of aid this would be true even if aid were earmarked to finance certain class of expenditures, such as investment. The aid inflow would be offset by an outflow of exactly the same size, and the predictions of the model would remain valid for *net* capital flows.

Things might be different, however, in the presence of financial frictions. Then aid could be used to relax some financial constraints and to finance an increase in domestic expenditures above and beyond what can be financed by private capital flows. Or capital controls could prevent aid inflows from being completely offset by a capital outflow. In those cases, aid would not be neutral and its impact on the level of net capital flows should be examined.

We now examine how aid inflows are correlated with the model's predicted capital flows. Our measure of official aid flows is the net overseas development assistance (net ODA) from the Development Assistance Committee (DAC). This measure is available for all countries in our sample, except Taiwan. According to Roodman (2006), DAC counts total grants and concessional development loans and subtracts principle repayments on these loans (hence the 'net').[24] As shown in Appendix B, it is possible to compute the PPP-adjusted cumulated net ODA flows normalized by initial GDP using the same method as for net capital flows.

To see how far aid flows can go in explaining the puzzle, we make the (extreme) assumption that those flows were not offset at all by other types of capital flows. That is, we assume that in the absence of aid flows the counterfactual net capital flows would have been equal to the observed net capital flows ΔD minus the aid flows ΔB,

$$\frac{\Delta D'}{Y_0} = \frac{\Delta D - \Delta B}{Y_0}.$$

Under this assumption, removing aid flows might eliminate the puzzle, to the extent that these flows are negatively correlated with the determinants of private capital flows. Table 4 reports the results for the aid-adjusted capital flows. Since net ODA flows are always positive in our sample (all developing countries are net recipients), $\Delta D'$ is always *smaller* than ΔD. As a result, the average developing country is found to *export* capital net of aid flows (23 percent of initial output, on average). The correlations between aid-adjusted capital flows and the determinants of capital flows are reported in Figure 7. The correlation becomes negative for capital scarcity and remains negative for productivity growth, although no longer significantly different from zero for the latter. A comparison of Figures 3 and 7, reveals that aid flows must be negatively correlated with productivity growth.

We conclude that official aid flows play a role in explaining why the correlation between capital inflows and productivity growth is negative: many countries with poor productivity performance are also net official aid recipients. However, aid flows per se do not resolve the allocation puzzle. As Table 4 shows, Asia exports capital while the model predicts substantial capital inflows. Moreover, Figure 7 demonstrates that the observed aid-adjusted capital flows are at best unresponsive to differences in long term productivity growth.

[24] Our results are remain unchanged if we use instead Roodman's (2006) Net Aid Transfer measure.

5 Discussion

This section discusses some possible approaches to the resolution of the allocation puzzle. It is meant as a tentative roadmap for future research, not as a definitive attempt to push forward a particular explanation.[25] We first look at the puzzle from the point of view of the literature on savings and growth. We then discuss the possible role of international trade and that of domestic financial frictions.

The allocation puzzle can be summarized in terms of the cross-country correlations between savings, investment and growth. Let us consider the following three variables in a sample of developing countries: g, the average growth rate of productivity; s the average savings rate and i the average investment rate. The net capital outflows are measured by the difference between the savings rate and the investment rate, $s-i$. The allocation puzzle is the finding that capital outflows are positively correlated with the growth rate of productivity across countries:

$$cov(g, s-i) > 0,$$

or equivalently, that the savings rate is *more* correlated with productivity growth than the investment rate:

$$cov(g, s) > cov(g, i). \tag{18}$$

We argued that this is a puzzle for the simple neoclassical open-economy model of growth, which predicts that the left-hand side of equation (18) is negative while the right-hand side is positive.

5.1 Savings and growth

We already know from the literature on savings and growth that the model's first prediction, $cov\,(g, s) < 0$, is at odds with the data. Empirically, the savings rate is positively correlated with growth (see, e.g., Mankiw et al. (1992)), and the explanations that have been put

[25]Indeed, the explanations reviewed below are not mutually exclusive, and are often complementary. Moreover, the most relevant explanation could depend on the countries or the regions.

forward in the literature for this positive correlation may help us to explain the allocation puzzle.

One such class of explanations considers the causality from savings to growth. Note that g is the growth rate in productivity, not output per capita, so the mechanism must involve some endogeneity of domestic productivity to domestic savings. This is the case in a number of closed-economy models of endogenous growth, but this feature does not easily survive perfect capital mobility, which makes domestic savings a small component of the global savings pool. For domestic savings to increase growth in the open economy, there must be a friction that prevents domestic savings and foreign savings from being perfect substitutes. An example of a model with those features is Aghion, Comin and Howitt (2006), in which domestic savings matters for innovation because it fosters the involvement of domestic intermediaries with a superior monitoring technology.

Another class of explanations considers the causality from growth to savings.[26] In Modigliani's (1970) life cycle model faster growth raises aggregate savings by increasing the saving of younger richer cohorts relative to the dissaving of older poorer cohorts. Other authors have pointed to a number of problems with the life-cycle model, and put forward an alternative theory based on consumption habit (Carroll and Weil (1994), Carroll et al. (2000)).

Whether the models discussed above can explain the allocation puzzle is an open question for future research. The answer is not obvious *a priori*: those models can account for a positive correlation between savings and growth, but cannot necessarily explain why this correlation is larger than that between investment and growth. The challenge is to explain why $cov(s, g)$ is larger than $cov(i, g)$ when the averages are taken over long periods of time.

5.2 Trade

Another way of presenting the allocation puzzle is that the ratio of net exports to GDP is positively correlated with the productivity growth rate across countries. Looking at this from

[26] Carroll, Overland and Weil (2000) present evidence suggesting that the causality runs from growth to savings.

the perspective of trade, the allocation puzzle is consistent with the view in development economics that emphasizes the importance of a competitive sector as an engine of modernization and growth (see Rodrik (2006) for a recent exposition). This also seems consistent with the pattern of capital flows observed in the recent period, in which the developing countries that grew the fastest (the Southeast Asian emerging market countries) were also those that had the largest trade surpluses.

Developing a dynamic general equilibrium model of this view is beyond the scope of this paper, but one can speculate on the assumptions and properties that such a framework would have. For instance, suppose that productivity take-offs originate in the tradable sector before spilling over to the nontradable sector. Then, the initial phase of the take-off should be associated with a surge in net exports, and capital outflows.[27] One could add a "mercantilist" twist to the story by assuming that the country aims to maintain a competitive real exchange rate so as to preserve and develop its export sector during the take-off phase. This could be achieved by repressing domestic demand, using capital controls or other forms of domestic financial repression. Those factors would magnify the size of the capital outflows associated with the economic take-off.

To restate the argument in the terms of the previous section, developing countries with higher productivity growth g tend to be countries in which the tradable sector is larger relative to the nontradable sector. Because domestic demand is constrained by the relative underdevelopment of the nontradable sector, these countries also have a higher savings rate s. The allocation puzzle would be explained if savings increase more than investment in the productivity take-off.

It remains to be seen whether a calibrated model designed along those lines can explain the cross-country correlation between growth and capital flows that we observe in the data, and whether other implications of the model (e.g., for the relative sizes of the nontradable

[27] In equilibrium this would happen only under some conditions. On the one hand the consumption of tradables would be held back by the low supply of nontradables. On the other hand, the consumption of tradables should be stimulated by the real exchange rate appreciation associated with the take-off. Net exports should increase if the elasticity of substitution between tradable and nontradable goods is sufficiently low relative to the elasticity of intertemporal substitution of consumption (see Obstfeld and Rogoff (1996, chapter 4)).

and tradable sectors, and for the real exchange rate) fit the facts.

5.3 Domestic financial frictions

International financial frictions that increase the cost of external finance relative to domestic finance cannot explain the puzzle: as mentioned earlier, they can mute the absolute size of capital flows, not change their direction. But *domestic* financial frictions might be able to do so, because of the impact they have on the relationship between savings, investment and growth. As shown by Gertler and Rogoff (1990) and Matsuyama (2004), domestic financial frictions can reverse the direction of capital flows between rich and poor countries. It would be interesting to know whether they might have the same effect between high-growth and low-growth countries.

Low domestic financial development may constrain domestic demand—and increase domestic savings—in several ways. First, it constrains the residents' ability to borrow against future income or store value in sound financial instruments (see Caballero, Farhi and Gourinchas (2007)). Second, it constrains their ability to insure efficiently and encourages precautionary savings (see Mendoza, Quadrini and Rios-Rull (2007)). Further, an inefficient financial intermediation system should also reduce the responsiveness of investment to productivity growth.

In terms of our previous discussion, and taking productivity growth g as an exogenous determinant of savings and investment, we would expect to find that $cov(g, s)$ is *decreasing* with the level of financial development, while $cov(g, i)$ is *increasing* with the level of financial development. Thus $cov(g, s-i)$ would be decreasing with the level of financial development, and could be positive for countries with a low level of financial development. For instance, in Caballero et al. (2007), financially underdeveloped countries run larger current account surpluses if they grow faster. The explanation for the allocation puzzle, then, would be that the correlations in our sample are determined by financially underdeveloped countries. Some of these countries would have high growth in spite of their financial underdevelopment (e.g., China), whereas others would remain trapped in a path with low growth.[28] The allocation

[28]This association seem at odd with the fact that financial development seems good for growth (King and

puzzle would result from $cov(g, s-i) > 0$ conditional on low financial development.

This explanation takes a different angle than, but is not inconsistent with, the other two. Domestic credit constraints have been mentioned as a possible explanation in the literature trying to explain the positive correlation between saving and growth (Carroll and Weil (1994)), and also as a way of maintaining a competitive real exchange rate (Jeanne (2007)).

6 Concluding Comments

This paper establishes a puzzling stylized fact: capital tends to flow more toward countries with lower productivity growth and lower investment. This is puzzling for neoclassical models of growth—in fact, this makes one wonder if the textbook neoclassical framework is the right model at all to think about the link betwee international financial integration and development.

Part of the puzzle is accounted for by aid flows, but this is far from the whole story. We have discussed three lines of explanations that seem the most promising to us for future research: one focuses on the relationship between savings and growth, the second one gives the key role to trade, while the last one emphasizes domestic financial underdevelopment. It seems important to know more about which channels explain the puzzling behavior of capital flows to developing countries if one wants to understand how international financial integration helps economic development.

Levine (1993)). However one must control for the initial level of development. The least developed countries tend to be less developed financially, but they have more scope for catching up.

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Average Investment Rate (percent of output)	(1) Total $\bar{s}_k$	(2) Convergence	(3) Productivity	(4) Trend	(5) Wedge τ	(6) Catch-up π	(7) Obs.
Non-OECD countries	13.47	0.13	-0.93	14.27	11.58	-0.10	69
Low Income	8.56	-0.14	-1.56	10.26	18.76	-0.22	27
Lower Middle Income	14.06	0.29	-1.64	15.42	8.84	-0.15	23
Upper Middle Income	15.69	0.40	-1.35	16.64	6.13	-0.06	13
High Income (Non-OECD)	28.52	0.20	5.52	22.79	1.62	0.54	6
Africa	10.27	-0.66	-1.20	12.12	16.00	-0.17	32
Latin-America	13.40	0.39	-2.67	15.69	8.50	-0.24	20
Asia	19.59	1.34	1.61	16.64	6.90	0.19	17
except China and India	13.40	0.13	-1.05	14.33	11.62	-0.12	67
China and India	15.76	0.40	3.02	12.34	10.35	0.53	2
except Africa	16.24	0.82	-0.70	16.13	7.77	-0.04	37

Table 1: Decomposition of Average Investment Rates between 1980 and 2000, percent of GDP. Convergence: $\frac{1}{T}\frac{\tilde{k}^* - \tilde{k}_0}{\tilde{y}_0}$; Productivity: $\frac{\pi}{T}\tilde{k}^{*(1-\alpha)}g^*n$; Trend: $\tilde{k}^{*(1-\alpha)}(g^*n + \delta - 1)$. Unweighted country averages.

Capital Flows (percent of initial output)	(1) $\Delta D/Y_0$	(2) $\Delta D^p/Y_0$ (3)–(6)	(3) $\Delta D^c/Y_0$	(4) $\Delta D^i/Y_0$	(5) $\Delta D^s/Y_0$	(6) $\Delta D^t/Y_0$	(7) $\Delta D^n/Y_0$ (3)+(4)+(6)	(8) Obs.
Non-OECD countries	32.77	-255.21	7.13	-28.77	-260.06	26.49	4.85	69
Low Income	58.08	-491.94	-11.04	-50.47	-457.39	26.96	-34.55	27
Lower Middle Income	37.02	-358.64	17.38	-62.62	-338.16	24.76	-20.48	23
Upper Middle Income	12.94	-80.48	22.85	-40.99	-98.65	36.31	18.18	13
High Income (Non-OECD)	-54.43	827.99	15.50	225.15	577.59	9.75	250.40	6
Africa	40.97	-452.75	-28.14	-42.38	-410.36	28.14	-42.39	32
Latin-America	36.89	-478.74	20.96	-100.07	-435.02	35.40	-43.72	20
Asia	12.48	379.61	57.25	80.75	228.69	12.92	150.92	17
except China and India	33.65	-289.49	7.00	-33.85	-289.89	27.24	0.39	67
China and India	3.21	893.39	11.39	141.57	739.14	1.29	154.25	2
except Africa	25.67	-84.36	37.63	-16.99	-130.07	25.07	45.71	37

Table 2: Predicted and actual capital flows between 1980 and 2000, in percent of initial output. $\Delta D/Y_0$ is the observed ratio. Predicted capital flows $\Delta D^p/Y_0$ given by (10). Convergence component $\Delta D^c/Y_0$ given by (11). Investment component $\Delta D^i/Y_0$ given by (13). Saving component $\Delta D^s/Y_0$ given by (14). Trend component $\Delta D^t/Y_0$ given by (12). Linear specification for $f(.)$: $f(t) = min(t/T, 1)$. Unweighted country averages.

Capital Flows (percent of initial output)	(1) $\Delta D/Y_0$	(2) $\Delta D^p/Y_0$ (3)–(6)	(3) $\Delta D^c/Y_0$	(4) $\Delta D^i/Y_0$	(5) $\Delta D^s/Y_0$	(6) $\Delta D^t/Y_0$	(7) $\Delta D^n/Y_0$ (3)+(4)+(6)	(8) Obs.
Non-OECD countries	38.79	-310.53	12.24	-39.10	-311.35	27.68	0.82	62
Low Income	61.55	-504.76	-9.72	-42.09	-478.62	25.67	-26.14	22
Lower Middle Income	43.33	-396.42	17.51	-68.68	-370.83	25.58	-25.59	23
Upper Middle Income	20.95	-130.74	24.40	-50.23	-142.43	37.51	11.69	13
High Income (Non-OECD)	-54.51	667.36	63.18	183.59	401.72	18.86	265.64	4
Africa	40.68	-511.50	-22.81	-50.09	-466.33	27.72	-45.17	28
Latin-America	47.79	-544.93	20.77	-111.53	-492.28	38.11	-52.65	19
Asia	23.86	361.53	66.85	73.15	207.14	14.40	154.39	15
except China and India	39.98	-349.95	12.27	-45.04	-345.75	28.56	-4.21	60
China and India	3.06	872.27	11.29	139.03	720.63	1.33	151.64	2

Table 3: Predicted and Actual Capital Flows between 1980 and 2000, in percent of initial output. The predicted capital flows are computed using the model with non-reproducible capital. Unweighted country averages.

Official Aid Capital Flows (percent of initial output)	(1) $\Delta D'/Y_0$	(2) $\Delta B/Y_0$	(3) $\Delta D^p/Y_0$	(4) $\Delta D^n/Y_0$	(5) Obs.
Non-OECD countries	-23.17	58.43	-275.96	1.71	68
Low Income	58.08	106.34	-491.94	-34.55	27
Lower Middle Income	37.02	35.39	-358.64	-20.48	23
Upper Middle Income	12.94	15.88	-80.48	18.18	13
High Income (Non-OECD)	-54.46	16.31	762.39	256.78	5
Africa	-45.16	86.13	-452.75	-42.39	32
Latin-America	13.59	23.30	-478.74	-43.72	20
Asia	-25.16	46.92	331.08	146.69	16
except China and India	-23.64	59.86	-311.40	-2.91	66
China and India	3.21	10.96	893.39	154.25	2

Table 4: Predicted and Actual Capital Flows between 1980 and 2000, percent of initial output.

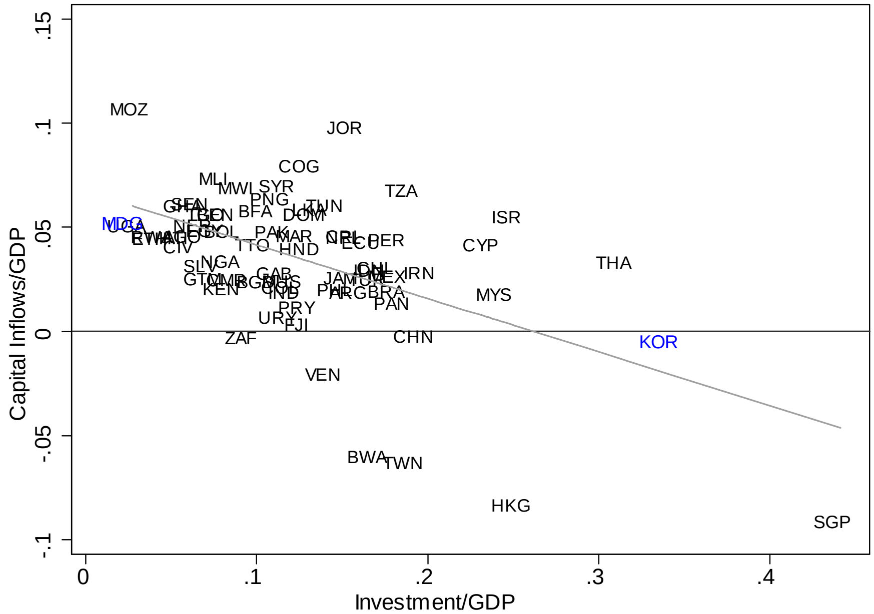

Figure 1: Average ratios of capital inflows and investment rates to GDP, 1980-2000.

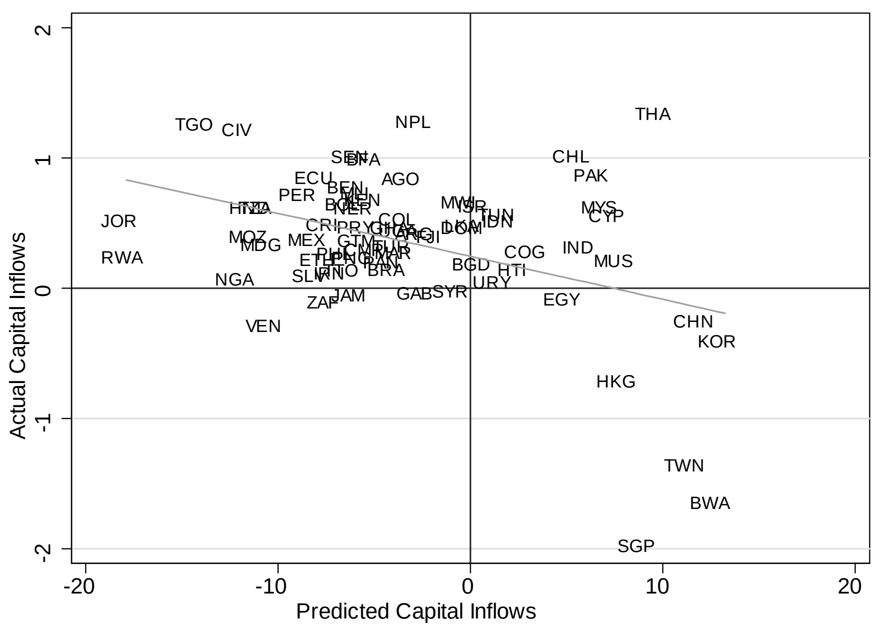

Figure 2: Predicted and actual capital inflows (as a share of initial GDP), 1980-2000.

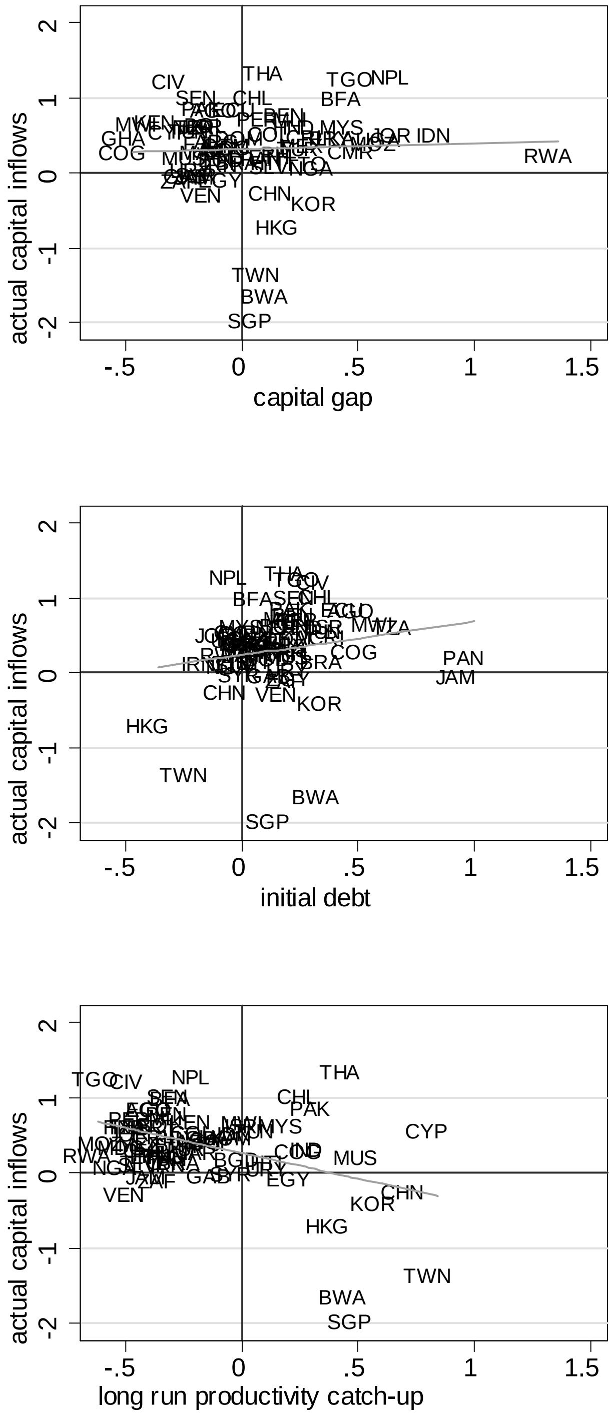

Figure 3: Actual capital inflows (as a share of initial GDP) against their determinants: capital gap $(k^* - k_0)/k_0$, initial debt to GDP ratio (d_0/y_0), and productivity catch-up (π), 1980-2000.

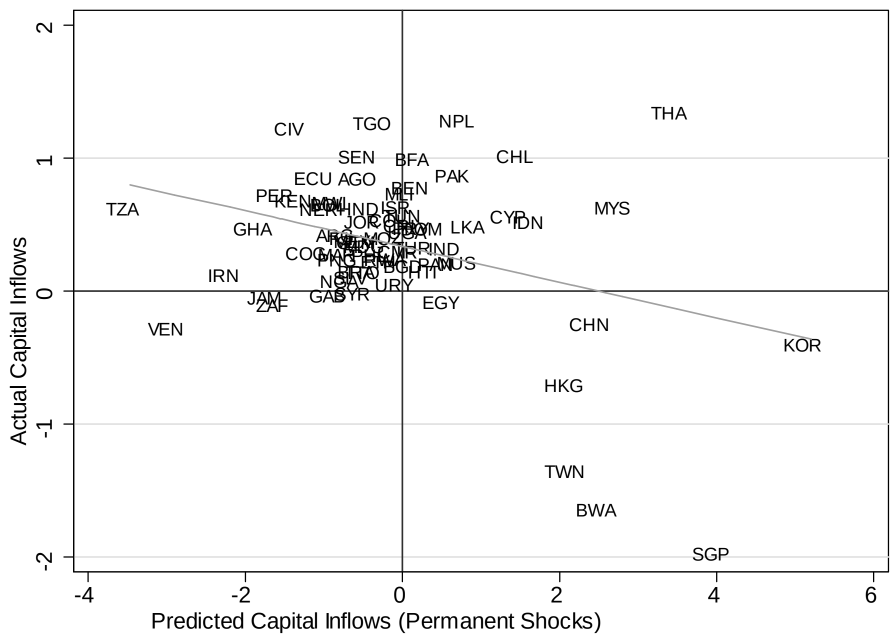

Figure 4: Predicted and actual capital inflows (as a share of initial GDP). Model with permanent productivity shocks. 1980-2000.

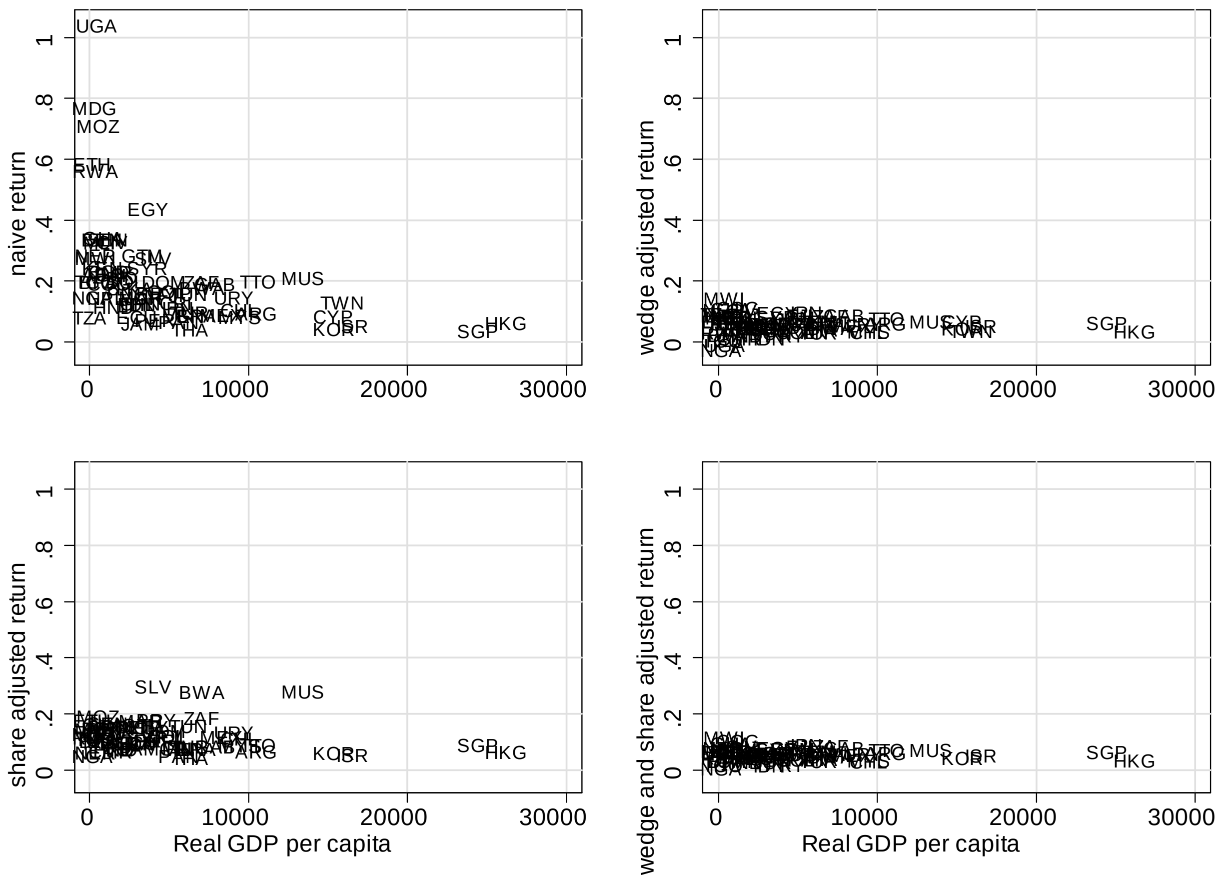

Figure 5: Various estimates of the private return on capital, 1980-2000.

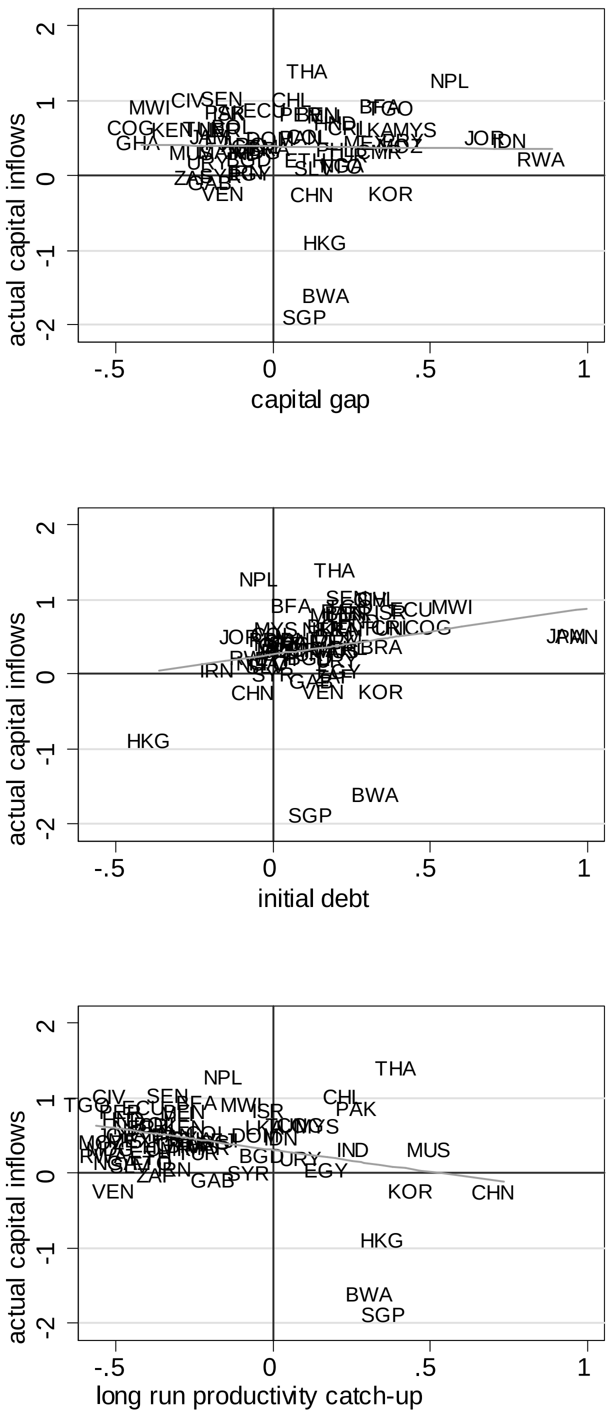

Figure 6: Actual land-adjusted capital inflows (as a share of initial GDP) against their determinants: capital gap $(k^* - k_0)/k_0$, initial debt to GDP ratio (d_0/y_0), and productivity catch-up (π), 1980-2000. Adjusted labor share.

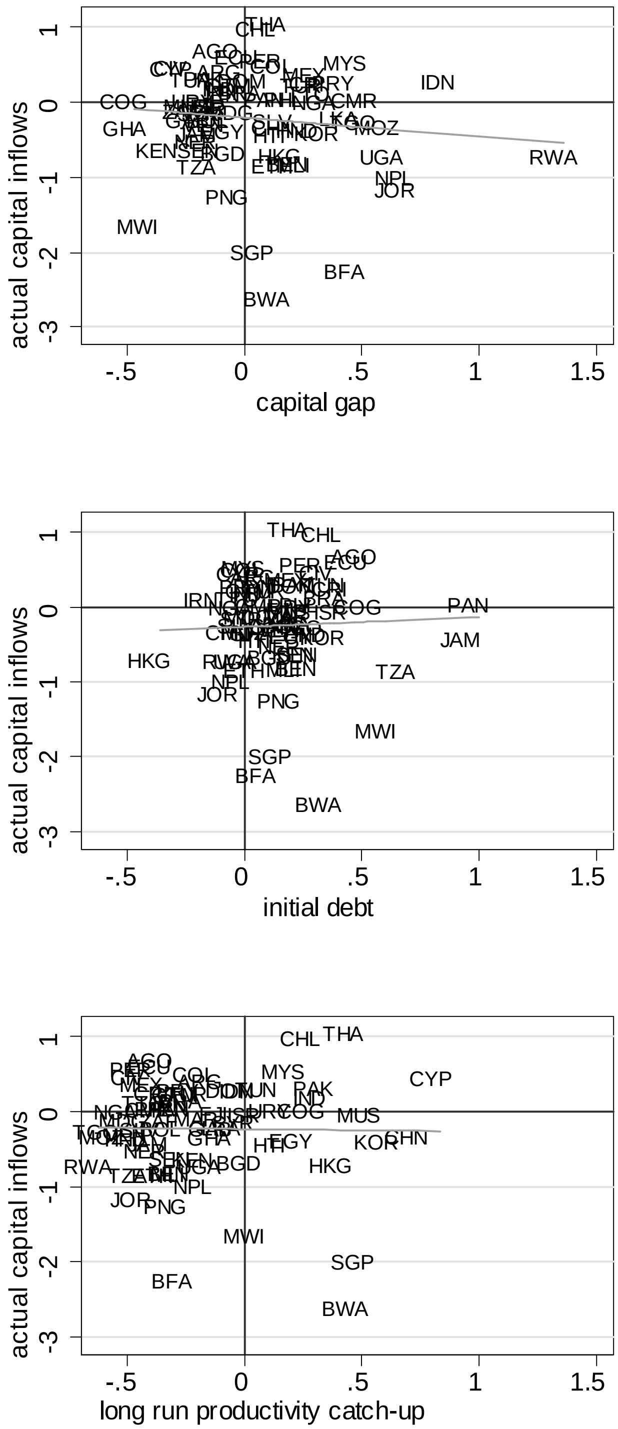

Figure 7: Observed aid-adjusted capital inflows (as a share of initial GDP) against their determinants: capital gap $(k^* - k_0)/k_0$, initial debt to GDP ratio (d_0/y_0), and productivity catch-up (π), 1980-2000.

A Proofs

A.1 Proof of Proposition 1.

The ratio of the debt increase to initial GDP is given by,

$$\frac{\Delta D}{Y_0} = \frac{D_T - D_0}{Y_0} = \frac{\widetilde{d}_T A_T N_T - \widetilde{d}_0 A_0 N_0}{A_0 N_0 \widetilde{k}_0^{\alpha}} = \frac{\widetilde{d}_T (g^* n)^T (1+\pi) - \widetilde{d}_0}{\widetilde{k}_0^{\alpha}}. \tag{19}$$

At the beginning of time 0 external debt jumps from $\widetilde{d}_0$ to $\widetilde{d}_0^+ = \widetilde{d}_0 + \widetilde{k}^* - \widetilde{k}_0$ to finance the initial capital gap. Note that although output is produced with the equilibrium level of capital $\widetilde{k}^*$ from period 0 onward, we normalize debt by the level of output before capital has jumped to $\widetilde{k}^*$.

We then compute $\widetilde{d}_T$. Let us denote by $g_t = A_t/A_{t-1}$ the growth rate of productivity. Dividing the budget constraint (4) by $N_t A_t$ and using $N_{t+1}/N_t = n$, $A_{t+1}/A_t = g_{t+1}$, $\widetilde{k}_t = \widetilde{k}^*$ gives

$$\widetilde{c}_t + n g_{t+1} \widetilde{k}^* + R^* \widetilde{d}_t = R^* \widetilde{k}^* + n g_{t+1} \widetilde{d}_{t+1} + \widetilde{w} + \widetilde{z}, \tag{20}$$

where the wage and transfer per efficiency unit of labor are constant and given by $\widetilde{w} = (1-\alpha)\widetilde{k}^{*\alpha}$ and $\widetilde{z} = \frac{\tau}{1-\tau} R^* \widetilde{k}^*$.

After time T the economy is in a steady growth path with $g_{t+1} = g^*$, $\widetilde{d}_t = \widetilde{d}_T$ and $\widetilde{c}_t = \widetilde{c}_T$. Equation (20) implies

$$\widetilde{d}_T = \widetilde{k}^* + \frac{\widetilde{w} + \widetilde{z} - \widetilde{c}_T}{R^* - n g^*}. \tag{21}$$

The next step is to compute $\widetilde{c}_T = c_T/A_T = c_0 g^{*t}/(1+\pi)A_0 g^{*t} = \widetilde{c}_0/(1+\pi)$. The level of net wealth per capita at the beginning of period 0 is $k^* - d_0^+ = k_0 - d_0$. Integrating the budget constraint (20) gives the intertemporal budget constraint,

$$\sum_0^{+\infty} \left(\frac{n}{R^*}\right)^t c_t = \sum_0^{+\infty} \left(\frac{n}{R^*}\right)^t (w_t + z_t) + R^*(k_0 - d_0).$$

Using $c_t = A_0 \widetilde{c}_0 g^{*t}$ and $w_t + z_t = (\widetilde{w} + \widetilde{z}) A_0 (1+\pi_t) g^{*t}$ this equation implies

$$\widetilde{c}_0 = (R^* - n g^*) \left(\frac{1}{R^*} \sum_{t=0}^{+\infty} \left(\frac{n g^*}{R^*}\right)^t (1+\pi_t)(\widetilde{w} + \widetilde{z}) + \widetilde{k}_0 - \widetilde{d}_0 \right). \tag{22}$$

Using this expression to substitute out $\widetilde{c}_T = \widetilde{c}_0/(1+\pi)$ from (21) gives

$$\widetilde{d}_T = \widetilde{k}^* - \frac{\widetilde{k}_0 - \widetilde{d}_0}{1+\pi} + \frac{1}{1+\pi} \frac{\widetilde{w} + \widetilde{z}}{R^*} \sum_{t=0}^{T-1} \left(\frac{n g^*}{R^*}\right)^t (\pi - \pi_t). \tag{23}$$

Finally, using this expression to substitute out $\widetilde{d}_T$ from (19) gives the expression in Proposition 1.
■

A.2 Comparing different measures of capital inflows.

In the main text we measured capital inflows by the ratio of cumulated capital inflows to intial GDP:

$$m_1 = \frac{D_T - D_0}{Y_0}.$$

Our results are robust to using other measures of foreign borrowing. For example, capital inflows could be measured as the average ratio of net capital inflows to GDP over the period $[0, T]$,

$$m_2 = \frac{1}{T} \sum_{t=0}^{T-1} \frac{D_{t+1} - D_t}{Y_t}. \tag{24}$$

This is the measure we used to introduce the allocation puzzle in Figure 1. Another possible measure of capital inflows is the change in the ratio of net foreign liabilities to GDP between time 0 and time T,

$$m_3 = \frac{D_T}{Y_T} - \frac{D_0}{Y_0}. \tag{25}$$

We show that these measures are all increasing with the productivity catch-up π, under assumptions 1 and 2 and the additional requirement that $f(t)$ increases with t. We have already shown this property for m_1. We now show that m_2 and m_3 are also increasing with π. First we derive a closed-form expression for $\widetilde{d}_t$ and show that it is increasing with π for any time t. The budget constraint (20) can be rewritten:

$$\widetilde{d}_t - \widetilde{k}^* = \frac{ng^*}{R^*} \frac{1 + \pi f(t+1)}{1 + \pi f(t)} \left(\widetilde{d}_{t+1} - \widetilde{k}^* \right) + \frac{\widetilde{w} + \widetilde{z} - \widetilde{c}_t}{R^*}.$$

Iterating forward then gives:

$$\widetilde{d}_t = \widetilde{k}^* + \sum_{s=0}^{+\infty} \left(\frac{ng^*}{R^*} \right)^s \frac{1 + \pi f(t+s)}{1 + \pi f(t)} \frac{\widetilde{w} + \widetilde{z} - \widetilde{c}_{t+s}}{R^*}.$$

Then using $(1 + \pi f(t+s))\widetilde{c}_{t+s} = \widetilde{c}_0$ and expression (22), one can substitute out $\widetilde{c}_0$ from the expression above to obtain,

$$\widetilde{d}_t = \widetilde{k}^* + \frac{\pi}{1 + \pi f(t)} \sum_{s=0}^{+\infty} \left(\frac{ng^*}{R^*} \right)^s \left(f(t+s) - f(s) \right) \frac{\widetilde{w} + \widetilde{z}}{R^*} - \frac{\widetilde{k}_0 - \widetilde{d}_0}{1 + \pi f(t)}, \tag{26}$$

which is increasing with π, for any t, provided that the second term is positive and the third term is negative. The second term is positive because $f(\cdot)$ is increasing monotonically. The third term is negative if external debt is not larger than the stock of capital at time 0 ($\widetilde{d}_0 \leq \widetilde{k}_0$).

Next, let us show that m_2 and m_3 are increasing with π. This is very easy to show for m_3 since

$$m_3 = \frac{\widetilde{d}_T}{\widetilde{k}^{*\alpha}} - \frac{\widetilde{d}_0}{\widetilde{k}_0^{\alpha}}.$$

The only term that depends on π is $\widetilde{d}_T$, which is increasing with π. Measure m_2 can be written

$$m_2 = \sum_{t=0}^{T-1} (g_{t+1}\widetilde{d}_{t+1} - \widetilde{d}_t).$$

Then using $g_{t+1} = g^*(1 + \pi f(t+1))/(1 + \pi f(t))$ and (26) to substitute out $\widetilde{d}_t$ and $\widetilde{d}_{t+1}$ we obtain (after some manipulations):

$$\begin{aligned} g_{t+1}\widetilde{d}_{t+1} - \widetilde{d}_t &= \left(g^* \frac{1+\pi f(t+1)}{1+\pi f(t)} - 1\right)\widetilde{k}^* + \frac{\pi}{1+\pi f(t)} \sum_{s=0}^{+\infty} \left(\frac{ng^*}{R^*}\right)^s (g^*(f(t+1+s) - f(s)) \\ &\quad - (f(t+s) - f(s)) \frac{\widetilde{w} + \widetilde{z}}{R^*} - (g^* - 1)\frac{\widetilde{k}_0 - \widetilde{d}_0}{1+\pi f(t)}. \end{aligned}$$

On can check that all the terms on the righ-hand side are increasing with π. Hence m_2 is increasing with π too.

The predictions of the model, therefore, are qualitatively the same for the three measures of capital flows. However, there is a sense in which those predictions are more robust for measure (9) than for measures (24) and (25). If the allocation puzzle is observed with measure (9) then it must also hold with the two other measures. The opposite may not be true. This is another reason to use measure (9) as a benchmark when we look at the data.

We will now assume that m_1, m_2 and m_3 are functions of π that could be different from the functions derived in the model. One could say that the puzzle is stronger with measure 1 than with measure 2 if having the puzzle for measure 1 implies that we have it for measure 2 too, i.e., if the fact that m_1 is decreasing with π implies that m_2 is also decreasing with π. We denote this relationship by $m_1 \succ m_2$. Then, under the simplifying assumption that debt accumulation is a constant fraction of GDP (that is $D_{t+1} - D_t = m_2 Y_t$ for $t = 0, .., T-1$), we can establish the following ordering,

$$m_1 \succ m_2 \succ m_3.$$

Using $Y_t = (1 + \pi f(t))n^t Y_0$ we have

$$D_T = D_0 + m_2 Y_0 \sum_{s=0}^{T-1} (1 + \pi f(s))(g^* n)^s.$$

Using the definition of m_1 we have

$$m_1 = \frac{D_T - D_0}{Y_0} = m_2 \sum_{s=0}^{T-1} (1 + \pi f(s))(g^* n)^s.$$

It follows that if m_1 is decreasing with π, so is m_2, which establishes $m_1 \succ m_2$. As for m_3 it can be written,

$$
\begin{aligned}
m_3 &= \frac{D_0 + m_2 Y_0 \sum_{s=0}^{T-1} (1+\pi f(s))(g^* n)^s}{(1+\pi)(g^* n)^T Y_0} - \frac{D_0}{Y_0}, \\
&= \frac{D_0}{Y_0}\left(\frac{1}{(1+\pi)(g^* n)^T} - 1\right) + m_2 \sum_{s=0}^{T-1} \frac{1+\pi f(s)}{1+\pi}(g^* n)^{s-T}.
\end{aligned}
$$

If m_2 is decreasing with π, so is m_3, which establishes $m_2 \succ m_3$.

A.3 Proof of Proposition 2.

For $t \geq 1$ we have

$$
s_{kt} = \frac{K_{t+1} - (1-\delta) K_t}{Y_t} = \frac{A_{t+1} N_{t+1} \widetilde{k}^* - (1-\delta) A_t N_t \widetilde{k}^*}{A_t N_t \widetilde{k}^{*\alpha}} = (g_{t+1} n + \delta - 1) \widetilde{k}^{*(1-\alpha)}.
$$

In period 0 this expression is augmented by a term reflecting that the level of capital per efficiency unit of labor jumps up from $\widetilde{k}_0$ to $\widetilde{k}^*$ at the beginning of the period,

$$
s_{k0} = (g_1 n + \delta - 1) \widetilde{k}^{*(1-\alpha)} + \frac{K_0^* - K_0}{Y_0} = (g_1 n + \delta - 1) \widetilde{k}^{*(1-\alpha)} + \frac{\widetilde{k}^* - \widetilde{k}_0}{\widetilde{k}_0^\alpha}.
$$

The average investment rate between $t = 0$ and $t = T - 1$ can be written,

$$
\begin{aligned}
\bar{s}_k &= \frac{1}{T} \sum_{t=0}^{t=T-1} s_{kt} = \frac{1}{T} \frac{\tilde{k}^* - \tilde{k}_0}{\tilde{k}_0^\alpha} + \frac{1}{T} \sum_{t=0}^{t=T-1} (g_{t+1} n + \delta - 1) \tilde{k}^{*(1-\alpha)}, \\
&= \frac{1}{T} \frac{\tilde{k}^* - \tilde{k}_0}{\tilde{k}_0^\alpha} + (\bar{g} n + \delta - 1) \tilde{k}^{*(1-\alpha)}, \\
&= \frac{1}{T} \frac{\tilde{k}^* - \tilde{k}_0}{\tilde{k}_0^\alpha} + (\bar{g} - g^*) n \tilde{k}^{*(1-\alpha)} + (g^* n + \delta - 1) \tilde{k}^{*(1-\alpha)},
\end{aligned}
$$

where $\bar{g} = \frac{1}{T} \sum_{t=0}^{t=T-1} g_{t+1}$ is the average productivity growth rate. Under the additional assumption that π is small, $\bar{g}$ can be expressed as a function of π as

$$
\begin{aligned}
\bar{g} &= g^* \frac{1}{T} \sum_{t=0}^{t=T-1} \frac{1+\pi_{t+1}}{1+\pi_t}, \\
&\approx g^* \frac{1}{T} \sum_{t=0}^{t=T-1} (1 + \pi_{t+1} - \pi_t), \\
&= g^* \left(1 + \frac{\pi}{T}\right),
\end{aligned}
$$

where the first line uses the definition of π_t, and the last equality uses $\pi_T = \pi$ and $\pi_0 = 0$. We can then write $\bar{s}_k$ as

$$\bar{s}_k = \frac{1}{T}\frac{\tilde{k}^* - \tilde{k}_0}{\tilde{k}_0^\alpha} + \frac{\pi}{T}\tilde{k}^{*(1-\alpha)}g^*n + (g^*n + \delta - 1)\,\tilde{k}^{*(1-\alpha)}.$$

■

A.4 Proof of Proposition 3.

The proof is similar to that of Proposition 1. The only difference is that the consumption path is determined as if future productivity were growing at rate g^*. This implies that consumption at time t is given by an equation similar to (22) with π set to zero:

$$\begin{aligned}\widetilde{c}_t &= (R^* - ng^*)\left(\frac{1}{R^*}\sum_{t=0}^{+\infty}\left(\frac{ng^*}{R^*}\right)^t(\widetilde{w} + \widetilde{z}) + \widetilde{k}^* - \widetilde{d}_t\right), \\ &= \widetilde{w} + \widetilde{z} + (R^* - ng^*)(\widetilde{k}^* - \widetilde{d}_t).\end{aligned}$$

Using this expression to substitute $\widetilde{c}_t$ out of (20) gives,

$$\begin{aligned}\widetilde{k}^* - \widetilde{d}_{t+1} &= \frac{g^*}{g_{t+1}}(\widetilde{k}^* - \widetilde{d}_t), \\ &= \frac{1 + \pi f(t)}{1 + \pi f(t+1)}(\widetilde{k}^* - \widetilde{d}_t).\end{aligned}$$

Iterating from $t = 0$ to $t = T$ gives

$$\widetilde{k}^* - \widetilde{d}_T = \frac{1}{1+\pi}(\widetilde{k}^* - \widetilde{d}_0^+) = \frac{1}{1+\pi}(\widetilde{k}_0 - \widetilde{d}_0).$$

Using this expression to substitute out $\widetilde{d}_T$ from (19) gives (16). ■

B Measuring PPP-adjusted Capital Flows.

For a given country, data expressed in constant international dollars (the unit used in the Penn World Tables for real variables) can be converted into current US dollars by multiplying them by the deflator,

$$Q_t = P_t\frac{CGDP_t}{RGDP_t},$$

where $CGDP_t$ ($RGDP_t$) is domestic GDP expressed in current (constant) international dollar and P_t is a price deflator. The ratio $CGDP/RGDP$ operates the conversion from constant international dollar into current international dollar, and P operates the conversion from current international dollar into current US dollar. We define the deflator P as the price of investment goods reported in the Penn World Tables, for reasons given in section 3.2. Multiplying a variable in constant international dollar, X, by the deflator Q gives its value in terms of current US dollars, $X^\$ = QX$.

The deflator Q can be used to obtain PPP-adjusted estimates of the observed cumulated capital inflows ΔD. To do this, we start from the external accumulation equation (in current US dollars):

$D_T^\$ = D_0^\$ - \sum_{t=0}^{T-1} CA_t^\$$,[29] and use the formulas $D_T = D_T^\$/Q_T$ and $D_0 = D_0^\$/Q_0$ to obtain:

$$\Delta D = \left(\frac{1}{Q_T} - \frac{1}{Q_0}\right) D_0^\$ - \sum_{t=0}^{T-1} \frac{CA_t^\$}{Q_T}. \tag{27}$$

The estimate of the initial net external debt in US dollar ($D_0^\$$) is obtained from Lane and Milesi-Ferretti (2006)'s External Wealth of Nations Mark II database (EWN), as the difference between (the opposite of) the reported net international investment position (NIIP) and the cumulated errors and omissions (EO) cumulated between 1970 and 1980.[30] The same approach is used to construct estimates of the initial debt output ratio d_0/y_0, which we need to compute the right-hand-side of (10).

To obtain PPP-adjusted cumulated aid flows, we compute:

$$\frac{\Delta B}{Y_0} = \sum_{t=0}^{T-1} \frac{NODA_t^\$}{Y_0 Q_T},$$

where $NODA_t^*$ is the current U.S. dollar value of the net overseas assistance in year t from all donors. We can then construct a measure of cumulated flows, net of official aid flows:

$$\frac{\Delta D'}{Y_0} = \frac{\Delta D - \Delta B}{Y_0} = \left(\frac{1}{Q_T} - \frac{1}{Q_0}\right) \frac{D_0^\$}{Y_0} - \sum_{t=0}^{T-1} \frac{CA_t^\$ + NODA_t^\$}{Y_0 Q_T}.$$

[29] Alternatively, one could use Lane and Milesi-Ferretti (2006)'s estimate of the net external position in year 2000. The difference between the two estimates lies in the treatment of valuation effects due to asset price and currency movements. The size and relative importance of these valuation effects has increased over time. We do not attempt to incorporate these effects in this paper.

[30] In keeping with usual practice, we interpret errors and omissions as unreported capital inflows.

C Data

Table 5: Data for 66 non-OECD countries, as well as Korea, Mexico and Turkey. The last three columns report the share of reproducible capital income α_k, the naive (RN) and wedge-adjusted (RW) returns for the case with non-reproducible capital described in section 4.2.

Country	Start	End	s_k(%)	g(%)	n(%)	τ(%)	π	α_k	RN(%)	RW(%)
Angola	1985	1996	6.16	-2.32	2.85	12.92	-0.36	.	.	.
Argentina	1980	2000	15.84	0.83	1.49	2.90	-0.15	0.25	6.61	6.14
Bangladesh	1980	2000	10.41	1.73	2.62	13.99	0.02	0.22	15.48	6.02
Benin	1980	2000	8.00	-0.00	3.02	19.41	-0.28	0.16	14.84	6.99
Bolivia	1980	2000	8.38	-0.23	2.46	12.51	-0.32	0.19	9.87	5.28
Botswana	1980	1999	16.95	3.84	3.56	11.07	0.47	0.43	27.71	4.79
Brazil	1980	2000	18.00	0.43	2.38	2.70	-0.23	0.28	7.50	5.88
Burkina Faso	1980	2000	10.33	0.11	2.41	14.50	-0.27	0.19	10.33	3.27
Cameroon	1980	1995	8.72	-1.22	2.80	17.74	-0.37	0.13	6.75	3.28
Chile	1980	2000	17.32	2.88	1.85	6.57	0.28	0.32	11.36	3.22
China	1982	2000	19.58	4.81	1.82	7.69	0.74	0.26	10.40	4.26
Colombia	1980	2000	11.79	0.74	2.61	11.42	-0.18	0.24	12.14	3.73
Congo, Rep.	1980	2000	12.95	3.17	2.90	6.78	0.28	0.21	11.88	10.18
Costa Rica	1980	2000	15.30	-0.58	3.02	6.21	-0.36	0.22	7.81	5.80
Cyprus	1980	1996	23.57	5.59	1.08	1.43	0.84	.	.	.
Côte d'Ivoire	1980	2000	5.74	-1.40	3.70	17.09	-0.46	0.15	13.71	8.45
Dominican Republic	1980	2000	13.26	1.57	2.61	9.82	-0.02	0.23	13.83	7.52
Ecuador	1980	2000	16.50	-0.47	3.08	3.40	-0.27	0.34	9.75	4.29
Egypt, Arab Rep.	1980	2000	7.42	2.73	2.62	23.81	0.24	0.13	15.26	7.89
El Salvador	1980	2000	7.10	-1.01	2.28	16.90	-0.41	0.32	29.54	6.03
Ethiopia	1980	2000	4.17	-0.50	2.61	32.68	-0.35	0.11	17.74	6.57
Fiji	1980	1999	12.64	1.10	1.65	5.83	-0.10	0.25	12.04	8.39
Gabon	1980	2000	11.53	1.14	2.44	8.61	-0.10	0.17	8.45	7.86
Ghana	1980	2000	6.11	1.14	3.40	17.44	-0.10	0.16	16.11	9.36
Guatemala	1980	2000	7.35	0.26	2.76	18.65	-0.25	0.19	15.88	4.89
Haiti	1980	1998	5.46	2.25	2.09	31.63	0.14	.	.	.
Honduras	1980	2000	12.91	-1.26	3.44	8.35	-0.46	0.23	7.37	2.84
Hong Kong, China	1980	2000	25.31	3.56	1.87	2.49	0.41	0.31	6.41	3.52
India	1980	2000	11.95	3.04	2.33	13.01	0.31	0.15	7.43	5.73
Indonesia	1981	2000	16.91	1.74	2.46	9.75	0.00	0.26	9.51	1.71
Iran, Islamic Rep.	1980	2000	19.84	-0.07	3.10	1.20	-0.28	0.24	7.76	9.10
Israel	1980	2000	24.97	1.88	2.72	0.09	0.03	0.31	5.52	5.26

continued on next page

Table 5 continued from previous page

Country	Start	End	$s_k(\%)$	$g(\%)$	$n(\%)$	$\tau(\%)$	π	α_k	$RN(\%)$	$RW(\%)$
Jamaica	1980	2000	15.39	-0.62	1.80	0.25	-0.37	0.34	7.70	5.84
Jordan	1980	2000	15.57	-1.12	5.09	9.98	-0.44	0.31	15.22	2.91
Kenya	1980	2000	8.33	0.76	3.70	14.43	-0.18	0.19	13.22	6.39
Korea, Rep.	1980	2000	34.05	4.13	1.83	-0.08	0.61	0.35	6.12	4.32
Madagascar	1980	2000	2.75	-1.50	2.84	38.59	-0.47	0.07	12.71	6.92
Malawi	1980	2000	9.24	1.84	2.64	10.56	0.04	0.18	14.50	11.54
Malaysia	1980	2000	24.42	2.65	3.07	4.31	0.21	0.31	8.74	3.54
Mali	1980	2000	7.83	-0.08	2.44	18.46	-0.29	0.12	9.80	7.19
Mauritius	1980	2000	11.96	3.85	1.62	11.66	0.53	0.38	27.99	9.08
Mexico	1980	2000	18.13	-0.74	2.95	3.34	-0.39	0.36	11.75	5.38
Morocco	1980	2000	12.74	0.86	2.75	7.91	-0.16	0.34	17.46	5.62
Mozambique	1980	2000	3.07	-2.52	1.93	36.89	-0.56	0.10	19.16	6.81
Nepal	1980	2000	15.45	0.64	2.29	8.65	-0.18	0.24	10.31	4.65
Niger	1980	1995	6.65	-1.58	3.28	13.88	-0.38	0.11	6.19	7.89
Nigeria	1980	2000	8.31	-1.82	2.93	14.90	-0.50	0.16	4.98	0.69
Pakistan	1980	2000	11.34	3.20	2.57	14.14	0.34	0.22	14.82	5.02
Panama	1980	2000	18.36	0.09	2.64	3.00	-0.28	0.27	5.11	3.69
Papua New Guinea	1980	1999	11.18	-0.19	2.86	9.34	-0.29	.	.	.
Paraguay	1980	2000	12.78	0.31	3.23	11.90	-0.24	0.33	17.89	1.95
Peru	1980	2000	18.02	-1.20	2.63	1.14	-0.44	0.37	10.39	6.03
Philippines	1980	2000	14.95	-0.40	2.73	5.84	-0.34	0.35	15.17	5.92
Rwanda	1980	2000	4.34	-2.99	2.96	33.93	-0.62	0.08	11.55	4.54
Senegal	1980	2000	6.50	0.03	2.88	19.25	-0.28	0.17	16.68	7.31
Singapore	1980	1996	44.14	4.29	2.94	-2.48	0.50	0.47	9.05	6.54
South Africa	1980	2000	9.52	-0.25	2.86	9.24	-0.33	0.29	18.39	8.58
Sri Lanka	1980	2000	13.45	1.33	1.91	10.57	-0.06	0.20	9.41	5.19
Syrian Arab Republic	1980	2000	11.64	1.69	3.92	13.04	0.00	0.17	11.60	7.42
Taiwan	1980	1997	19.05	5.42	1.56	8.24	0.84	.	.	.
Tanzania	1980	2000	18.89	-1.39	3.27	-0.96	-0.46	.	.	.
Thailand	1980	2000	31.30	3.64	2.18	0.04	0.46	0.31	4.42	4.00
Togo	1980	2000	7.47	-2.71	2.92	16.06	-0.59	0.20	11.04	1.80
Trinidad and Tobago	1980	2000	10.18	-0.76	1.57	10.06	-0.39	0.18	9.09	7.02
Tunisia	1980	2000	14.41	2.19	2.89	7.83	0.09	0.30	15.81	6.80
Turkey	1980	2000	16.87	0.54	2.76	5.96	-0.21	0.28	8.32	3.31
Uganda	1980	2000	2.84	0.86	2.65	51.47	-0.15	.	.	.
Uruguay	1980	2000	11.65	2.37	0.66	7.61	0.15	0.29	13.46	5.85
Venezuela, RB	1980	2000	14.35	-1.48	2.86	1.71	-0.47	0.28	7.51	6.78