Costly Intermediation and the Poverty of Nations[1]

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Abstract

This paper has two goals: (i) reduce the almost 7-times productivity differences across countries that is required to explain the observed 33-times relative income differences between the richest and poorest countries of the world; and (ii) explain the cross-country differences in capital-output ratios. To achieve the first goal we expand the production function of the standard neoclassical growth model to introduce a role for public capital whose provision is subject to intermediation costs. For the second goal we distort private investment by introducing credit frictions. We quantify the model using cross-country data. The model generates an income gap of 33 with TFP differences of *only 3* when we introduce the measured variations in public capital and private capital jointly. Moreover, when we introduce an additional home-production sector the required TFP difference declines even further to 2.1. On the second goal however, we find that credit frictions do a poor job in explaining the cross-country variation in capital-output ratios.

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1 Introduction

Per capita income in the richest countries exceeds that in the poorest countries of the world by a factor of 33. Correspondingly, the capital-output ratio in the richest countries is 3.6 times greater than in the poorest countries. The standard one-sector neoclassical growth model when confronted with these numbers, implies that TFP in the richest countries must be almost 7-times higher (assuming a capital share of 1/3). This paper has two goals: (i) reduce the productivity differences across countries that is required to explain the observed 33-times relative income differences between the richest and poorest countries of the world; and (ii) explain the cross-country differences in capital-output ratios.

We introduce two key modifications to the standard neoclassical model. First, productive public capital in our model requires intermediation by public agents, a service for which they have to be compensated. This leakage of tax revenues directly reduces steady-state output. Second, private investment is subject to two distortions: agency costs in converting savings into capital (a credit friction), and a direct conversion cost of consumption into savings. This distorts households' consumption-savings decisions, inducing cross-country dispersions in steady-state capital-output ratios. We calibrate these distortions using cross-country data.

The model generates an income gap of 33 with TFP differences of *only 3* when we introduce the measured variations in public capital and private capital jointly. We also find that if a home production sector is introduced along with the standard market sector, the TFP difference required to generate an income gap of 33 in the market sector declines further to 2.1. On the second goal however, we find that credit frictions do a very poor job in explaining the cross-country variation in capital-output ratios. This is primarily because the measured credit market frictions show relatively small cross-country variation. Hence, credit frictions, by themselves, induce a relative price of investment goods that is unable to reproduce the actual magnitudes in the data.[1]

To account for the effect of credit frictions on technology rather than capital accumulation, we then modify Parente's (1995) model of technology adoption. We require the cost of adopting a superior technology in the basic Parente model to be financed through bank borrowing. The results are again discouraging. We find that while the ratio of incomes of

[1] These conclusions are not at odds with growth regressions that find financial development to be associated with higher growth and income. The correlation between the observed and model-predicted relative income series is 0.60, indicating that there does exist a systematic relationship between credit frictions and relative incomes. Moreover, cross-country regressions of average growth rates between 1990 and 1997 on our two measures of credit frictions reveal significant coefficients with the correct signs: higher frictions significantly reduce growth rates in our data. The key point being made in this paper is that these effects are quantitatively small from the standpoint of explaining the world income distribution.

the five richest to the five poorest countries in our sample is 33 (data for 1997, Penn World Tables 5.6), the corresponding ratio that is generated in the model by credit frictions ranges between 1.06 and 1.16. Hence, even when credit frictions have a first-order effect through technology adoption, they are unable to explain the observed income gap between the richest and poorest countries.

We use as our starting point two features of the cross-country data. First, the relative price of investment goods in poorer countries is higher than that in richer countries. Large and systematic variations in this price have been shown to be important in accounting for income differences across nations (see Jones (1994) and Chari *et al.* (1997)). Growth economists have long discussed the role of financial institutions in intermediating investment (see Bencivenga and Smith (1991) and Greenwood and Jovanovic (1990) for instance). An extensive empirical literature on this, summarized by Levine (1997), concludes that financial development correlates significantly with economic growth.[2] These two bodies of work suggest that credit frictions in particular, and intertemporal distortions in general, are important for understanding cross-country income differences.

The second building block for this paper is provided by the empirical literature emphasizing the significant positive effect publicly provided capital/infrastructure has on output (see Eberts (1986); Aschauer (1989); Easterly and Rebelo (1993); and World Bank (1994)). We interpret this literature as suggesting that productive public capital, and distortions in their provision, are potentially important channels for generating cross-country income dispersions.

In view of the above, we modify the standard one-sector neoclassical growth model along two lines. First, we introduce a productive role for public capital as in Barro (1990). Following Glomm and Ravikumar (1994), we assume that non-rival public capital is funded through an optimally chosen uniform tax on wage and capital income. However, public capital has to be intermediated through a public agent. Unlike Barro and Glomm-Ravikumar, this intermediation is costly because of an agency problem. Specifically, by devoting his time to non-productive activities, a public agent can divert some tax revenues for self-consumption. In order to mitigate the potential moral hazard problem, public agents have to be paid wages that are at least as large as the amount they can divert. This pure public consumption generates an additional leakage that reduces the steady-state capital stock and income. However, this is only a static distortion which leaves the capital-output ratio unchanged. Hence, it is equivalent to changing the level of technology.

Second, private investment is subject to two distortions. Households face a cost of converting consumption goods into savings. While we shall refer to this as an investment tax

[2]This work also finds an echo in the business cycle literature on credit frictions. See, for example, Bernanke, Gertler and Gilchrist (2000), Carlstrom and Fuerst (1997), and Azariadis and Chakraborty (1999).

in the balance of the paper, this could have either a tax interpretation or a technology interpretation. In addition to the investment tax, investors who borrow household savings from banks to produce private capital face an idiosyncratic productivity shock that is private information, but may be observed by banks at a cost. Costly state verification introduces a wedge between the lending rate charged to investors and the deposit rate received by savers. We call this a credit friction cost. Both these costs distort the relative price of investment away from unity. This generates cross-country variation in the steady-state capital-output ratio.[3]

The model is calibrated to cross-country data for 1990-97 for a sample of 79 countries. We use the 1990-97 averages from data on net interest rates and central government wages and salaries (as a fraction of total government spending) to calibrate the country-specific credit market friction and the public investment distortion. We then calibrate the investment tax such that the model generates a relative price of investment goods that exactly matches the data. Assuming that all countries are in steady-state, we then generate a predicted value for each country's per capita income relative to the US and compare the properties of this series with those from the actual data.

We start in the next section with some basic accounting to set the stage for our work. The following three sections present the model, the competitive equilibrium and the optimal fiscal policy respectively. Section 6 studies the general equilibrium and steady-state properties of the model while Section 7 presents the calibration methodology and results. Section 8 presents calibration results from a credit augmented version of Parente's (1995) technology adoption model while the last section concludes.

2 Some Basic Accounting

To motivate our approach, consider the following production function:

$$Y_t = A g_t^{\lambda} K_t^{\alpha} L_t^{1-\alpha}, \quad \alpha, \lambda \in (0,1). \tag{1}$$

[3]We should note that two types of CSV models are typically used in the literature. The more commonly used one is where the size of investment is fixed and there are some internal funds. The outcomes are credit rationing (under certain assumptions) and lending rates that are increasing in the amount borrowed. The other type of model, less often used, has flexible borrowing size. When borrowers have positive net worth/internal funds, the lending rate is again decreasing in the amount of internal funds.

In both cases, if average internal funds are lower in developing countries, borrowing rates will be higher due to low internal funds as well as a higher costs of verification. Since our model does not allow for internal funds to affect the loan rate, we underestimate the cost of intermediated finance in poorer countries. But at the same time, since we allow all borrowing to be intermediated, we overestimate the impact of verification costs.

Here K denotes the aggregate stock of private capital, g denotes public capital per worker, and A is a productivity parameter. This production function can be rewritten in intensive form as

$$y = A^{\frac{1}{1-\alpha}} g^{\frac{\lambda}{1-\alpha}} \left(\frac{k}{y}\right)^{\frac{\alpha}{1-\alpha}}$$

where all lower case letters are variables expressed per unit labor. Studies like Gollin (2002) find the capital share α to be roughly 1/3 across countries. In our sample the income gap between the five richest and poorest countries is 33.2. Hall and Jones (1999) find that k/y in rich countries is 3.6 times the k/y in poor countries. Later in this paper our estimates suggest that in our sample estimates for g_{rich}/g_{poor} around 3 are reasonable. Substituting these numbers in the equation above leads to some interesting implications which we summarize in the following table:

TABLE: $\frac{y_{rich}}{y_{poor}}$ with $\alpha = 0.33$, $\frac{(k/y)_{rich}}{(k/y)_{poor}} = 3.6$, $\frac{g_{rich}}{g_{poor}} = 3$

	$\lambda = 0$	$\lambda = 0.17$
$\frac{A_{rich}}{A_{poor}} = 1$	1.9	2.5
$\frac{A_{rich}}{A_{poor}} = 3$	9.7	12.8
$\frac{A_{rich}}{A_{poor}} = 6.9$	33.2	43.9

The column under $\lambda = 0$ shows the implied differences in per capita income in the standard one-sector model. Measured differences in capital-output ratios imply income differences of only 2 if there is no difference in the level of technology across countries. Raising the productivity difference to 3 increases the implied income difference between the richest and poorest countries to 11. When the technology difference is 6.9 the model reproduces the observed income gap of 33.2. The entries under $\lambda = 0.17$ (our baseline case in the paper) show that expanding the production function to include productive public capital raises the predicted income gap for each level of TFP difference. Hence, a fully specified model of public capital could potentially reduce the technology differences required to explain the income gap between these countries.

3 The Model

Our model of costly capital accumulation stays close to the infinite horizon neoclassical framework. The key new element we introduce is intermediation in the production of capital goods. The economy is inhabited by five types of economic agents: final goods producers, households, investors, public agents and banks.

3.1 Final Goods Producers

A unique final consumption good is produced through a technology utilizing raw labor and capital. The production technology is given by equation (1) [4] According to this specification, public capital subsumes services like law and order, transportation, and communication facilities that the government provides to the private sector. Although these services improve the efficiency of private production processes, they are pure public goods and external to each firm's production decision.

This implies that while the private technology exhibits constant returns in private capital and labor, there are increasing returns overall. However, labor endowments are fixed in this economy and cannot be augmented by human capital investment. Hence, we rule out the possibility of endogenous growth by restricting output elasticities of the two types of capital to $\alpha + \lambda < 1$.

The private production function may now be expressed in intensive form as:

$$y_t = X_t k_t^{\alpha}, \tag{2}$$

where we define

$$X_t \equiv A g_t^{\lambda}. \tag{3}$$

The representative final goods producer chooses capital and labor to maximize his profits per unit labor:

$$\text{Max}_{\{k_t\}} \quad X_t k_t^{\alpha} - w_t - R_t k_t, \tag{4}$$

(w_t, R_t) being the vector of prices for labor and private capital. Private inputs are hired in perfectly competitive markets, so that they earn their marginal products in equilibrium.

3.2 Households

Infinitely lived households of unit mass comprise the worker-consumers of this economy. Every period they supply 1 unit of labor inelastically to final goods producers and invest their savings in bank deposits, the only asset available to them.

They maximize their lifetime utility

$$U_0^H = \sum_{t=0}^{\infty} \beta^t \ln c_t, \tag{5}$$

subject to period budget constraints

$$c_t + (1+p)s_t \leq (1-\tau_t)\left[w_t + R_t^D s_{t-1} + Div_t\right], \quad \forall\, t = 0, 1, \ldots \infty, \tag{6}$$

[4] Since our primary interest lies in studying the determinants of relative steady-state income across countries, we assume, without loss of generality, that A is time invariant.

taking as given the vector of prices (w_t, R_t^D). Here s_t denotes a representative household's savings in period-t, τ_t is a proportional tax on income from all sources, and R_t^D is the (gross) return on period-$(t-1)$ bank deposits paid out at the end of period-t. Div_t denotes dividends received by households from firms and banks. p represents a savings/investment tax. We are agnostic about the precise interpretation of p; it could be positive either due to trade and fiscal policy distortions, or due to technological reasons, i.e., a cost of converting the consumption good into an investable good (as emphasized by Hsieh and Klenow (2003)).

3.3 Investors

Private capital is produced by a class of one-period lived agents, also of unit measure, called investment goods producers or, *investors*. These investors are born each period without any endowment of goods or labor time that may be supplied in final goods production. Instead, they are endowed with entrepreneurial skills – the ability to produce capital goods using resources. All investors are *ex ante* identical, producing the same type of capital.

Since investors are born without any resource endowment, the only way they produce capital is through bank-borrowing. At the beginning of period-t, banks have at their disposal savings, s_{t-1}, that were deposited at the end of $t-1$. These are loaned out to investors who produce capital and rent it out. Investors are expected to pay back their loans at the end of period-t out of their rental incomes.

Consider an investor i who borrows an amount, b_t^i, from the bank at the beginning of period-t and converts it into capital, k_t^i. We assume that all investors are risk-neutral and maximize their expected utility function:

$$U_t^i = E_t c_t^i \tag{7}$$

subject to a budget constraint,

$$c_t^i \leq R_t k_t^i - R_t^L b_t^i. \tag{8}$$

Here R denotes the rental received on private capital and R^L denotes the loan-rate payable to the bank.

Production of capital goods is characterized by an uncertainty that is resolved only after a loan is taken out.[5] In particular, each investor uses a stochastic constant returns technology to convert loans into capital:

$$k_t^i = \theta^i b_t^i. \tag{9}$$

The productivity shock θ^i is *privately observed* and distributed identically and independently across investors. We assume that θ^i has an expected value of unity and is drawn from a cumulative distribution function $H(\theta^i)$ defined on the bounded support $\Theta \equiv [\underline{\theta}, \overline{\theta}]$.

[5] Expectations in (7) are formed with respect to information available at the beginning of period-t, before the investor approaches a bank for a loan.

An investor realizes her productivity shock after she borrows from a bank. But while she observes her shock, outsiders do not. In fact, outsiders can learn about its value only by paying a cost. Hence, unless lenders are willing to incur verification costs to ascertain project outcomes, investors may renege on loan repayments by under-reporting their capital output. Optimal loan contracts between banks and investors will then have to make certain provisions for project verification. We postpone a discussion of the exact nature of these contracts until later when we analyze financial intermediation.

3.4 Public Agents

Similar to the role performed by investors, a set of *public agents* govern the production of public capital. Also of unit mass, these agents live for only one period. They collect tax revenues from households, are paid salaries out of these revenues as they carry out public investment, and consume at the end of the period. Unlike private capital, public capital intermediated in period-t is not available for use until the beginning of period-$(t+1)$. But the output of public capital is observed costlessly at the end of the period before public agents consume.

What are unobservable, though, are the actions of public agents. Specifically, we assume that these agents have one unit of *indivisible* work time which they can devote to either building public capital or diverting tax revenues for their own consumption. We assume that one unit of time devoted to diversionary activities always succeeds in diverting a fraction, $\rho \in (0,1)$, of tax revenues for the private consumption of these agents. Outsiders are unable to detect such activities until they observe how much public capital has been produced. Hence, to alleviate this moral hazard and induce agents to produce capital, public agents have to be ensured incentive-compatible wages. In other words, for tax revenues totalling T_t, public agents have to be paid at least ρT_t.[6,7]

Since there is a continuum of these agents, in equilibrium, government salaries exactly equal ρT_t. Tax revenues, net of intermediation costs, are then converted into public capital using a constant returns technology:

$$g_{t+1} = (1-\rho)T_t. \tag{10}$$

[6] Note that we are implicitly assuming that a public agent cannot simultaneously draw a salary and divert a fraction of investment resources.

[7] An alternative way of formalizing the public investment process is to assume that public agents have one unit of labor time which can be supplied either to the market or to public sector employment. Hence, the reservation wage of the public agent is the current wage rate. Unless the agent receives at least this reservation wage he would not supply any labor to the public sector. Under this formulation, the leakage would be ρw, with ρ being interpreted as the ratio of public sector employment to the labor force. This formulation leads to similar analytical results.

For ease of analysis, we assume that public capital depreciates fully upon use as does private capital.

3.5 Banks

As discussed above, costly state verification (CSV) in the production of private capital induces a moral hazard problem in the loan market. Williamson (1987) shows that it is optimal to entrust the function of lending to financial intermediaries, or *banks*, in this environment. By intermediating between borrowers (investors) and savers (households), banks economize on resources spent in verifying project outcomes.

Moreover, by lending to multiple investors at the same time, banks are able to diversify investor-specific risks and guarantee a risk-free return to households. This is possible because they exploit the law of large numbers to predict with certainty the proportion of projects that will go bankrupt every period. Risk-neutral banks maximize their expected returns net of the costs of loan production and operate in a perfectly competitive environment.

3.6 Financial Intermediation

An optimal loan contract between a potential investor and a bank has to recognize the possibility that the investor may misreport project returns. Specifically, an optimal contract has to trade-off the need to acquire information through project verifications with the cost of acquiring it. It is well known from the works of Townsend (1979) and Gale and Hellwig (1985) that in CSV environments such as this a borrower declares bankruptcy when her realized productivity shock is below a critical state x since she is unable to pay the agreed-upon return R^L.[8]

When an investor declares bankruptcy under such conditions, we assume that the bank verifies the realized state by spending γ units of *capital* per unit lent. In equilibrium, an investor never declares bankruptcy unless her productivity turns out to be below x, in which case the bank verifies the state, takes over the project, brings it to completion and recoups an amount $Q(\theta)$ from the investment. The recovery amount is essentially the rental income from the project, $R\theta b$.

Should the realized state be above x, the investor remains solvent and is able to pay back the contracted amount, $R^L b$. However, for such behavior to be incentive-compatible, the repayment amount cannot depend upon the actual state θ^i since the bank does not verify in solvent states. Hence, by continuity of the bank's payoff function, the loan amount can only be:

$$R^L b = Q(x) = Rxb. \tag{11}$$

[8] The formalization of the CSV problem closely follows that in Azariadis and Chakraborty (1999).

The optimal loan contract can now be characterized by a standard debt contract of the form $\delta = (b, x) \in \mathbf{R}_+^2$ that specifies a loan amount and a critical value of the state space of idiosyncratic shocks. Given an investor's utility function (7), her expected payoff from such a contract is:

$$\begin{aligned} U^i(\delta) &= \int_x^{\overline{\theta}} \left[R\theta b - R^L b\right] \, dH(\theta) \\ &= Rb\mu(x), \end{aligned} \tag{12}$$

where $\mu(x) \equiv \int_x^{\overline{\theta}} \theta \, dH(\theta) - x[1 - H(x)]$.

Consider now the bank's expected profit from a contract δ. The bank earns a return of $R^L = Rx$ for all states $\theta \in [x, \overline{\theta}]$. For all other states $\theta \in [\underline{\theta}, x]$, the bank's return net of verification costs is simply $(\theta - \gamma)R$.[9] The expected profit function is then:

$$\Pi(\delta) = Rxb \int_x^{\overline{\theta}} dH(\theta) + Rb \int_{\underline{\theta}}^{x} (\theta - \gamma) \, dH(\theta) - R^D s, \tag{13}$$

which the bank maximizes subject to its resource constraint

$$b \leq s. \tag{14}$$

An optimal loan contract solves the principal-agent problem where a bank offers contract δ to a potential investor, taking as given the flow of deposits s, the return on bank deposits R^D, and the rental on capital R. In making such an offer, the bank has to recognize an investor's participation constraint. We assume that all investors have an identical reservation utility, $\overline{U}$. The principal-agent problem can then be stated as:

$$\begin{gathered} \text{Max}_{\{\delta\}} \ \Pi(\delta) \\ \text{subject to (14) and } U^i(\delta) \geq \overline{U}, \end{gathered} \tag{15}$$

where $U^i(\delta)$ and $\Pi(\delta)$ are defined by (12) and (13) above.

3.6.1 The Optimal Loan Contract

Since a profit-maximizing bank will clearly lend out as much as it can, so that (14) holds as an equality. The bank's expected profit function may now be expressed as:

$$\begin{aligned} \Pi(\delta) &= \left[Rx \int_x^{\overline{\theta}} dH(\theta) + R \int_{\underline{\theta}}^{x} (\theta - \gamma) \, dH(\theta) - R^D\right] b \\ &= Rb\left[\sigma(x, \gamma) - q\right], \end{aligned} \tag{16}$$

[9]Since verification costs are incurred in units of capital, the bank has to hire γ units of capital per unit lent.

where,

$$\sigma(x,\gamma) \equiv \left[x \int_x^{\overline{\theta}} dH(\theta) + \int_{\underline{\theta}}^{x} (\theta - \gamma)\ dH(\theta) \right] , \qquad (17)$$
$$\text{and,} \quad q \equiv R^D/R.$$

Here σ represents the bank's return (net of auditing costs) relative to the rental on capital. Note that if $\int_{\underline{\theta}}^{x} (\theta - \gamma)\ dH < 0$, the loan contract is not renegotiation-proof, as the bank would prefer to abandon bankrupt projects. To rule this out, we assume that γ is small enough, that is, $\gamma \in [0, \overline{\theta}]$. The details of the optimal contract are characterized by Theorem 1 below.[10]

Theorem 1 *Given (R, γ) and the expected investor payoff $\overline{U}$, the optimal loan contract $\widehat{\delta}$ satisfies the following conditions:*

$$(i) \quad \widehat{x}(\gamma) = \arg\max_{x \in \Theta}\ \sigma(x, \gamma),$$
$$(ii) \quad \widehat{b} = \overline{U}/R\mu\left[\widehat{x}(\gamma)\right].$$

Since the banking industry is perfectly competitive, with free entry and exit, maximal bank profits can only be equal to zero in equilibrium. Given our solution $\widehat{x}(\gamma)$, this zero profit condition, together with (13), determines the deposit rate, R^D, as a function of the rental rate, R:

$$R^D = \sigma\left[\widehat{x}(\gamma), \gamma\right] R. \qquad (18)$$

Note that $\sigma < 1$ as long as $\gamma > 0$, so that agency costs distort the incentive to save.

To obtain closed-form solutions, we shall henceforth assume that $H(\theta)$ is uniform on $[1-\varepsilon, 1+\varepsilon]$, $\varepsilon \in (0,1)$. Under this assumption, it is easy to check that $\mu(x) = (1+\varepsilon-x)^2/4\varepsilon$ and

$$\sigma(x,\gamma) = \left[x(1+\varepsilon-x) + (x-1+\varepsilon)\{(x+1-\varepsilon)/2 - \gamma\}\right]/2\varepsilon. \qquad (19)$$

From Theorem 1, the critical state is given by

$$\widehat{x}(\gamma) = 1 + \varepsilon - \gamma. \qquad (20)$$

We impose the condition that $\gamma < 2\varepsilon$ to obtain sensible results. This ensures that states over which verification occurs are of positive measure, that is, $\widehat{x} > \underline{\theta}$. Equations (19) and (19) can be combined to get:

$$\sigma = 1 - \gamma + \frac{\gamma^2}{4\varepsilon} \qquad (21)$$

[10] The investor's payoff is monotonically decreasing in x, while bank profits are inverted-U shaped. The tangency of $U^i(x)$ with $\Pi(x)$ occurs in the downward sloping part of the latter; both parties would prefer an x lower than the one corresponding to that tangency point. Hence, $\widehat{x}$ is given by the maximal point of $\Pi(x)$, with $\widehat{b}$ adjusted such that $U^i(\widehat{\delta}) = \overline{U}$. Flow of savings in the economy determines $\overline{U}$ in equilibrium.

As can be seen from this expression, σ falls as ε or γ rise. In other words, the distortion rises with both the variance of the idiosyncratic shock and the cost of verification. Finally, the proportion of investment projects that go bankrupt every period is given by

$$\psi = H[\widehat{x}(\gamma)] = 1 - \frac{\gamma}{2\varepsilon}. \tag{22}$$

4 Competitive Equilibrium

Given a tax rate, we shall now characterize and solve for the competitive equilibrium of this economy. Households and firms take the fiscal policy as given in deciding to consume and save. Consider first the representative household's problem of maximizing lifetime utility (5) subject to the budget constraint (6). The first-order condition for this is the Euler equation,

$$\frac{c_{t+1}}{c_t} = \beta(1-\tau_{t+1})(1+p)R^D_{t+1}, \tag{23}$$

that equates marginal utility from current consumption to that from future consumption, discounted by the subjective discount factor and adjusted for investment distortions and taxes on interest income.

A representative final goods producer, on the other hand, faces a static maximization problem. At an interior optimum, a firm hires labor and capital to equate marginal products and costs:

$$\begin{aligned} w_t &= (1-\alpha)X_t k_t^{\alpha}, \\ R_t &= \alpha X_t k_t^{\alpha-1}. \end{aligned} \tag{24}$$

Using (18) and (24), we obtain the equilibrium return on savings as:

$$R^D_t = \sigma R_t = \alpha\sigma X_t k_t^{\alpha-1}. \tag{25}$$

Banks lend to a large number of investors, predicting with certainty the fraction of bankrupt projects. By the law of large numbers, since the expected value of θ is unity, as much capital is produced every period as was lent out. However, not all of the capital is available for production of final goods since some of it is spent auditing bankrupt investors. In particular, for every bankrupt project, γ units of capital are 'lost' on project verification. Since capital depreciates fully upon use, this implies that

$$k_{t+1} = (1-\gamma\psi)b_{t+1} = (1-\gamma\psi)s_t, \tag{26}$$

in equilibrium, where ψ is the bankruptcy rate given by (22) above.

The equilibrium relations (24), (25) and (26) can be used to construct the economy's period-t resource constraint:

$$c_t + \frac{(1+p)k_{t+1}}{1-\gamma\psi} = (1-\tau_t)\left[R^D_t s_{t-1} + w_t\right] = (1-\tau_t)\nu A g_t^{\lambda} k_t^{\alpha}, \tag{27}$$

where $\nu \equiv \alpha\sigma/(1-\gamma\psi) + 1 - \alpha < 1$ as long as $\gamma > 0$. Note that this expression can be rewritten to yield the standard national income accounting relationship:

$$c_t + (1-\nu)Ag_t^\lambda k_t^\alpha + \rho\tau_t\nu Ag_t^\lambda k_t^\alpha + \frac{(1+p)k_{t+1}}{1-\gamma\psi} + (1-\rho)\tau_t\nu Ag_t^\lambda k_t^\alpha = Ag_t^\lambda k_t^\alpha.$$

The first three terms on the left hand side of this expression are, respectively, consumption of households, consumption of private investors, and public consumption. The last two terms on the left hand hand side are private and public consumption. The right hand side of the equation is just GDP. Note that $(1-\nu)Ag_t^\lambda k_t^\alpha$ is consumption of private investors who consume in those states of the world where the productivity state is above the threshold at which bankruptcy is declared. That consumption of private investors is $(1-\nu)Ag_t^\lambda k_t^\alpha$ follows from a little algebra on equation (12).

From equation (27), the effective relative price of investment goods in this economy is given by

$$p_I = \frac{1+p}{1-\gamma\psi}$$

Substituting the expression of ψ (equation (22) into this gives

$$p_I = \frac{1+p}{1-\gamma+\gamma^2/4\varepsilon} \tag{28}$$

The relative price of investment has two components. The first is the investment tax (the numerator) which the household faces in converting the final good into savings. The second (the denominator) is the resource loss in the process of converting savings into capital due to agency costs of intermediation (or credit frictions).

As in Glomm and Ravikumar (1994), we define a competitive equilibrium given an arbitrary fiscal policy $\mathcal{F} = \{\tau_t, g_{t+1}\}_{t=0}^\infty$:

Definition 1 *An $\mathcal{F}$-competitive equilibrium is a set of allocations $\{c_t, s_t, k_{t+1}\}_{t=0}^\infty$ and prices $\{w_t, R_t^D, R_t\}_{t=0}^\infty$ such that, given (k_0, g_0),*

(i) $\{c_t, s_t\}_{t=0}^\infty$ solves a representative household's problem, given prices;

(ii) $\{k_{t+1}\}_{t=0}^\infty$ solves a representative final goods producing firm's problem given prices; and

(iii) Markets clear, so that (26) and (27) are satisfied.

We can solve explicitly for the optimal decision rules in an $\mathcal{F}$-competitive equilibrium.[11] Assume first that per-capita consumption is proportional to post-tax per capita GDP

$$c_t = \chi(1-\tau_t)X_t k_t^\alpha. \tag{29}$$

[11] As long as the arbitrary fiscal policy $\mathcal{F}$ is bounded above, the solution obtained below is the unique $\mathcal{F}$-competitive equilibrium. See Glomm and Ravikumar (1994) for details.

Combining (29) with the equilibrium returns on savings, (25), and the Euler equation, (23), yields the decision rule for capital accumulation:

$$k_{t+1} = \frac{\alpha\beta\sigma}{1+p}(1-\tau_t)X_t k_t^{\alpha}. \tag{30}$$

Our assumption of a linear decision rule for consumption is verified by using (29) and (30) in (27):

$$\chi = \nu - \alpha\beta\sigma = \left[(1-\beta)\alpha\sigma/(1-\gamma\psi) + 1 - \alpha\right]. \tag{31}$$

5 Optimal Fiscal Policy

The optimal decision rules obtained above allow us to solve for the optimal fiscal policy. Denoting by $z(\mathcal{F})$ the value of z in an $\mathcal{F}$-competitive equilibrium, define an optimal fiscal policy as a sequence $\{\widehat{\tau}_t, \widehat{g}_{t+1}\}_{t=1}^{\infty}$ that solves:

$$\text{Max} \sum_{t=0}^{\infty} \beta^t \log c_t(\mathcal{F})$$

subject to:

$$\begin{aligned} g_{t+1} &= (1-\rho)\tau_t[w_t(\mathcal{F}) + R_t^D(\mathcal{F})s_t(\mathcal{F})], \\ \tau_t &\in [0,1], \text{ given } (k_0, g_0). \end{aligned}$$

For analytical simplicity, we restrict ourselves to an equilibrium where the tax rate is time-invariant. In that case, the optimal tax rate $\widehat{\tau}$ is chosen to maximize the value function and is given by[12]

$$\widehat{\tau} = \lambda\beta. \tag{32}$$

This uniform tax rate effectively equates the proportion of national income invested in public capital to the discounted marginal contribution of that capital. The subjective discount rate factors in since public capital is utilized with a lag of one period. Note also that the optimal tax rate is independent of public intermediation costs as well as distortions in private sector investment.[13]

[12] Details of this derivation are available from the authors upon request or from the website: http://www.uoregon.edu/~shankhac/research.htm

[13] We should note that using the optimal fiscal policy route allows us to substitute out for the tax rate and work simply with the estimates of the deeper parameters of the models in the quantitative part of the paper. We feel that this a better approach than working with actual tax rates which are extremely misleading due to widespread tax avoidance in a number of the countries that are part of our sample. Moreover, one can interpret the optimal tax rate rate as determining the "willingness-to-pay" of the domestic tax payer in each country.

6 General Equilibrium Analysis

Combining the optimal tax rate from (32) with the production function for public capital (10) and the decision rule (30), we can characterize the general equilibrium of this economy by a set of difference equations

$$k_{t+1} = (1-\lambda\beta)\alpha\beta\left(\frac{\sigma}{1+p}\right)Ag_t^{\lambda}k_t^{\alpha}, \tag{33}$$

$$g_{t+1} = (1-\rho)\lambda\beta\nu A g_t^{\lambda}k_t^{\alpha}. \tag{34}$$

Note that (33) and (34) imply the ratio of public to private capital is constant along the saddle-path equilibrium:

$$\frac{g_t}{k_t} = (1-\rho)\left(\frac{\lambda\beta}{1-\lambda\beta}\right)\frac{\nu(1+p)}{\alpha\beta\sigma} \equiv \phi. \tag{35}$$

Thus, the general equilibrium may be characterized by a single difference equation in capital per worker:

$$k_{t+1} = (1-\lambda\beta)\alpha\beta\left(\frac{\sigma}{1+p}\right)A\phi^{\lambda}k_t^{\alpha+\lambda}. \tag{36}$$

This monotonically increasing policy function allows us to obtain closed-form solution for the steady-state income level and compare it across nations that differ only in intermediation costs of capital.

6.1 Steady-State Comparisons

Since $\alpha + \lambda < 1$ by assumption, equation (36) possesses a unique asymptotically stable steady-state given by

$$\overline{k} = \left[\frac{(1-\lambda\beta)\alpha\beta\sigma A\phi^{\lambda}}{1+p}\right]^{1/[1-(\alpha+\lambda)]}. \tag{37}$$

By substituting (35) into the private production function (2), we can relate per capita GDP solely to per capita private capital,

$$y_t = Ag_t^{\lambda}k_t^{\alpha} = A\phi^{\lambda}k_t^{\alpha+\lambda}.$$

Using equation (35) and the expression for the steady state capital stock in the above, gives steady-state per capita income as

$$\overline{y} = \Omega\left[A(1-\rho)^{\lambda}\left(\frac{\sigma}{1+p}\right)^{\alpha}\left(\frac{\alpha\sigma}{1-\gamma\psi}+1-\alpha\right)^{\lambda}\right]^{1/[1-(\alpha+\lambda)]}, \tag{38}$$

where

$$\Omega \equiv \left[(\lambda\beta)^{\lambda}(1-\lambda\beta)^{\alpha}(\alpha\beta)^{\alpha}\right]^{1/[1-(\alpha+\lambda)]}.$$

Note that the expression for steady state income (equation (38)) has three terms within the square brackets (ignoring the A term). The first term is purely the effect of public capital while the second term reflects purely the effects of private capital. The last term is interesting as it reflects an interactive effect between private capital and public capital. Hence, distortions along one margin are likely to have a multiplier effect on per capita output.

Consider now two countries that differ in their intermediation costs, investment distortions and TFP, that is, in $(\gamma, \varepsilon, \rho, p, A)$. Their ratio of steady-state per capita incomes is given by

$$\frac{\bar{y}'}{\bar{y}} = \left[\left(\frac{A'}{A} \right) \left(\frac{1-\rho'}{1-\rho} \right)^{\lambda} \left(\frac{\sigma'/(1+p')}{\sigma/(1+p)} \right)^{\alpha} \left(\frac{\alpha\sigma'/(1-\gamma'\psi')+1-\alpha}{\alpha\sigma/(1-\gamma\psi)+1-\alpha} \right)^{\lambda} \right]^{1/[1-(\alpha+\lambda)]} . \tag{39}$$

Equations (37) and (39) imply that steady-state capital stocks as well as income ratios across countries are functions of distortions to both types of capital – ρ, p and σ. Since σ is a function of the variance of the idiosyncratic shock ε, and the cost of verification γ, both $\bar{k}$ and $\bar{y}'/\bar{y}$ are functions of ρ, p, ε and γ.

Turning now to the implications of the model for steady state capital-output ratios, we can use equations (37) and (38) to get

$$\frac{\bar{k}}{\bar{y}} = (1-\lambda\beta)\alpha\beta\sigma/(1+p) \tag{40}$$

This implies that in steady state, the relative capital-output ratios across countries with the same preference and technology, i.e., identical α, β and λ, is given by

$$\frac{\bar{k}'/\bar{y}'}{\bar{k}/\bar{y}} = \frac{\sigma'/(1+p')}{\sigma/(1+p)}.$$

Cross-country variations in the steady-state capital-output ratio, in this model, arise solely from distortions to private investment. In other words, intermediation costs in private capital (in addition to other policy distortions) introduce an intertemporal distortion in our model, whereas costs of intermediating public capital are purely static distortions.

7 Calibration

Our calibration exercise quantifies the effect of intermediation costs in private and public capital formation on steady-state incomes. We assume that the world income distribution is in steady-state during 1990-97 and that nations differ solely in their costs of intermediation, i.e., there are no differences in technology. Our data comes from the World Development Indicators (World Bank, 2000) and the Financial Structure Database (Beck *et al.*, 1999). The basic exercise is to calibrate the model to the 1990-97 average for the relevant data series, and then compare predicted relative incomes to the actual series, averaged over the same period. We use averages to avoid the usual pitfalls of picking a particular year.

The distortion, ρ, in the provision of public capital, has a direct interpretation in our model as the proportion of total government spending devoted to wage and salary payments. Government employment practices and sizeable presence of the public sector, especially in poorer countries, raise the labor cost of governance as also the scope for corruption. The efficiency with which tax revenues are converted into public capital ought to be, in that case, systematically related to the cost of employing public servants. We therefore feel comfortable assuming that the proportion of government expenditure spent on the wages of these workers reflect costs of intermediating public capital. Accordingly, we calibrate ρ for each country in our sample to its share of total central government expenditure (net of military spending) spent on wages and salaries. The data for this comes from the World Development Indicators.[14]

Intermediation costs in private capital formation, on the other hand, depend upon two parameters, ε and γ. These parameters have a distinct prediction in our model for the spread between lending and deposit rates. From (11), (25) and (40), the lending spread is

$$\Delta = R^L - R^D = \frac{1}{\beta(1-\lambda\beta)}\left[\frac{1+\varepsilon-\gamma}{1-\gamma+\gamma^2/4\varepsilon} - 1\right].$$

The spread Δ is thus a function of two parameters (ε, γ). However, we have only one data series with which to estimate both. To get around this problem, we postulate a linear specification, $\gamma = a\varepsilon$, and estimate γ from the lending spread data based upon different values for a. Since ε captures the standard deviation of idiosyncratic shocks, θ (variance $= \varepsilon^2/3$), it seems reasonable to assume that verification costs are proportional to ε: the more uncertain the process of converting savings into capital, the greater the costs of ascertaining the true productivity shock.

For the lending spread, we use data on net interest rate from the Financial Structure Database. This variable gives bank net interest income as a fraction of total bank assets, and corresponds exactly to the lending spread in our model. We preferred this series to the lending spread data in the International Financial Statistics (IFS) Yearbook for two reasons. First, the net interest rate series is constructed from microdata on individual banks in each country. Second, the IFS lending spread series reflects mostly prime lending rates and is also often subject to the problem of managed lending rates. This problem is less severe for the net interest rate data.

Finally, our data on per capita income and the relative price of investment goods comes from the PPP-adjusted GDP per capita series reported in the World Development Indicators.

[14] We also experimented with government spending unadjusted for military spending and obtained broadly similar results.

We express each country's per capita income relative to the US. Table 1 shows statistical properties of the data on the three variables that are of interest to us: relative per capita income, net interest rate series, and central government wages and salaries as a fraction of total government expenditure (ρ). It is important to note that both the net interest rate and ρ are negatively correlated with relative income. It is worth noting that our estimates for the highest and lowest ρ imply that the for the

We calibrate the model in three steps. First, we use the average annual value of the net interest rate for 1990-97 to estimate γ for each country under the assumption $\gamma = a\varepsilon$. We then use the country-specific γ in conjunction with the expression for the relative price of investment (equation 28) to fix p for each country. In other words, we pick the investment tax such that the relative price of investment in the model exactly matches the data for each country. Lastly, the calibrated γ, p and ρ are then used to predict each country's per capita income relative to the US for that period, assuming that all countries in our sample are on a balanced growth path by 1990. We then compare the resulting series with actual data on relative income.

7.1 Parameter Choices

To operationalize the model, a few parameter choices need to be made. For the discount rate, the choice of $\beta = 0.94$ is standard in the literature. Choices of the private and public capital share parameters, α and λ, are more problematic. In our model $\alpha + \lambda$ is the income share of a broadly measured capital stock. Gollin (2002) finds that the capital share is quite stable across countries at roughly 0.35. A number of measures for the public capital share have also been suggested in the literature. An excellent overview of this literature is contained in World Bank (1994). Table 2 summarizes the main estimates that have been proposed. For our baseline case we fix the share at $\lambda = 0.17$. While conservative, we chose to set $\alpha + \lambda = 0.5$ for all our quantitative exercises. We should note that using this relatively low number handicaps the ability of the model to magnify the distortions. A number of authors have used numbers in the range of $0.67 - 0.75$.

7.2 Baseline Results

We first look at the ability of credit distortions to explain the variation in the relative price of investment across countries, and hence the cross-country variation of the capital-output ratio. To get a handle on this, note that our model implies that if there was no investment tax then the relative price of investment would be given by $\hat{p}_I = 1/(1 - \gamma + \gamma^2/4\varepsilon)$ (see equation 28). Hence, in Figure 1 we plot $\hat{p}_I$ against the relative investment price in the data. It is clear from the figure that the credit friction does very poorly in explaining the cross-country variation in the price of investment goods. Hence, it does a poor job of explaining the variation in the capital-output ratio across countries as well.

The lower explanatory power of credit frictions is not surprising given the implied estimates for verification costs reported in Table 3. These costs are generally higher for poorer countries as one would expect, and range from 1% to 12% of total investment for the full sample of countries (second column). But its low variability reflects a similar pattern observed in the net interest rate data, and contributes directly to the weak explanatory power of the credit friction channel.

Next, we look at the implications of the model for the cross-country income distribution. Figure 2 plots the model relative income against the relative income in the data while Table 4 reports the statistical properties of the simulated series. The correlation of predicted income relative to the US with the actual relative income series is 0.60, while the mean squared error (MSE) of the predicted series relative to the actual is 0.33. The fourth row of column 2 shows that the ratio of the variance of the model's relative income to that of actual relative income is 0.21. In this sense, the model can account for 21% of the cross-country variation in relative incomes.

The results from the baseline model have a couple of key implications. First, the high correlation between the predicted and actual relative incomes suggests that there is indeed a systematic effect of financial and public capital distortions on cross-country income. Moreover, there is also some support for the structure of the model since the correlation of predicted relative income with actual relative income (0.60) is higher than the correlations with relative GDP of either of the individual series used for calibration (see Table 1).

Second, the model fails to account for the big differences in per capita income between the richest and the poorest countries. In our sample the income ratio of the richest five countries to the poorest five countries is $y^R/y^P = 33.1$. However the model only generates $y^R/y^P = 3$. Hence, it leaves unexplained most of the huge income gap between the richest and poorest countries.

7.3 Parameter Sensitivity of Results

We next turn to the parameter sensitivity of our results. In particular, there are three parameters, α, λ and a, for which we do not have tight estimates. Table 4 also reports the implications of varying these parameters for the full sample. Columns 3 and 4 show calibration results for alternative values of a. Recall that we imposed the identifying restriction $\gamma = a\varepsilon$ in order to estimate the two credit friction parameters, γ and ε, from net interest rate data. As Table 4 shows, the results are not sensitive to the proportionality factor a. Lower values of a change the results only marginally relative to the baseline case (see Table 4).

Columns 5-6 of Table 4 show the effect of varying λ. Importantly, in these experiments we keep $\alpha+\lambda = 0.5$. Raising λ implies an offsetting reduction in the share of private capital α so that the share of broadly measured capital is held constant at 0.5. The range over which we vary λ is based on the range of parameter estimates for λ that have been reported in the literature and summarized in Table 2. Increasing λ results in a marginal reduction of the correlation between the predicted and relative income series. But it improves all other statistics significantly. In particular, higher values of λ reduce the MSE, increase the variance ratio and also increase the maximum income disparity that the model generates.

These results suggest to us that relative to the financial friction margin, the public capital distortion appears to be more substantive in accounting for the cross-country income distribution. While the financial friction as measured by the lending spread does not exhibit much cross-country variation, the public capital distortion as measured by the wage share of government expenditures, does so significantly. So, if one is willing to accept relatively high estimates of the output elasticity of public capital (between 0.24 and 0.30), public capital distortions can indeed account for a large part of the cross-country income dispersion as well as generate large income gaps.

7.4 Allowing for TFP differences

One of the key assumptions we have made in our computations thus far is that technological efficiency, A, is identical across countries. A number of authors (for instance, Hall and Jones, 1999, and Parente and Prescott, 1994) have pointed out that dispersions in total factor productivity and barriers to technology adoption are fundamental determinants of the world income distribution. We turn to this issue next. In particular, we ask the following question: Given the measured relative price of investment and the public investment distortions, how big a TFP difference do we need in order to explain the observed 33-times income gap between the richest and poorest five countries in our sample?

Recall that the model implies that in steady-state, the relative per-capita income of country i is given by

$$\frac{\bar{y}_i}{\bar{y}} = \left[\left(\frac{A_i}{A}\right) \left(\frac{1-\rho_i}{1-\rho}\right)^{\lambda} \left(\frac{\sigma_i/(1+p_i)}{\sigma/(1+p)}\right)^{\alpha} \left(\frac{\alpha\sigma_i/(1-\gamma_i\psi_i)+1-\alpha}{\alpha\sigma/(1-\gamma\psi)+1-\alpha}\right)^{\lambda} \right]^{1/[1-(\alpha+\lambda)]}$$

where σ and ψ are both functions of the verification cost parameter γ under our identifying restriction $\gamma = \varepsilon$ (see equations (19) and (22)). The five richest countries in our sample are Canada, Luxembourg, Norway, Switzerland and US while the five poorest are Burundi, Kenya, Madagascar, Sierra Leone and Yemen. We compute the average values of y, ρ, p, σ and ψ for each set of countries and then use the expression above to compute y_{rich}/y_{poor}. The relative income ratio in the data is $y_{rich}/y_{poor} = 33.1$ $(= 24672/745)$.

Table 5 gives the main results. The Table has three panels. Column 2 of panel (a) shows that the measured relative price of investment goods (which distorts private capital accumulation) by itself can only generate $y_{rich}/y_{poor} = 3.3$. Correspondingly, Column 3 shows that our measured public capital distortions generate income gaps of $y_{rich}/y_{poor} = 1.1$. But, introducing both of them together along with a technology difference of 3.02 ($A_{rich}/A_{poor} = 3.02$) generates a $y_{rich}/y_{poor} = 33.1$. Recall that the standard one-sector model without public capital requires $A_{rich}/A_{poor} = 6.9$ to generate $y_{rich}/y_{poor} = 33.1$. Hence, introducing public capital into the model reduces the required technology difference by about 56 percent. We consider this significant.

Panels (b) and (c) of Table 5 show the effect of raising $(1 - \rho_{rich})/(1 - \rho_{poor})$ while keeping the relative price of investment at it measured level in the data. Thus, panel (b) shows the results when we set $(1 - \rho_{rich})/(1 - \rho_{poor}) = 3$. Recall that in our data set $(1-\rho_{\min})/(1-\rho_{\max}) = 3.3$. The fourth column of panel (b) shows that at this higher level of $(1-\rho_{rich})/(1-\rho_{poor})$ the model can generate $y_{rich}/y_{poor} = 33.1$ with $A_{rich}/A_{poor} = 2.7$. Lastly, panel(c) shows that when $(1 - \rho_{rich})/(1 - \rho_{poor}) = 4$, the model produces $y_{rich}/y_{poor} = 33.1$ with $A_{rich}/A_{poor} = 2.5$. This is a 64% reduction in the required TFP difference relative to the standard model.

Are the higher numbers for the public investment leakage represented in panels (b) and (c) of Table 5 sensible? To answer this, recall that the parameter ρ in the model corresponds to the fraction of total spending devoted to activities that are not directly productive or are non-developmental. Wages and salaries are only one component of non-productive spending. Subsidies and interest payments, for instance, are typically major claimants of government spending. We looked at the breakdown of total government spending into developmental and non-developmental expenditures for some selected poor countries. For India, the ratio of non-developmental to total expenditure was 0.61 in 2000-01.[15] The corresponding number for Indonesia was 0.69 for the same period. For Kenya, which is one of the five poorest countries in our sample, non-developmental spending amounted to 85% of total government expenditure in 2000-01.[16] Given that we are not directly accounting for corruption which, from all accounts, is a major issue in these countries, numbers for ρ in the range $0.90 - 0.95$ seem quite plausible (though possibly shocking). These numbers suggest to us that $(1 - \rho_{rich})/(1 - \rho_{poor})$ in the range of 3 or 4 may not be unreasonable.

[15] The actual number is higher still since food subsidies are included under developmental spending in the Indian budget.

[16] *Sources*: (i) Reserve Bank of India: Handbook of Statistics on the Indian Economy 1999-2000 (online: www.rbi.org.in); (ii) Bank of Indonesia: Government Finance Operations Statistics (online: www.bi.go.id); Central Bank of Kenya: Monthly Economic Review, July 2000 (online: http://home.centralbank.go.ke).

7.5 Adding a Home Production Sector

In recent work Parente, Rogerson and Wright (1999, 2000) have shown that adding a home production to the standard one sector model enables the model to generate bigger income gaps between the richest and poorest countries for any given level of investment distortions. Intuitively, a distortion to investment in the market sector induces a resource reallocation to the home production sector as long as the home production sector is less capital intensive than the market sector or faces a smaller investment distortion than the market sector. The flip side of this argument is that introducing a home production sector should reduce the TFP difference that is required to explain a given income gap for any measured level of investment distortions. Since our interest is in precisely this issue, adding a home production sector seems a logical next step. Moreover, the presence of productive public capital which is complementary to private capital in the market sector could provide an additional reason for greater resource allocation to home production in economies with lower levels of public capital.

Our specification of an economy with home production follows closely the Parente-Rogerson-Wright specification. The key difference is that we do not introduce an endogenous labor-leisure choice. We continue to assume that agents supply one unit of labor time inelastically which is now allocated between the market sector and the home sector. Utility is still log-linear in c but now c is a consumption aggregate defined as

$$c = \left[\mu c_m^{\varepsilon} + (1-\mu)\, c_n^{\varepsilon}\right]^{1/\varepsilon} \tag{41}$$

where c_m is consumption of the market good while c_n is consumption of the non-market (or home) good. In order to keep things simple, in this sub-section we abstract from credit frictions completely. Instead, we assume that the price of capital relative to the market consumption good is distorted away from unity and is equal to $1+p$.

The constraints facing the representative agent are

$$\begin{aligned} c_{mt} + (1+p)(K_{mt+1} + K_{nt+1}) &= (1-\tau)\, A g_t^{\lambda} K_{mt}^{\alpha} l_{mt}^{1-\alpha} \\ c_{nt} &= A K_{nt}^{\phi} l_{nt}^{1-\phi} \\ l_{mt} + l_{nt} &= 1 \end{aligned}$$

There are three key assumptions in this specification. First, all saving/capital accumulation occurs out of the market-sector output. Second, public capital enters the production function for the market sector but not the home sector. Third, home production is sheltered from taxation.

We omit the derivations of the optimality conditions and their corresponding steady state versions since these are straight forward. As before, we let $g = \tau(1-\rho)y_m$where y_m denotes output per unit labor in the market sector. Then using the fact that $y_m = Ag^\lambda k_m^\alpha$ we can write

$$g = [\tau(1-\rho)Ak_m^\alpha]^{1/(1-\lambda)}$$

Note that k_m is capital per unit labor in the market sector. Substituting this into the steady state conditions gives the following two key equations

$$k_m = \left[\frac{\alpha\beta}{1+p}\right]^{\frac{1-\lambda}{1-\alpha-\lambda}} \left[\tau^\lambda(1-\tau)^{1-\lambda}(1-\rho)^\lambda A\right]^{1/(1-\alpha-\lambda)} \tag{42}$$

$$l\left[\left[(1-\tau)^{1-\lambda}\tau^\lambda(1-\rho)^\lambda A\right]^{1/(1-\lambda)} k_m^{\alpha/(1-\lambda)} - (1+p)k_m\right] \tag{43}$$

$$= \left[\frac{1-\mu}{\mu(1+p)}\phi\beta A^\varepsilon k_n^{\phi\varepsilon-1}\right]^{1/(\varepsilon-1)} + (1+p)k_n.$$

where $l = l_m/l_n$. Once p, τ and A are known we can solve for k_m and l_m from equations (42) and (43). Since $k_n = \frac{\phi(1-\alpha)}{\alpha(1-\phi)}k_m$ and $l_n = 1 - l_m$ this solves the entire model.

In order to quantify the model we set $\mu = 0.5, \varepsilon = 0.5$ and $\phi = 0.2$. In the previous sections we solved for τ through the optimal fiscal policy route which yielded the result that τ was identical across all countries ($\tau = \lambda\beta$). The optimal fiscal policy problem is more complicated in an environment with home production. This is an interesting exercise but beyond the scope of this paper. To make progress here we assume that τ is identical across countries and set it equal to $\lambda\beta$.

Our primary interest here is in determining the difference in TFP that is required to generate income gaps of 33.1 given the measured levels of the distortions in private and public investment, i.e., in p and ρ. Table 6 reports the results along with the corresponding numbers in a model without home production. The first row of numbers shows that with home production one requires a TFP difference of 2.1 in order to generate $y_{rich}/y_{poor} = 33.1$ at the measured levels for p and ρ. This contrasts sharply with the fact that without home production the corresponding TFP gap is 3. The next two rows show the required TFP gaps when we set $\frac{1-\rho_{rich}}{1-\rho_{poor}}$ at higher levels than those measured in the data. Recall that our estimate for that number from the data is 1.5. As can be seen from the table, when $\frac{1-\rho_{rich}}{1-\rho_{poor}} = 3$ the required TFP gap comes down to 1.8. It falls further to 1.7 when $\frac{1-\rho_{rich}}{1-\rho_{poor}} = 4$.

The numbers above lead us to conclude that a model with distortions in private and public investment when combined with home production can go a long way in rationalizing the observed income differences between the richest and poorest countries without having to assume huge TFP differences.

8 Borrowing Costs and Investment in Technology

A number of recent papers such as Hall and Jones (1999) and Parente and Prescott (1994, 1999) have argued that the key to understanding income differences across countries is to understand differences in total factor productivity (or equivalently, differences in the levels of technology). These authors argue that differences in capital-output ratios contribute very little to cross-country income differences. Given that our baseline CSV model affects steady state income levels through the capital-output ratio, our results are open to the criticism that we are ignoring more substantive ways credit frictions affect development, that is, through their effect on technology adoption. To address this issue, in this section we calibrate a version of Parente's (1995) model of technology adoption augmented to incorporate credit frictions.

The key idea of the Parente model is that upgrading to a better technology is costly: it requires investment. We modify the Parente model by assuming that this investment has to be funded by borrowing from banks. The world stock of knowledge is assumed to grow at a constant rate $\gamma > 0$ so that

$$W_{t+1} = (1+\gamma)W_t$$

Given W_t, the investment required to go from a technology level $A_t = A$ to $A_{t+1} = A'$ is

$$x_t(A, A') = \pi \int_A^{A'} \left[\frac{s}{W_t}\right]^\alpha ds, \quad \alpha > 0,$$

where π is the size of the technology adoption barrier. Integrating this equation gives

$$A_{t+1}^{1+\alpha} = A_t^{1+\alpha} + \left[\frac{1+\alpha}{\pi}\right] W_t^\alpha x_t$$

Assume that the production technology for firms is given by

$$y_t = A_t h_t n_t$$

where $h \in [0,1]$ denotes amount of time a firm/plant is operated and $n_t \in \{0, \overline{n}\}$ denotes number of workers. We normalize $\overline{n} = 1$. Since each consumer is endowed with one unit of time and faces no labor-leisure choice, assuming that the number of firms equals the number of consumers implies that all firms operate and that they do so by hiring one worker and running full-shift:

$$y_t = A_t.$$

Assume that the typical firm borrows the entire investment amount x_t and pays it back at the end of the period. The firm's dividend at t is

$$v_t = y_t - w(h_t) - n_t - (1+c)x_t$$

where $w(h)$ is the wage paid to a worker working a work-week of length h and c is the interest cost of borrowing.

The solution to the model implies that in steady state where all per capita variables grow at the rate γ we have

$$A_t = \frac{W_0(1+\gamma)^{t-1}}{(1+c)^{1/\alpha}(1+\bar{r})^{1/\alpha}\pi^{1/\alpha}}, \tag{44}$$

which gives output per capita along the balanced growth path from (**??**).

Consider two countries that differ only in borrowing costs and face otherwise similar technology adoption barriers, π. The model implies that the steady state income ratio of two countries is given by

$$\frac{y^R}{y^P} = \left(\frac{1+c^P}{1+c^R}\right)^{1/\alpha},$$

where y^R and y^P respectively denote incomes of the rich and poor country. Parente (1995) calibrates $1/(1+\alpha) = 0.57$ to match the speed of convergence of Japan to the USA. This implies that $1/\alpha = 1.33$.

Let us first calibrate the borrowing cost, c, to the net interest rate data as before. Based upon the five richest and five poorest countries in our sample, we have $c^P = 0.0684$ and $c^R = 0.0219$, so that

$$\frac{y^R}{y^P} = (1.05)^{1/\alpha} = 1.06.$$

If instead we calibrate c to Beck *et al.*'s (1999) overhead cost data, we have $c^P = 0.1270$ and $c^R = 0.0090$. In this case,

$$\frac{y^R}{y^P} = (1.12)^{1/\alpha} = 1.16.$$

Put differently, in our sample the income ratio of the richest five countries to the poorest five countries is $y^R/y^P = 33.1$. To match this figure in the model using the overhead cost data, we need $\alpha = 0.03$ while to match the income ratio using the net interest rate data requires that $\alpha = 0.01$. Hence one needs a very high elasticity of A_t with respect to $1+c$. But such high elasticities imply a counterfactually fast speed of convergence as per Parente's estimates. Hence, we find measures of α in this range to be implausible.

These numbers imply that the credit friction margin can barely explain about 3% ($=$ $1.16/33.2$) of the observed income gap between the richest and poorest five countries in our sample even when this margin directly affects the level of technology. Since this magnitude is similar to the numbers obtained from the CSV model of capital accumulation, we conclude that the poor performance of credit frictions in explaining the poverty of nations is a more general phenomenon rather than being specific to a particular model.

9 Conclusion

Agency costs in the process of intermediating savings and private investment have been the focus of a lot of work on growth and financial development. Intermediation costs, or leakages, in the process of converting tax revenues into productive public capital has also been a commonly cited issue among growth researchers. While neither idea is novel to this paper, our chief contribution has been to bring the two together in the context of the one-sector neoclassical growth model and quantify their explanatory power.

We interpret our results as delivering a mixed verdict for the two margins isolated here. The calibration results suggest that the private investment distortion as measured by the lending spread data is insufficient to quantitatively account for both the observed variation in the capital-output ratio as well as the huge income dispersion observed in the data. We find that while there are systematic and large investment distortions in the data as measured by the relative price of investment, these are orthogonal to those induced by credit frictions. Moreover, abstracting from differences in technology, neither the measured relative price of investment nor distortions in public investment can account for the 33-times income difference between the five richest and five poorest countries in our sample. However, the introduction of both margins together along with TFP differences of a factor of 3 between the richest and poorest five countries can jointly account for the observed income gap. This stands in sharp contrast with the standard one-sector model without public capital where one needs a TFP ratio of 6.9 to generate the income gap in the data. We consider this result as indicative of the importance of introducing a role for productive public capital. We also found that adding a home production sector to the one-sector model reduces the required TFP gap even further to 2.1.

Moreover, we believe that the weak explanatory power of credit frictions for the world income distribution is a general result and not a function of the specific model of credit frictions that we studied. This belief stems from the fact that the calibration of an alternative model where credit frictions directly affect the level of technology reveals similarly weak effects of credit frictions.

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Table 1. Statistical Properties of the Data

Sample: 79 countries, 1990-97 annual average

	$\frac{y}{y_{US}}$	*Net interest rate*	ρ
Mean	0.36	0.04	0.25
Standard deviation	0.29	0.03	0.14
Max	1.12	0.13	0.70
Min	0.02	0.01	0.02
Correlation with $\frac{y}{y_{US}}$	1	-0.48	-0.50

Table 2. Public Capital Share Estimates

Sample	λ	*Author/year*	*Public capital measure*
USA	0.39	Aschauer 1989	Nonmilitary public capital
OECD	0.07	Canning and Fay 1993	Transportation
Developing	0.07	Canning and Fay 1993	Transportation
Developing	0.16	Easterly and Rebelo 1993	Transport & communication

Table 3. Baseline Model: Predicted Verification Costs (γ)

	Full Sample	*Rich*	*Upper-middle*	*Lower-middle*	*Poor*
Mean	0.04	0.03	0.05	0.04	0.05
Standard deviation	0.02	0.01	0.03	0.02	0.02
Max	0.12	0.06	0.12	0.08	0.10
Min	0.01	0.01	0.02	0.01	0.03

Table 4. Model: Predicted Relative Income

Baseline Parameters: $\beta = 0.94$, $\alpha = 0.33$, $\lambda = 0.17$, $a = 1$

	Baseline	$a = 0.75$	$a = 0.5$	$\lambda = 0.10$	$\lambda = 0.24$
Corr with $\frac{y}{y_{US}}$	0.60	0.58	0.55	0.64	0.58
MSE	0.33	0.34	0.34	0.38	0.30
Variance ratio	0.21	0.20	0.19	0.11	0.33
Max	1.11	1.10	1.09	1.08	1.13
Min	0.49	0.48	0.48	0.66	0.36

Table 5. TFP Differences and Income Gaps

Predicted $\frac{y_{rich}}{y_{poor}}$; Parameterization: $\alpha + \lambda = 0.5$

	Private investment only	Public capital only	Both together
5a. $\frac{1-\rho_{rich}}{1-\rho_{poor}} = 1.5$ (data); $\frac{P_I}{P_C}$: data			
$\frac{A_{rich}}{A_{poor}} = 1$	3.3	1.1	3.6
$\frac{A_{rich}}{A_{poor}} = 2$	13	4.5	14.6
$\frac{A_{rich}}{A_{poor}} = 3$	29.6	10.2	33.1
5b. $\frac{1-\rho_{rich}}{1-\rho_{poor}} = 3$; $\frac{P_I}{P_C}$: data			
$\frac{A_{rich}}{A_{poor}} = 1$	3.3	1.5	4.7
$\frac{A_{rich}}{A_{poor}} = 2$	13	5.8	18.9
$\frac{A_{rich}}{A_{poor}} = 2.7$	22.8	10.2	33.1
5c. $\frac{1-\rho_{rich}}{1-\rho_{poor}} = 4$; $\frac{P_I}{P_C}$: data			
$\frac{A_{rich}}{A_{poor}} = 1$	3.3	1.6	5.2
$\frac{A_{rich}}{A_{poor}} = 2$	13	6.4	20.9
$\frac{A_{rich}}{A_{poor}} = 2.5$	20.6	10.2	33.1

Table 6. TFP Gap Required to Generate $\frac{y_{rich}}{y_{poor}} = 33.1$

Parameters: $\alpha = 0.33$, $\lambda = 0.17$, $\mu = \varepsilon = 0.5$, $\phi = 0.2$

	Home Production	No Home Production
$\frac{1-\rho_{rich}}{1-\rho_{poor}} = 1.5$(data)	2.1	3
$\frac{1-\rho_{rich}}{1-\rho_{poor}} = 3$	1.8	2.7
$\frac{1-\rho_{rich}}{1-\rho_{poor}} = 4$	1.7	2.5

Figure 1: Relative price of investment

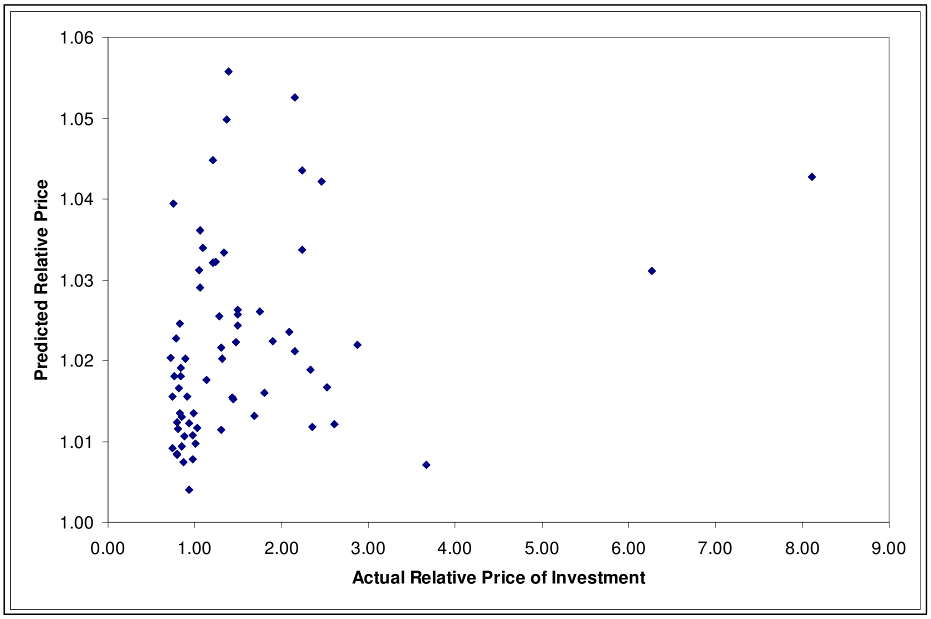

Figure 2: Relative Income