NEW EVIDENCE ON THE MARGINAL PRODUCT OF CAPITAL

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Why doesn't capital flow from rich to poor countries? This paper attempts to shed light on this crucial question by examining the role of capital market imperfections in accounting for perceived differences in the marginal product of capital (MPK) across countries. The model in this paper builds on the Ricardian trade model of Eaton and Kortum (2001, 2002) to derive predictions on the share of world expenditure in capital goods across countries based on differences in the probability that these countries have the highest MPK in the world. In contrast to recent evidence on MPKs across countries, empirical evidence supports the view that capital market imperfections are indeed important in explaining why capital does not flow from rich to poor countries.

JEL No. E22, F1, O11, O16, O33

1 Introduction

In his celebrated paper, Lucas (1990) poses the question "why doesn't capital flow from rich to poor countries". The simplest neoclassical model of trade and growth predicts that poor countries with low levels of capital relative to labour would offer high returns on investment and therefore attract capital flows from rich, capital abundant countries. However, as Lucas points out, poor countries are often lacking in factors of production that are complementary to capital, such as human capital, implying that the marginal product of capital in these countries is not likely to be as large as what simple differences in capital-labour ratios would suggest. While Lucas (1990) considers capital market imperfections as a candidate explanation for why capital does not flow to poor countries, he is sceptical that it is an important development issue relative to the need to foster accumulation of human capital.

In a recent paper, Caselli and Feyrer (2007) calculate the marginal product of reproducible capital (capital goods and structures) and find that they are roughly equalized across countries, both rich and poor. The authors draw a much stronger conclusion than Lucas (1990) as they find no evidence that capital market imperfections play a significant role in preventing capital flow from rich to poor countries.

We provide new evidence on this issue by calculating the marginal product of tradable capital goods (equipment and machinery) across countries. The focus on tradable capital goods enables the marginal product of capital (MPK) to be based on trade based estimates of capital good prices, rather than the commonly used survey based estimates of capital good prices constructed by the World Bank's International Comparison Program (ICP).

An interesting feature of the ICP estimates for capital goods is that they do not show any clear relationship with development, even though the vast majority of capital goods are sourced from a handful of developed countries. Indeed, according to the ICP, a country like Bangladesh is able to source capital goods at a price less than 50% of the price of capital goods in the USA. The combination of higher productivity in developed countries together with transport costs should give rise to a clear negative relationship between capital good prices and development.

A difficulty faced by the ICP in their surveys of capital good prices is the need to control for differences in quality. Unlike consumption goods, differences in capital good prices across countries will, in large part, reflect differences in their functionality and, hence, the quality of capital goods. To this extent the ICP's low capital good price estimate for Bangladesh might reflect a low average quality of capital goods in Bangladesh relative to developed countries.

Our trade based estimates of quality adjusted capital good prices show a clear negative relationship to levels of development. We find, taking this relationship into account, that developing countries tend to exhibit a higher marginal product of tradable capital goods compared to developed countries if the effect of capital market imperfections are ignored.

In order to make sense of this finding we investigate the role of capital market imperfections as a barrier to capital flows equating the MPK across countries. Banerjee and Duflo (2005) argue that credit markets are likely to function poorly in developing countries due to poor information systems, difficulty in enforcing contracts, a greater incentive of borrowers to cheat lenders, and political pressure to protect borrowers from lenders in these countries. Given these problems, the extent to which credit will be available will depend on the size of borrowers' collateral, the ability of lenders to monitor borrowers' activities, and many other borrower characteristics. In countries where capital markets are inefficient many high return investments may then be foregone leading to those countries exhibiting a higher perceived MPK. Differences in the perceived MPK might then be a result of differences in the imperfections of capital markets across countries.

To investigate this hypothesis we build on the Ricardian trade model of Eaton and Kortum (2002) to incorporate the potential for capital market imperfections to drive a wedge between MPKs across countries. This model relates cross country shares of world expenditure on capital goods to the probability that these countries have the highest MPK in the world. We then use this relationship to estimate the elasticity of the marginal product of capital goods with respect to our measure of capital market imperfections. As suggested by Levine, Loayza and Beck (2000), we use the exogenous component of the degree of financial intermediary imperfections across countries (in turn, measured by the inverse of the ratio of private credit to GDP) as a measure of the inefficiency of domestic capital markets. Financial intermediaries facilitate the flow of capital to where returns are the highest by lowering the costs of researching potential investments, exerting corporate control, managing risk, mobilizing savings and conducting exchanges.

Our results support the finding that capital market imperfections driven by low levels of financial intermediary sector development act as a significant barrier to flows of capital from rich to poor countries. One implication of this result is that development of domestic capital markets in poor countries will tend to increase investment and the stock of capital goods in these countries. To this extent these findings support the literature that links financial development to higher levels of income per capita. However, some degree of caution is needed in this regard as the data intensive nature of the approach in this paper heavily constrains sample size, especially in terms of the number of developing countries. Furthermore, whether or not the gains from reducing capital market imperfections outweigh the benefits from any forgone accumulation of human capital is a question that remains unanswered.

The rest of the paper proceeds as follows. The methodology and findings in Caselli and Feyrer (2007) and other papers that focus on the marginal product of capital are described in section 2. Section 3 presents the theory that underpins the econometric analysis. Section 4 describes the data and econometric results are presented in section 5. Section 6 concludes.

2 Previous evidence on MPK

Banerjee and Duflo (2005) provide a comprehensive review of much of the literature that attempts to examine differences in the MPK across countries. There are many different approaches in this regard. An indirect approach involves examining differences in interest rates across countries people are willing to pay, although financial distortions and the extent of default of loans in many developing make this measure problematic. Direct approaches to estimating the MPK tend to be at the firm level using an assumed production function and estimates of the size of factors complementary to capital. A clear finding of this literature is that estimates of very high rates of return on capital can be found in particular industries in some countries but it is highly unlikely that this finding is broadly representative within those countries.

In contrast, Caselli and Feyrer (2007) use a novel approach to estimate the aggregate MPK across countries. Their methodology is based on the standard one-sector neoclassical model with constant returns in production and perfectly competitive capital markets. While they consider a number of measures of the MPK, their preferred measure is,

(1) $$MPK_n^{CF} = \frac{\alpha_n P_n^Y Y_n}{P_n^K K_n},$$

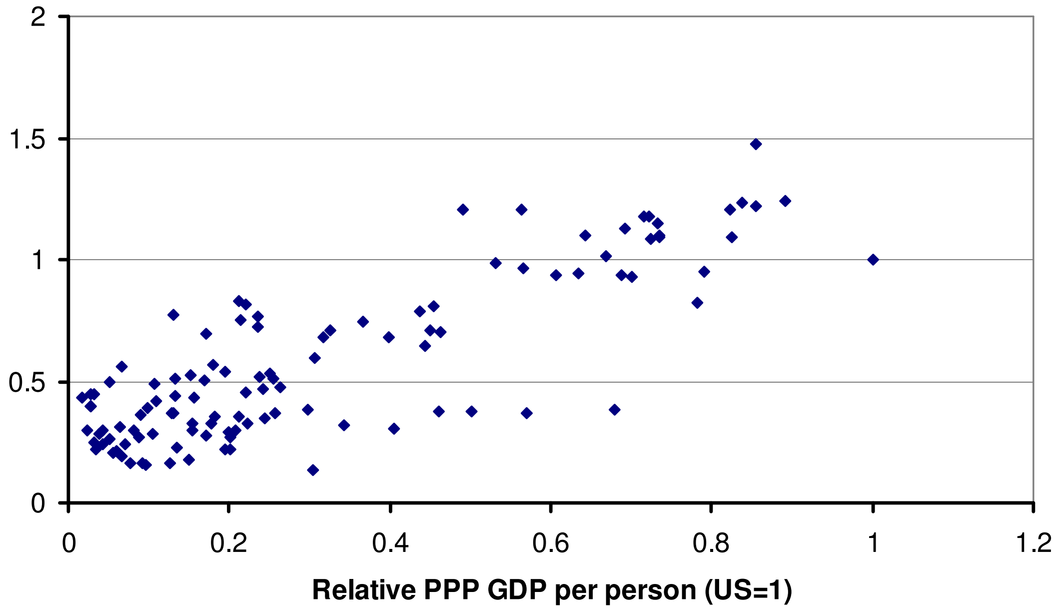
where α_n is country n's reproducible-capital share in income and P_n^Y / P_n^K is a measure of the average price of final goods relative to the price of reproducible capital in country n. The logic behind equation (1) is as follows. With perfect competition in the capital market, MPK is equal to the return on capital. Since the return on capital multiplied by the value of the capital stock is capital income then MPK can simply be recovered from data on the value of total income and the capital share in income.

Caselli and Feyrer (2007) use estimates of the parameters in equation (1) to calculate MPK_n^{CF} across countries. The objective of their research is to see whether or not less developed countries tend to exhibit higher levels of MPK_n^{CF} relative to rich countries.

Caselli and Feyrer (2007) use data from the Penn World Tables (6.1) and estimates of the non-reproducible-capital share in income (based on estimates from Bernake and Gurkaynak, 2001) to estimate (1) across countries. The authors broadly conclude that there is little difference in MPK_n^{CF} across rich and poor countries (in 1996) and, if anything, estimates of MPK_n^{CF} are slightly higher in rich countries. The implication that they draw from this finding is that increased aid flows to developing countries will not significantly increase capital stocks and incomes in these countries.

The finding the MPK is roughly equalized across countries is driven by the tendency of poor countries to have a low price of output relative to capital (see Figure 1) and a low reproducible-capital share in income which tends to offset the high ratio of output to the capital stock in these countries. However a potential problem in Caselli and Feyrer (2007) is the reliance on the ICP's survey data on capital prices which are used to construct cross country data on the international value of reproducible capital stocks.

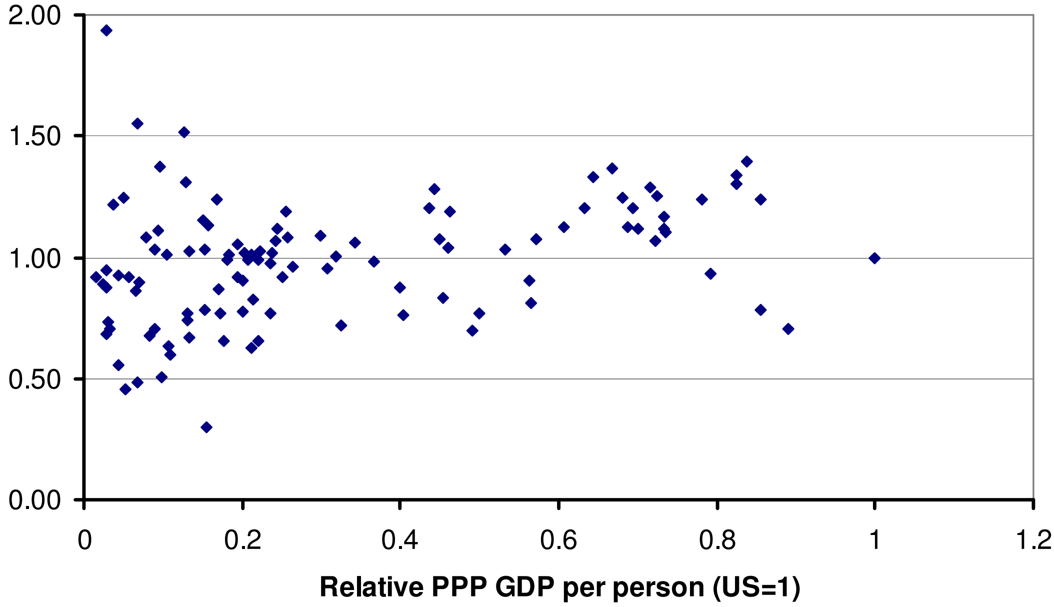
Figure 1: ICP Consumer prices for 1996 (USA = 1)



The ICP's producer durable price series (relevant for tradable capital goods) is shown in Figure 2. While there is no clear correlation between relative PPP GDP per person and the price of tradable capital goods, many developing countries have an estimated price substantially lower than developed countries. To some degree this may reflect a lower cost of retail and distribution in developing countries but this is unlikely to offset the international cost of shipping since most capital goods are produced in developed countries. Furthermore, to the extent that poor countries do produce capital goods domestically the low level of technology and productivity of this production is again unlikely to offset the cost of international shipping of capital goods from rich countries. Hence, on a quality adjusted basis, the validity of the ICP data on producer durable prices is questionable.

In the following section we use the methodology proposed by Eaton and Kortum (2001, 2002) to derive trade based estimates of the quality adjusted price of tradable capital goods. We then use these trade based estimates to provide new evidence on the MPK across countries.

Figure 2: ICP Producer Durable Prices for 1996 (USA = 1)



3 Theory

In this section we extend the Ricardian trade model of Eaton and Kortum (2001, 2002) to derive the likelihood that a country has the highest marginal product of capital goods and show that this is equal to the share of world expenditure on capital goods. Since we are interested in the potential for capital market imperfections to impact on the MPK across countries the approach in this section is to allow for a country's MPK to vary with the imperfections of its capital market. The importance of the imperfections of capital markets to investment in capital good decisions can then be estimated using the model's prediction that a country's share of world investment expenditure on capital goods is equal to the probability that it has the highest MPK in the world.

In order to highlight the implications of this approach, the model's prediction of capital good prices can be used to construct estimates of the MPK in the same way as Caselli and Feyrer (2007) – that is, by not accounting for the potential impact of capital market imperfections on the MPK. Since the Caselli and Feyrer (2007) approach does not explicitly account for capital market imperfections, these MPK estimates will vary across countries to the extent that the imperfections of capital markets is important to investment decisions.

The starting point for the model in this paper is Eaton and Kortum (2001) who relate a country's share of expenditure on capital goods from a particular source country to the probability that that source country supplies the lowest quality adjusted price of capital goods.

Each country n is able to source a continuum of capital good types indexed by $j \in [0,1]$ from country $i \in \{1,...,N\}$, including itself. Source country i faces a production cost per unit of capital good of c_i and delivering a capital good to country n from country i incurs an iceberg cost of $d_{ni} \geq 1$, where $d_{nn} = 1$. Country i also embodies a quality level of $z_i(j)$ in each capital good j it produces and this level of quality is assumed not to vary by destination, country n.

With perfect competition, firms in country n are presented with a menu of quality adjusted prices for each capital good j,

(2) $$P_{ni}^K(j) = \frac{c_i d_{ni}}{z_i(j)} \text{ for all } i \in \{1, ...N\},$$

and differences in $P_{ni}^K(j)$ will therefore drive differences in the marginal product of capital good j in country n.

In contrast to Caselli and Feyrer (2007), I model country n's marginal product of capital good j sourced from country i as

(3) $$MPK_{ni}(j) = \frac{\alpha_n P_n^Y Y_n}{P_{ni}^K(j) K_n \gamma_n^{\omega}},$$

where $\gamma_n \geq 1$ $\omega \geq 0$. Equation (3), explicitly allows for the possibility of destination country specific capital market imperfections, γ_n, to potentially act to prevent the marginal product of capital (gross of the impact of capital market imperfections) from equalising across countries. The parameter ω, assumed to be common to all countries, is the elasticity of MPK with respect to the measure of capital market imperfections. As described below, the value of ω is central to the analysis in this paper as $\omega = 0$ implies that capital market imperfections does not affect the marginal product of capital across countries. Alternatively, a strictly negative value of ω implies that capital market imperfections tend to drive up the gross measure of the marginal product of capital across countries in countries where capital market imperfections is poor.

Equation (3) also differs from equation (1) by accounting for country n's quality adjusted price of capital good j sourced from country i, $P_{ni}^K(j)$, rather than assuming a price of capital common to purchases of all capital goods in country n irrespective of country of origin.

In practice, firms in country n will only source capital good j from the country that offers the lowest quality adjusted price (or the highest marginal product of capital), therefore:

(4) $$P_n^K(j) = \min_i \left\{ P_{ni}^K(j) \right\}.$$

As calculation of equation (4) is generally intractable, I follow Eaton and Kortum (2001) methodology and use a probabilistic approach to modelling differences in the quality embodied in capital goods. In particular, I assume a probabilistic representation of technology where the quality embodied by country i in capital good j, $z_i(j)$, is the realisation of a random variable z_i

(drawn independently for each j) from the country specific probability distribution $F_i(z) = \Pr[z_i \leq z]$. By the law of large numbers, $F_i(z)$ is also the fraction of goods for which country i's or quality is below z.

Following Eaton and Kortum (2001), the quality distribution is Frechet (or type II extreme-value distribution):

$$(5) \qquad F_i(z) = \Pr(z_i \leq z) = \exp\left(\frac{-T_{it}}{z^\theta}\right),$$

where $T_i \geq 0$ is a location parameter that governs the average quality of all capital goods in country i at time t and $\theta \geq 1$ is a shape parameter that affects the variability of quality of each capital type.[1] The reason for taking this approach is that we only need to know parameter values for T_i and θ in order to keep track of intrinsic quality differences of capital good types produced in different countries. In Eaton and Kortum (2001, 2002) the preferred value for the shape parameter is $\theta = 8.3$ which implies that realisations of z_i tend not to vary much for large differences in T_i.

The reason we use the Frechet distribution is that the quality of a new good developed as part of the process of innovation can be thought of a random draw. However, only the good with the highest realised quality value will ever be used. Hence the extreme-value distribution, which represents the maximum of a set of draws, is appropriate here.[2]

Given the quality of capital goods produced in country i can be represented by the distribution in equation (5), equations (2) and (3) imply that prices and each capital good's marginal product will also be random variables. To determine the distribution of MPK_{ni} note that

$$(6) \qquad MPK_{ni}(j) = \frac{\alpha_n P_n^Y Y_n}{K_n \gamma_n^\omega} \frac{z_i}{c_i d_{ni}},$$

from equations (2) and (3). Let $MPK_{ni}(j)$ be drawn from the distribution

$$G_{ni}(MPK) = \Pr[MPK_{ni} \leq MPK] = \Pr\left[\frac{\alpha_n P_n^Y Y_n}{K_n \gamma_n^\omega} \frac{z_i}{c_i d_{ni}} \leq MPK\right]$$

$$(7) \qquad = \Pr\left[z_i \leq \frac{c_i d_{ni} K_n \gamma_n^\omega}{\alpha_n P_n^Y Y_n} MPK\right].$$

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[1] The geometric mean is $e^{\frac{\gamma}{\theta}} T_i^{\frac{1}{\theta}}$ and the standard deviation of the log is $\frac{\pi}{\theta\sqrt{6}}$ where $\gamma = 0.577...$ is Euler's constant.

[2] The generalised extreme-value distribution converges to one of three distributions; of this three only for the Frechet does the distribution of prices inherit an extreme-value distribution and was therefore most appropriate.

Substituting from equation (5) gives

$$(8) \qquad G_{ni}(MPK) = F_i\left(\frac{c_i d_{ni} K_n \gamma_n^{\omega}}{\alpha_n P_n^Y Y_n} MPK\right) = \exp\left\{-T_i\left(\frac{c_i d_{ni} K_n \gamma_n^{\omega}}{\alpha_n P_n^Y Y_n}\right)^{-\theta} MPK^{-\theta}\right\},$$

Equation (8) shows how the probability that country n's marginal product of capital sourced from country i is no greater than some critical value depends on the level of technology and cost of production in country i, the cost of trade from i to n, as well as specific country n characteristics.

The probability that country n's marginal product of capital sourced from any country in the world is no greater than some critical value is then the product of $G_{ni}(MPK)$ across all source countries i

$$(9) \qquad G_n(MPK) = \prod_i^N G_{ni}(MPK) = \exp\left\{-\sum_i^N T_i\left(\frac{c_i d_{ni} K_n \gamma_n^{\omega}}{\alpha_n P_n^Y Y_n}\right)^{-\theta} MPK^{-\theta}\right\}.$$

The probability that any country's marginal product of capital sourced from any country in the world is no greater than some critical value is the product of $G_n(MPK)$ across all destination countries n

$$(10) \qquad \begin{aligned} G(MPK) &= \prod_n^N \prod_i^N G_{ni}(MPK) = \exp\left\{-\sum_n^N \sum_i^N T_i\left(\frac{c_i d_{ni} K_n \gamma_n^{\omega}}{\alpha_n P_n^Y Y_n}\right)^{-\theta} MPK^{-\theta}\right\} \\ &= \exp\left\{-\sum_n^N \Phi_n MPK^{-\theta}\right\} \end{aligned},$$

where $\Phi_n = \sum_i^N T_i\left(\frac{c_i d_{ni} K_n \gamma_n^{\omega}}{\alpha_n P_n^Y Y_n}\right)^{-\theta}$.

The probability that country n's marginal product of capital sourced from country i is no less than some critical value of MPK is therefore

$$(11) \qquad 1 - G(MPK) = 1 - \prod_n^N \prod_i^N G_{ni}(MPK) = 1 - \exp\left\{-\sum_n^N \Phi_n MPK^{-\theta}\right\}.$$

Now that the marginal product of capital distribution has been defined, a crucial feature of this distribution is that the probability that country n's marginal product of capital sourced from country i is the highest in country n is

$$(12) \qquad \pi_{ni} = T_i\left(\frac{c_i d_{ni} K_n \gamma_n^{\omega}}{\alpha_n P_n^Y Y_n}\right)^{-\theta} \Big/ \Phi_n ,$$

that is, i's contribution to the MPK parameter Φ_n. Hence country n will source the fraction π_{ni} of its total investment in capital goods from country i. Furthermore, the probability that country n's marginal product of capital is the highest in the world is

$$\pi_n = \sum_i^N \pi_{ni} \Big/ \sum_n^N \Phi_n$$

(13) $$= \sum_i^N T_i \left(\frac{c_i d_{ni} K_n \gamma_n^{\omega}}{\alpha_n P_n^Y Y_n} \right)^{-\theta} \Big/ \sum_n^N \Phi_n \, .$$

$$= \Phi_n \Big/ \sum_n^N \Phi_n$$

Hence the share of world investment in capital goods flowing to country n is equal to π_n.

The next step is to link the probability that country n has the highest marginal product of capital in the world to country n's fraction of world expenditure on capital goods. To do so note that the marginal product of capital actually bought in destination country n will not vary across source countries i. A source country that is able to supply at a lower price (as a result of having a higher level of technology, lower unit costs, or lower trade barriers) will supply a wider range of capital goods to the destination country up until the distribution of the MPK from that source country is equal to the overall distribution of the MPK in that destination country. Since the distribution of the MPK in country n does not vary by source countries i the share of n's expenditure on capital goods devoted to a particular source country i will simply be equal to the probability that country i has the highest MPK in country n, that is

(14) $$\frac{X_{ni}}{\sum_n^N X_n} = T_i \left(\frac{c_i d_{ni} K_n \gamma_n^{\omega}}{\alpha_n P_n^Y Y_n} \right)^{-\theta} \Big/ \sum_n^N \Phi_n$$

At the world level a similar argument holds. A country that is expected to have a higher MPK than other countries will attract a higher share of world investment in capital goods, therefore driving down the expected MPK in that country, up until the overall distribution of MPK in that country was exactly equal to the overall distribution of the MPK across all countries. Since the world distribution of the MPK does not vary by destination countries the share of world expenditure on capital goods devoted to a particular destination country n will simply be equal to the probability that country n has the highest MPK in the world, that is

(15) $$\frac{X_n}{\sum_n^N X_n} = \frac{\sum_i^N X_{ni}}{\sum_n^N X_n} = \frac{\Phi_n}{\sum_n^N \Phi_n} \, .$$

In order to see why equation (15) holds, imagine a world consisting of ten countries, each of which has an equal probability of having the highest marginal product of capital. As it is optimal to devote capital expenditure where returns are expected to be the highest, the optimal distribution of world capital expenditure in this example would be for each country to receive a one tenth share.

Equation (15) forms the basis of the equation I use to test the importance of capital market imperfections in driving differences in the marginal product of tradable capital across countries.

To proceed note that Eaton and Kortum (2001) show that country n's exact price index for capital goods, assuming equation (2) and (5), is equal to

$$(16) \qquad P_n^K = \left(\sum_i^N T_i \left(c_i d_{ni} \right)^{-\theta} \right)^{-\frac{1}{\theta}},$$

which shows that a country will face a lower capital good price if it faces low barriers to trade with countries that have a high the level of technology (T_i) and low unit cost of production (c_i).

Normalising equation (15) by the USA's share of world expenditure on capital goods and using equation (16) gives

$$(17) \qquad \begin{aligned} \frac{X_n}{X_{USA}} &= \frac{\Phi_n}{\Phi_{USA}} \\ &= \frac{\sum_i^N T_i \left(\dfrac{c_i d_{ni} K_n \gamma_n^{\omega}}{\alpha_n P_n^{\ Y} Y_n} \right)^{-\theta}}{\sum_i^N T_i \left(\dfrac{c_{USA} d_{USAi} K_{USA} \gamma_{USA}^{\omega}}{\alpha_{USA} P_{USA}^{\ \ Y} Y_{USA}} \right)^{-\theta}} \\ &= \left(\frac{P_n^K K_n \gamma_n^{\omega}}{\alpha_n P_n^{\ Y} Y_n} \Big/ \frac{P_{USA}^K K_{USA} \gamma_{USA}^{\omega}}{\alpha_{USA} P_{USA}^{\ \ Y} Y_{USA}} \right)^{-\theta} \end{aligned} \; .$$

The problem with estimation based on equation (17) is that it is not possible to identify the unknowns on the right-hand-side (T_i, c_i, d_{ni} and ω,) for all n, $i \in \{1,...,N\}$) with cross-country observations of the left-hand-side in a particular year.

The approach I use to attempt to deal with this problem is to use the bilateral pair prediction of the model in equation (14) to estimate $T_i c_i^{-\theta}$ and $d_{ni}^{-\theta}$, and then use these first stage estimates in equation an based on (17) in order to derive a second stage estimate of ω.

To do this we normalise equation (14) by country n's home sales which gives

$$(18) \qquad \begin{aligned} \frac{X_{ni}}{X_{nn}} &= T_i \left(\frac{c_i d_{ni} K_n \gamma_n^{\omega}}{\alpha_n P_n^{Y} Y_n} \right)^{-\theta} \Big/ T_n \left(\frac{c_n d_{nn} K_n \gamma_n^{\omega}}{\alpha_n P_n^{Y} Y_n} \right)^{-\theta} \\ &= T_i \left(c_i d_{ni} \right)^{-\theta} \Big/ T_n \left(c_n d_{nn} \right)^{-\theta} \end{aligned} \; ,$$

which allows for the estimation of $T_i c_i^{-\theta}$ and $d_{ni}^{-\theta}$. We estimate (18) in log form and model iceberg trade costs for all $i \neq n$ as

(19) $\ln d_{ni} = \sum_{1}^{6} d_k + m_n + adj_{ni} + lang_{ni} + \delta_{ni}$,

where the first four terms on the right-hand-side are coefficients on dummy variables (suppressed for notational simplicity). In equation (19), the coefficient d_k ($k = 1,...,6$) captures the effect of distance between i and n lying within the kth interval, m_n is the coefficient on a dummy variable equal to one for each destination country and zero otherwise, adj_{ni} and $lang_{ni}$ is the coefficient that captures the effect of i and n having shared border and common language, respectively. The error term, δ_{ni}, captures all other geographic barriers not accounted for and is assumed to be orthogonal to the other regressors. Following EK (2001), the six distance intervals in miles are [0,375), [375,750), [750, 1500), [1500, 3000), [3000, 6000), and [6000, maximum].

Note that the first stage estimates of $T_i c_i^{-\theta}$ and $d_{ni}^{-\theta}$, together with a prior estimate of θ, allows for an estimate of the exact price index of capital goods in each destination country to be constructed using equation (16). Estimates of this price index can then be used to construct estimates of the MPK across countries using the Caselli and Feyrer (2007) definition of the MPK in equation (1).

The parameter of interest in equation (17), ω, can therefore be estimated using a two-step procedure whereby the estimates of $\tilde{P}_n^K$ are derived from equation (18) and fed into equation (17) to give

(20) $$\frac{X_n}{X_{USA}} = \frac{\left(\dfrac{\alpha_n P_n^Y Y}{\tilde{P}_n^K K_n \gamma_n^{\omega}} \right)^{\theta}}{\left(\dfrac{\alpha_{USA} P_{USA}^{\ Y} Y_{USA}}{\tilde{P}_{USA}^K K_{USA} \gamma_{USA}^{\omega}} \right)^{\theta}} .$$

Equation (20) is then estimated in log form, that is

(21) $$-\frac{1}{\theta} \log\left(\frac{X_n}{X_{USA}} \right) + \log\left(\frac{\alpha_n P_n^Y Y}{\tilde{P}_n^K K_n} \Big/ \frac{\alpha_{USA} P_{USA}^{\ Y} Y_{USA}}{\tilde{P}_{USA}^K K_{USA}} \right) = \omega \log\left(\frac{\gamma_n}{\gamma_{USA}} \right),$$

where the only unknown to be estimated is ω.

4 Data

Estimation of equations (18) and (21) for a particular year requires data on bilateral trade in capital goods X_{ni}, geographic characteristics, the quality adjusted real capital stock K_n, the relative price of output P_n^Y, the real value of output Y_n, the capital good share in income α_n, and a measure of capital market imperfections γ_n.

Data for X_{ni} requires bilateral trade expenditure data in capital goods as well as expenditure on home production of capital goods across countries. The Center for International Data at UC Davis provides bilateral trade data constructed by Robert Feenstra and Robert Lipsey from 1962 to 2000 (based on UN trade data) at the SITC4 level (4-digit standard international trade classification). Data on home production is used to construct X_{nn} and is available from the United Nations Industrial Development Organisation (UNIDO). In this paper, the UNIDO data is taken from the World Bank's Trade, Production and Protection database (Nicita A. and M. Olarreaga, 2006), which reports data at the ISIC2 3-digit level. The trade data was converted to the ISIC2 3-digit classification where capital goods were defined as the sum of category 381 (fabricated metal products), 382 (non-electrical machinery), 383 (electrical machinery) and 385 (professional goods). Data on geographic characteristics are also taken from accompanying files contained in the Trade, Production and Protection database.

X_{nn} is assumed to be equal to home production minus exports, which poses a problem for "entrepôt" countries which tend to export goods that have been officially recorded as being originally imported. While there is no obvious way to identify entrepôt countries from the data, entrepôt countries are likely to have negative values for X_{nn} and are therefore deleted from the country sample.

Data for K_n is constructed by using the perpetual inventory method over quality adjusted real investment. Following Caselli and Feyrer (2007), the initial level of K_n is assumed to be equal to the first period (quality adjusted) real investment (in this case 1977) divided by the sum of the average geometric growth rate of quality adjusted real investment (between 1977 and 1996) and the rate of depreciation (assumed to equal 0.06). As Caselli and Feyrer (2007) point out, this formula for the initial value of K_n is based on the steady state value of the capital stock predicted by the Solow-Swan model. While there is little evidence to support this assumption, this is nonetheless considered best practice.

While Caselli and Feyrer (2007) use PWT data for real investment, which adjusts for cross-country differences in the price of capital as measured by the International Comparison Program (ICP), I use equation (18) to estimate parameters that determine the quality adjusted exact price index for new capital goods. Therefore, an estimate of P_n^K is required to deflate each year of real investment in order to calculate the quality adjusted stock of capital goods.

Estimation of equation (18) is not possible for countries that do not export (or import) capital goods in a particular year and are therefore deleted from the country sample (Bolivia did not record any exports of capital goods in 1984 and 1985 within the country sample).

In order to calculate P_{nt}^{k} a value for the shape parameter of the Frechet distribution, θ, is needed. However, the model does not provide any way to identify a value for θ and hence a prior estimate of this parameter is needed. The parameter θ regulates the degree of heterogeneity of capital good quality in the model. A lower value of θ implies a higher level of comparative advantage, every thing else equal, and so it is more likely that comparative advantage exerts a stronger force for trade relative to the opposing force of trade barriers. Hence an appropriate value of θ will generate an appropriate amount of trade between countries given difference in domestic prices and estimates of trade costs. Eaton and Kortum (2002) show that dividing equation (18) by the analogous expression for country i's share at home and substituting in the expression for P_{nt}^{k} gives

(22) $$\frac{X_{ni}/X_n}{X_{ii}/X_i} = \frac{\Phi_i}{\Phi_n} d_{ni}^{-\theta} = \left(\frac{P_i d_{ni}}{P_n} \right)^{-\theta} .$$

Equation (22) relates country i's normalised import share in country n to the price of goods in country i relative to n also accounting for the cost of transporting those goods from i to n. The intuition here is that as the average price of goods in country i relative to n increases then the model predicts that country i's normalised import share in country n falls; that is, a higher price in i means that the competitiveness of i falls and so does it's market share in other countries, everything else equal. This effect is also the same if the cost of transporting goods from i to n increases. The magnitude of this effect depends on the value of θ. Eaton and Kortum (2002) use equation (22) to estimate θ using ICP data for relative prices and the physical distance between countries for d_{ni} which implies a value of $\theta = 8.3$.

Following CF (2007), I take P_n^Y and Y_n from the PWT (6.2), where P_n^Y can be thought of as a weighted average of final good domestic prices (also constructed by the ICP).

A possible source of data for α_n is from Caselli and Feyrer (2007), although this data is based on the share of reproducible-capital share in income as distinct from the capital good share in income. The difference is that reproducible-capital includes non-tradable capital such as building and other structures (but does not include land and natural resources) where as capital goods only include tradable items. Nonetheless, the methodology suggested by Caselli and Feyrer (2007) for calculating their version of the capital share is also appropriate for calculation of α_n, in particular

(23) $$\alpha_n = \frac{K_n}{W}\alpha_n^w,$$

where W is domestic value of total tangible wealth (estimated by the World Bank, 2006) and α_n^w is the total capital share in income (estimated by Benanke and Gurkaynak, 2001). Equation (23) assumes that the domestic value of total capital (equal to the sum of the value of natural resources, capital structures and tradable capital goods) is equal to W, and that differences in returns across these capital types is small. It is important to note that the domestic value of the stock of tradable capital goods is relevant for calculating the income share since total income here is valued at domestic prices.

The key variable of interest is γ_n. While there is not a definitive measure of capital market imperfections, it is likely to be negatively correlated with the functionality of financial intermediaries across countries. As argued by Levine, Loayza and Beck (2000), financial intermediaries "lower the costs of researching potential investments, exerting corporate control, managing risk, mobilizing savings and conducting exchanges". Investors would then face a higher cost of acquiring and monitoring domestic assets in a country with a relatively poor functioning financial intermediation sector.

Levine, Loayza and Beck (2000) suggest a number of measures of imperfections in the financial intermediary sector, where their preferred measure is the inverse of the ratio of private credit to GDP. Private credit measures the value of credits to the private sector issued by private sector financial institutions and does not include credit issued to government and their agencies (or enterprises) by themselves or other institutions. Hence this measure also excludes credits issued by the central bank. Levine, Loayza and Beck (2000) argue that a higher ratio of private credit to GDP indicates higher levels of financial services and a more developed financial intermediary sector. We are interested in the degree of capital market imperfections and hence we use the inverse of the private credit to GDP ratio as our measure.

The data intensive approach in this paper places a heavy constraint on sample size. The estimation of the final regression equation is based on 1996 data (in addition to the estimated quality adjusted capital stock data which requires data from previous years) since it maximises the sample size. A total of 34 countries are included in the estimates of the quality adjusted price of capital goods and this number falls to 28 in the estimation of the importance of capital market imperfections.

5 Estimation and Results

Estimation of equation (21) requires prior estimates quality adjusted capital stocks, capital good share in income, and the quality adjusted price of capital goods. Since the quality adjusted capital stock is constructed using the perpetual inventory method, estimates of the quality adjusted price of capital goods is also needed over each year capital stock number is constructed.

In order to do this we estimate (18) in the following in log form for all country pairs ni except where $n = i$,

(24) $$\log\left(\frac{X_{ni}}{X_{nn}}\right) = S_i - S_n - \sum_1^6 \theta d_k - \theta m_n - \theta adj_{ni} - \theta lang_{ni} + \delta_{ni},$$

where $S_i = \log T_i - \theta \log c_i$ is the source effect, that is, the coefficient on the source (or exporter) country dummy and is indicative of country i's "competitiveness" in capital good production. An issue with the log linearization of equation (24) is the large number of zero trade observations between country pairs. Eaton and Kortum (2001) suggest a Tobit estimator with import-country-specific censoring points.

However, following Silva and Tenreyno (2006), I employ a pseudo-maximum-likelihood (PML) estimation technique which utilises the Poisson distribution even though the data is not Poisson at all. PML estimation is in levels rather than in log form and is therefore able to deal with the zero value observations. Silva and Tenreyno (2006) also suggest the use of a robust covariance matrix estimator to deal control for heteroskedasticity.

I estimate (24) in levels using the PML estimator in SAS (the Proc Genmod command with a Poisson distribution with a log link function and treating each observation as a cluster to generate robust standard errors). The regression equation contains dummy variables for each source country (other than the USA) and dummy variables for each destination country (other than the USA). The regression equation does not contain an intercept term so that the coefficient on each distance category can be estimated. However, to avoid perfect multicollinearity the source and destination dummies for the USA are dropped from the regression. Following Eaton and Kortum (2001), the source effects (S_i) and destination effects (m_i) are each normalised to equal zero in a particular year, that is $\sum_i^N S_i = 0$ and $\sum_i^N m_i = 0$, so that an estimate for S_{USA} and m_{USA} is implied.

Average estimated price for each country across the years 1977-1996 is shown in Table 1. First stage regression results (for 1996) are shown in Table 2.

In contrast to the ICP based estimates of capital goods, our trade based price estimates show a clear negative relationship between development and growth. The reason for this can be seen in Table 2 which shows the source and destination effects across countries. Many developing countries are estimated to be very inefficient in the production of capital goods (low S_i). Furthermore, developing countries tend to face high trade barriers (independent of distance) where this is captured through a low estimate of the destination effect (m_i). A country that has both a low source effect and a low destination effect will tend to source a large proportion of capital goods from low productivity firms located domestically since home sourced capital goods are not subject to trade costs. Countries with these characteristics will tend to face a very high quality adjusted capital good price and hence their quality adjusted capital stock will be much lower than the value of the capital stock measured in domestic prices.

For this reason, our trade based estimates of the MPK (gross of the impact of capital market imperfections) varies across countries. The ratio of output measured in international prices to the quality adjusted value of the stock of capital goods is much higher than one in many developing countries. While the capital good share in income tends to be lower for developing countries, this is not enough to offset the ratio of price adjusted output to the capital good stock. These trade based estimates of the MPK for 1996, shown in Table 3, are much higher for developing countries than the estimates found in Caselli and Feyrer (2007), although the latter estimates are based on the marginal product of reproducible capital rather than capital goods.

To what extent do capital market imperfections impact on the MPK across countries? Taking our first stage estimates to the estimation of equation (21) is potentially hazardous as it is possible, if not likely, that capital market imperfections, as measured by the inverse of the ratio of private credit to GDP, cannot be considered exogenous. Countries that are more productive earn higher incomes and are able to devote a larger amount of expenditure to the development of their capital markets. If capital market functionality is important to allocating resources to where returns are highest then higher levels of investment and income can be expected thereby generating a greater ability to developing capital market functionality. For this reason we follow Levine, Loayza and Beck (2000) and try to identify the exogenous component of the inverse of the ratio of private credit to GDP. In this regard we use legal origin to instrument for the inverse of the private credit ratio since the English, French, German and Scandinavian legal systems where spread primarily through imperialism and can be considered exogenous to factors that impact on the MPK today. We then implement a 2SLS regression to identify the exogenous effect of capital market imperfections on the MPK across countries.

In order for legal origin to be valid instruments for our measure of capital market imperfections it must be the case that a country's legal origin is important to the imperfections of that country's capital market today. Indeed the type of legal systems used in a country can be expected to influence the effectiveness of contract enforcement, level of accounting standards, and the regulatory environment that financial activities take place. Table 4 presents the first stage regression results (of the 2SLS regression) where the dependent variable is the ratio of private credit to GDP. The P-value of the regression indicates that the legal origin dummies are important to explaining our measure of capital market imperfections today.

The results of instrumental variable estimation (2SLS) of equation (21) are shown in Table 5. The estimated coefficient on our relative measure of capital market imperfections is significantly different from zero at the 1% level and is positive in sign. This estimate implies that the elasticity the MPK with respect to our measure of capital market imperfections is around -1.2 or, in other words, an increase in capital market imperfections more than proportionally reduces the MPK by that amount. This result explains why our naïve estimates of the trade based MPK, as shown in Table 3, are high for many developing countries which are likely to have poorly functioning capital markets. Taking the impact of these capital market imperfections into account we would then see the expected MPK across countries to be equalized.

This result provides support for the view that countries that have poorly developed capital markets suffer from a misallocation of resources whereby high return investments are foregone due to the high costs that potential investors must bear. These costs may be seen as search costs, difficulties in raising capital, costs of monitoring investments and perhaps costs associated with exiting investments (especially in an illiquid market).

6 Conclusion

This paper provides new evidence that supports the view capital market imperfections play an important role determining the marginal product of capital goods across countries. If capital market imperfections are ignored then the marginal product of capital goods is likely to be higher in countries where there is little financial development. Furthermore, this result is consistent with anecdotal evidence that capital tends to flow from developing countries to rich countries. While the perceived (or naïve) returns on investment (in capital goods) is likely to be high in many developing countries, investors bear relatively high cost of making investments when a large capital market imperfections are present – if the impact of capital market imperfections is large enough then capital will tend to flow from poor to rich countries.

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Table 1: Estimated capital good prices (1977-1996)[a] and ICP producer durables price estimates (1996)

Country	Mean	Standard deviation	Minumum	Maximum	ICP[b]
Australia	1.48	0.19	1.09	1.84	1.24
Austria	1.40	0.05	1.30	1.48	1.16
Bangladesh	3.82	0.64	2.81	5.49	0.46
Canada	1.34	0.08	1.25	1.62	0.93
Chile	2.11	0.57	1.56	4.13	0.95
China	1.55	0.23	1.26	2.07	-
Colombia	1.93	0.56	1.51	4.18	-
Costa Rica	2.53	0.44	1.73	3.50	-
Denmark	1.28	0.04	1.22	1.39	1.34
Ecuador	2.31	0.25	2.01	3.03	1.03
Egypt	2.92	0.31	2.27	3.32	1.51
Finland	1.47	0.04	1.25	1.40	1.37
France, Monaco	1.06	0.09	1.33	1.63	1.20
Greece	1.90	0.17	1.68	2.25	1.20
Hungary	1.85	0.18	1.40	2.03	1.09
India	1.52	0.11	1.33	1.82	-
Indonesia	2.11	0.45	1.53	3.06	0.67
Ireland	1.43	0.08	1.31	1.55	1.20
Israel	1.73	0.12	1.45	1.91	0.90
Italy	1.07	0.05	0.99	1.15	1.12
Japan	0.99	0.05	0.92	1.10	1.30
Kenya	3.32	0.57	2.03	3.86	0.92
Korea Rep.	1.28	0.13	1.15	1.53	0.70
Morocco	2.64	0.39	1.98	3.25	0.74
Malta	1.86	0.27	1.49	2.45	-
Mauritius	2.58	0.30	1.85	2.92	0.67
Norway	1.53	0.05	1.45	1.66	1.24
Portugal	1.78	0.09	1.63	1.94	1.19
Spain	1.33	0.04	1.25	1.40	1.03
Sweden	1.19	0.05	1.13	1.31	1.29
Turkey	2.27	0.48	1.67	3.38	0.99
UK	1.07	0.06	0.94	1.14	1.12
Uruguay	3.72	1.21	2.57	6.56	1.00
USA	1.00	-	1.00	1.00	1.00

[a] The price for the USA is normalised to 1 in each year.

[b] ICP prices are from the “Producer Durables” price series for 1996 (USA=1).

Table 2: First stage parameter estimates (1996)[a]

Country	Source effect	Std. error	Destination effect	Std. error	Price of capital	Price of output	y	k
Australia	1.46	0.37	2.55	0.51	1.79	1.07	22,040	9,929
Austria	1.68	0.42	0.59	0.50	1.86	1.27	22,958	17,829
Bangladesh	-7.61	0.56	-7.06	0.62	13.24	0.22	1,634	6
Canada	1.34	0.32	1.71	0.44	1.65	0.95	21,556	14,817
Chile	-0.23	0.45	1.72	0.49	2.25	0.53	9,896	814
China	2.41	0.34	1.71	0.41	1.62	0.25	2,809	452
Colombia	0.43	0.56	0.95	0.59	2.12	0.45	5,791	381
Costa Rica	-2.78	0.43	0.14	0.46	2.72	0.50	6,901	431
Denmark	1.89	0.35	1.53	0.42	1.64	1.48	23,716	15,209
Ecuador	-3.55	0.75	-2.51	0.77	4.71	0.42	4,243	274
Egypt	-4.46	0.46	-4.54	0.50	6.54	0.31	3,885	153
Finland	2.47	0.21	1.62	0.31	1.54	0.98	15,873	6,241
France, Monaco	1.55	0.26	0.43	0.42	1.93	1.38	18,127	14,383
Greece	4.17	0.41	3.00	0.46	1.08	1.28	21,012	28,740
Hungary	3.58	0.50	2.42	0.53	1.21	1.01	20,371	25,683
India	-1.13	0.38	-0.65	0.46	2.91	0.99	11,716	1,925
Indonesia	-0.36	0.42	-0.03	0.47	2.50	0.49	9,118	4,975
Ireland	-0.24	0.28	1.37	0.50	2.42	0.30	3,669	142
Israel	1.07	0.40	-0.45	0.62	2.29	0.19	2,054	143
Italy	1.39	0.18	1.40	0.34	1.68	1.20	17,082	13,541
Japan	1.18	0.20	0.83	0.47	1.97	1.02	18,916	5,852
Kenya	4.01	0.82	2.11	0.90	1.19	1.08	19,928	14,771
Korea Rep.	4.09	0.13	2.00	0.32	1.20	1.65	22,640	50,559
Morocco	-6.51	0.63	-6.71	0.67	11.51	0.27	1,241	65
Malta	3.15	0.46	2.43	0.55	1.37	0.86	14,317	9,075
Mauritius	-2.90	0.66	-2.44	0.79	4.37	0.36	3,639	166
Norway	-2.71	0.35	-1.33	0.41	3.52	0.67	14,142	6,510
Portugal	-5.49	0.30	-2.40	0.36	5.68	0.32	12,009	386
Spain	0.32	0.24	0.22	0.34	2.25	1.44	25,272	21,132
Sweden	0.03	0.22	-0.29	0.33	2.50	0.78	14,323	2,529
Turkey	2.27	0.30	2.37	0.38	1.44	1.46	21,140	25,248
UK	-0.75	0.22	-1.29	0.59	3.07	0.55	5,016	569
Uruguay	-4.74	0.73	-3.05	0.76	6.33	0.64	9,904	299
USA	4.97	-	1.64	-	1.00	1.00	28,484	36,484

[a] Estimation based on the PML estimator assuming $\theta = 8.3$. The dependent variable is the exponent of the left-hand-side of equation (24) and a log link function is imposed. y is output per person and k is quality adjusted tradable capital stock per person. The source effect and destination effect are both normalised so that each sum to zero. Robust standard errors are reported. y is output per person. k is the quality adjusted stock of capital goods per person.

Table 2: First stage parameter estimates (1996), continued.

Parameter	Estimate	Std. error
d1	-3.93	0.41
d2	-4.92	0.21
d3	-5.29	0.18
d4	-5.15	0.18
d5	-6.42	0.14
d6	-7.03	0.21
Common language	0.09	0.31
Common border	0.32	0.34

Table 3: Capital Good Share in Income, Trade Based MPK, ICP Based MPK and Private Credit Ratio[a]

Country	Capital good Share in Income	Trade Based MPK (%)	ICP Based MPK (%)	Inverse of Private Credit / GDP
Australia	0.08	13.01	8.00	1.47
Austria	0.14	16.23	8.00	1.08
Canada	0.10	9.93	7.00	1.07
Chile	0.05	18.62	9.00	1.66
Colombia	0.03	13.25	6.00	2.98
Costa Rica	0.04	13.57	3.00	8.94
Denmark	0.08	15.04	8.00	3.31
Ecuador	0.05	14.80	3.00	3.79
Egypt	0.04	11.92	5.00	2.68
Finland	0.13	15.32	8.00	1.68
France,Monaco	0.14	12.17	8.00	1.20
Greece	0.04	14.51	5.00	3.07
Hungary	0.23	13.28	-	4.81
Ireland	0.13	13.83	11.00	1.41
Israel	0.10	18.74	11.00	1.61
Italy	0.10	12.39	8.00	1.85
Japan	0.12	8.23	8.00	0.56
Korea	0.16	15.78	10.00	0.89
Morocco	0.09	30.62	9.00	2.39
Mauritius	0.08	36.11	12.00	2.34
Norway	0.11	12.89	8.00	1.24
Portugal	0.07	16.70	8.00	1.38
Spain	0.09	16.29	9.00	1.41
Sweden	0.14	13.64	7.00	0.97
Turkey	0.09	21.51	-	6.31
UK	0.13	9.24	9.00	0.88
Uruguay	0.06	45.13	12.00	4.28
USA	0.11	8.05	8.00	0.74

[a] Trade based MPK are calculated using equation (1) where the price of capital goods are the trade based estimates shown in Table 2 and the capital stock is the quality adjusted capital good stock estimates shown in Table 2 (although shown on a per person basis). ICP Based MPK are from Caselli and Feyrer (2007) using reproducible capital stock data and ICP estimates of the price of reproducible capital across countries.

Table 4: Legal origin and Financial intermediary development (1996)[a]

	Estimate	Std. error	P-Value
Intercept	1.28	0.16	0.000
English	-0.75	0.19	0.001
German	-0.74	0.47	0.126
Scandinavian	-0.50	0.29	0.100
N	27		
Prob>F	0.008		
R square	0.282		
adj R squared	0.350		

[a] Dependent variable is the inverse of PRIVATE CREDIT where PRIVATE CREDIT is credit by deposit money banks and other financial institutions to the private sector divided by GDP. French legal origin is the omitted category.

Table 5: Financial intermediary development and MPK (1996)[a]

	Estimate	Std. error	P-Value
Intercept	0.44	0.40	0.288
ω	1.21	0.39	0.005
N	27		
Prob>F	0.005		
Hansen J Statitic	0.217		

[a] 2SLS estimation of equation (21) for 1996. Instrumental variables are legal origin dummy variables. The critical value for the Hansen overidentification test of all instruments is 5.99 (2 d.f.) at the 5% level.