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and Inequality Correlation?

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What Drives the Cross-Country Growth and Inequality Correlation?*

by

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Abstract

We present a neo-classical model that explores the determinants of growth-inequality correlation and attempts to reconcile the seemingly conflicting evidence on the nature of growth-inequality relationship. The initial distribution of human capital determines the long run income distribution and the growth rate by influencing the occupational choice of the agents. The steady state proportion of adults that innovates and updates human capital is path-dependent. The output elasticity of skilled-labor, barriers to knowledge spillovers, and the degree of redistribution determine the range of steady state equilibria. From a calibration experiment we report that a combination of a skill-intensive technology, low barriers to knowledge spillovers, and a high degree of redistribution characterize the group of countries with a positive growth-inequality relationship. A negative relationship arises in the group with the opposite characteristics.

JEL Classification Code:

E1, General Aggregative Models

O4, Economic Growth and Aggregate Productivity Characteristics

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1. Introduction

While an enormous literature investigates the effect of inequality on growth, less attention has been given to explore the determinants of growth-inequality correlation. The issue is important because the sign and magnitude of growth-inequality correlation depend on the sample of countries. Barro reports no evidence of any growth-inequality for the whole world. However, when he sorts countries into rich and poor, he finds that growth and inequality correlate positively for rich and negatively for poor countries.¹ One still needs an explanation for this finding in a general equilibrium model where growth and income inequality are endogenously driven by the deep parameters. With this objective in mind, we ask the question in this paper: what drives the cross-country correlation between inequality and growth? A major result of this paper is that the initial distribution of human capital may provide an important clue in understanding the variation of growth and income inequality across countries.

The initial distribution of human capital has been receiving attention in the recent literature on growth and inequality. Castello and Domenech (2002) empirically document a strong link between human capital inequality and cross-country growth disparity. Our theoretical model provides an interpretation of this finding as well. In our model, the steady state range of human capital distribution, and the correlation between growth and income inequality over that range are functions of technology and policy parameters. The model thus suggests an algorithm for partitioning the cross-country growth-inequality data, based on country specific technology and policy parameters. Our calibrated model provides an explanation of Barro's (2000) finding that the cross-country correlation between growth and income inequality relationship may differ between samples of rich and poor countries. The difference in growth-inequality correlation between rich and poor countries arises for two reasons. First, rich and poor countries have widely different skill intensity and knowledge barriers to technology. Second, rich and poor nations have very different redistributive policy. Both these technology and policy characteristics alter the growth-inequality correlation by impacting the threshold for undertaking investment in human capital.

¹ The sign of the growth-inequality correlation is still an empirically unsettled issue. Persson and Tabellini (1994) report a strong negative relationship between growth and inequality. Forbes (2000) finds a positive association between growth and inequality. Banerjee and Duflo (2000) find a non-linear relationship between inequality and growth rates for cross-country data. Castello and Domenech (2002) find a negative relation between growth and human capital inequality. We attempt here to understand the determinants of growth-inequality correlation.

Our model builds on a recent stream of literature in which the initial inequality of endowments shapes a country's occupational structure and growth.² The model has several features. First we abstract from physical capital. Prescott (1998) and others point towards economic factors that are more fundamental than physical capital for understanding cross-country disparity in economic growth. The absence of a tangible capital that can be used as a collateral rules out a viable credit market, as in Loury (1981), and allows for path dependence.³ Second, to show the interplay between occupational structure, the distribution of human capital, and growth, we combine Lucas's (1988) notion of external effects from human interaction with Prescott's (1998) idea of the usability of knowledge. Total factor productivity differs across countries because of differences in country-specific external effects of average human capital and the usability of knowledge. Moreover, the initial distribution of human capital characterizes the proportion of the innovators in the labor force, and, therefore, determines both the stock and the usability of knowledge. Third, in the model as in Alessina and Rodrik (1994), the government redistributes income from the owners of accumulated human capital to the owners of a non-reproducible input, labor. This redistributive policy via influencing the occupational distribution, impacts the cross-country growth-inequality relationship.

Numerical examples in the paper illustrate that everything else equal, the sign and *magnitude* of the cross-country growth-inequality correlation depend critically on the values of three parameters of the model: (i) the output elasticity of skilled labor, (ii) the extent of knowledge spillovers, and (iii) the degree of policy induced redistribution. These technology and policy parameters by influencing the threshold level for human capital investment in schooling set an upper bound for the steady state distribution of skills. These parameters also affect the lower bound for the proportion of the labor force that must innovate and invest in human capital in order to ensure a non-negative balanced growth rate. The model thus provides a mapping from the proportion of innovators to the long run growth rate of per capita income,

² See, for example, Banerjee and Newman (1993), Galor and Zeira (1993), Bandyopadhyay (1993) and Freeman (1996).

³ There are two distinct branches of literature dealing with long run inequality. In the models of Alessina and Rodrik (1994) and Bertola (1993), a perfect credit market rules out path dependence of the steady state equilibrium. The long run inequality is thus independent of the initial conditions in their models. On the other hand, in Galor and Zeira (1993), Banerjee and Newman (1993), and Aghion and Bolton (1993), historical inequality may persist in the long run in the presence of credit market imperfections. We follow this second strand by considering an extreme scenario, where the credit market does not exist. Mookherjee and Ray (2000) present a general framework to encompass various scenarios of credit market imperfections giving rise to persistent income inequality and multiple steady states. However, they do not address the issue of endogenous growth and income inequality relationship.

and to the income gini-coefficient. Technology and policy parameters partially determine the possible pairs of growth rate and gini coefficients in the set of steady states. The growth-gini correlation may, therefore, differ depending on the sample.

In a calibration exercise based on 66 countries, we explore the specific reasons for the difference in growth-inequality correlation between rich and poor countries. We infer that given the same preference and the world technology frontier, poor countries have a low degree of policy induced income redistribution, a low skill intensity, and a barrier to the diffusion of knowledge that is twice as large as the barrier in rich countries. As a result, in poor countries the maximum attainable steady state proportion of managers in the labor force is less than the growth-maximizing proportion. Assuming countries in the sample are in different steady states, countries with a relative scarcity of managers have a higher skill-premium, which means higher income inequality. On the other hand, since managers are the vehicles of knowledge spillovers, long run growth is lower in countries where the proportion of managers in the labor force falls below the growth-maximizing level. Consequently, the growth-inequality correlation is negative for poor countries and positive for rich countries, which is consistent with Barro's empirical finding.

The rest of the paper is organized as follows. In section 2, we lay out the model and define the notion of equilibrium. Section 3 derives the steady state properties of the model. Section 4 examines the growth-inequality relationship under alternative tax policies and alternative technological environments. Section 4 also reports some calibration results regarding the growth-inequality correlation. Section 5 concludes.

2. The Model

We consider an environment consisting of a single perishable consumption good, variable human capital, manual labor, and a technology that is partly determined by the distribution of human capital. An agent lives two periods, one as a child attached to an adult, and one as an adult with a child of her own. There is a continuum of dynasties with measure one, and at each date t , a typical dynasty consists of an adult and a child. The adult has one unit of labor and h units of human capital. She earns her income by choosing an occupation of a manager or a worker and then divides her income between current consumption and investment in her child's education. Investment in human capital is the only means of transferring consumption in our model. We assume that human capital cannot be used as collateral for loans and there is no

separate tangible capital in the economy. This rules out a viable credit market in the model, which is crucial in terms of preserving dynastic heterogeneity.

Preferences display intergenerational altruism, and so the adult maximizes the present discounted value of consumption of her dynasty. Dynasties differ only in terms of the adult's endowment of human capital at date 0. At date t , Ψ_t denotes the cumulative distribution of human capital among the date t adults. The history specifies the initial distribution Ψ_0 .

Groups of adults carry out production. Each group consists of a manager and one or more workers. The output q of a group at date t depends on the manager's human capital h , the number n_t^d of workers she employs and the total factor productivity (TFP) level $A_t > 0$ such that $q_t = A_t h^{1-a} (n_t^d)^a$, where $0 < a < 1$ measures the output elasticity of a worker. We model TFP to combine a parametric effect of world stock of non-rival knowledge, A highlighted in Romer (1990) and the effect of endogenously determined average human capital stock, H_t highlighted in Lucas (1988) as a country-specific externality to determine the potential stock of knowledge or potential TFP of a country. However, how much of this knowledge would be exploited depends critically on the endogenous proportion m_t of innovators in the labor force. This idea follows Prescott's (1998) insight of usability of knowledge.⁴

In particular, we assume that at each date t :

$$A_t = A m_t^\theta H_t^b. \quad (1)$$

Note that a higher value of θ lowers the value of TFP in the economy. The parameter θ , therefore, proxies various barriers to spillover of information facilitated by the innovators and hence determines how far innovative activities inside a country can push its TFP. If θ equals 0, there are no such barriers and therefore, a manager can exploit 100% of the technology AH_t^b available to the economy where she operates.⁵ In such a case, the production function reduces to

⁴ Prescott (1998) argues that the cross-country disparity in income is more explained by how much non-rival knowledge a country could exploit rather than the availability of non-rival knowledge itself. In a similar vein, Galor and Tsiddon (1997) also highlight the importance of high-ability individuals in determining economic growth.

⁵ These barriers may arise due to the absence of a suitable information technology. Alternatively, one may interpret θ as barriers at the plant level due to regulatory system as in Parante and Prescott (2000, pp. 81-89) with an important difference. In their model, a larger barrier implies that each firm (or a group led by a manager) needs to undertake greater investment to get the same increase in TFP as in the case of no barrier. In our model, a larger barrier means that a greater proportion of adults needs to innovate to get the same increase in TFP as in the case of no barrier.

a technology similar to Lucas (1988). To summarize, at each date $t \geq 0$ the output q_t of a manager is given by:

$$q(h, n_t^d; H_t, m_t) = A m_t^\theta H_t^b h^{1-a} (n_t^d)^a, \quad t=0, 1, 2, \dots \quad (2)$$

This specification of total factor productivity has also been used earlier in Bandyopadhyay (1993).⁶ Since we focus on the relationship between long run growth and inequality, we assume $b=a$.⁷ This assumption makes the aggregate production function linear in the reproducible input H_t .⁸

At each date $t \geq 0$ given the wage rate w_t , and the two external factors H_t and m_t , a manager with h units of human capital employs n_t^d number of workers so as to

$$\underset{n_t^d > 0}{\text{Maximize}} \left| q(H_t, m_t, n_t^d, h) - w_t n_t^d \right| \quad t=0, 1, 2, \dots \quad (3)$$

The first order condition of (3) yields $w_t = aA H_t^a m_t^\theta h^{1-a} (n_t^d)^{a-1}$, or, equivalently, the optimal number $n_t^d(h)$ of workers employed by a manager with h units of human capital is:

$$n_t^d(h) = \left(\frac{aA m_t^\theta H_t^a}{w_t} \right)^{\frac{1}{1-a}} h, \quad t=0, 1, 2, \dots \quad (4)$$

By (3) and (4), at each date t , the indirect profit of a manager is proportional to her human capital stock h and is given by $r_t h$, where,

⁶ As in Bandyopadhyay (1993), in our model, along a balanced growth path, the educated elite chooses a managerial occupation and undertakes all the investment in human capital. The motivation for including the proportion of managers in the labor force in the total factor productivity function stems from the study of Bandyopadhyay (1997) who finds that the proportion of educated people significantly explains cross-country disparity in growth rates.

⁷ This assumption implies that for a given stock of aggregate human capital, H_t , the external effects on TFP due to human interaction is larger (meaning higher b) if the production technology is more skill intensive (meaning lower a).

⁸ In section 3, we demonstrate that a steady state equilibrium is characterized by the following two properties: (i) labor market clears with the property that the workers and managers do not switch their respective occupations; (ii) only managers invest in human capital. Such a steady state ensures that the aggregation of the production function (2) across all managers yields a linear relationship between per capita output and the economy's average human capital H making it an "AK" type growth model à la Rebelo (1991).

$$r_t = (1-a)Am_t^\theta H_t^a (aAm_t^\theta H_t^a / w_t)^{a/(1-a)}, t=0, 1, 2, \dots \quad (5)$$

The Government

The government in this economy undertakes a redistributive tax-subsidy program in the following sense: The government transfers resources from rich to poor. The rich possess sufficient human capital to operate as a viable manager while the poor do not. At any date t , the government thus levies a constant proportional tax (τ) on the income of the managers and makes a lump-sum redistributive transfer, z_t to each worker.⁹ Let the adult's occupation $n_t(\cdot)$ be an indicator function of her human capital stock h such that if she is a worker, $n_t(\cdot) = 1$, otherwise, if she is a manager, $n_t(\cdot) = 0$. Let H_{mt} denote the total human capital of all managers at date t . Then the budget constraint of the government can be written as:

$$(1 - m_t)z_t = \tau r_t H_{mt}, \text{ where, } H_{mt} = \int_{\{h: n_t(h)=0\}} h d\Psi_t(h). \quad (6)$$

The budget constraint (6) can be rewritten as:

$$z_t = \frac{\tau r_t H_{mt}}{(1 - m_t)} \quad (7)$$

The parameter τ represents the degree of fiscal redistribution, which we calibrate. The higher the value of τ , the greater the degree of redistribution.¹⁰

The Breakeven Skill Level

Let \bar{w}_t and \bar{r}_t respectively denote the post subsidy wage rate and the after-tax price of human capital at each date t . In other words, $\bar{w}_t = w_t + z_t$ and $\bar{r}_t = (1 - \tau)r_t$. At each date t , let x_t denote

⁹ The tax-subsidy scheme is occupation specific here along the lines of Judd (1985, 1999). Although the transfer, z_t is lump sum, along a balanced growth path it grows at the same rate as the wage rate, w_t . The steady state proportion, z_t/w_t thus proxies the rate of redistributive transfer to workers, which we calibrate in section 4.

¹⁰ In principle τ can as well be negative which means a proportional educational subsidy financed by lump-sum wage taxation. A natural question arises: what is the optimal τ ? Bandyopadhyay and Basu (2001) explore this issue in a separate paper and find that the optimal τ depends on the initial proportion of skilled people. In this paper, we keep τ as a redistributive policy parameter, which may not correspond to the optimal rate. We calibrate τ in section 4.

the level of *breakeven skill* such that an adult with x_t units of human capital earns an equal amount net of tax and subsidy either as a manager or as a worker. By (5), it follows, therefore, that x_t satisfies

$$\bar{w}_t = \bar{r}_t x_t, \quad t=0, 1, 2, \dots \quad (8)$$

At each date $t \geq 0$, her occupational choice $n_t(\cdot)$ and the resulting income $y_t(\cdot)$ as functions $h \geq 0$ are

$$\begin{aligned} n_t(h) &= 1, \text{ if } h < x_t; & n_t(h) &= 0 \text{ if } h > x_t; \\ n_t(h) &= 1 \text{ or } 0, & \text{ if } h &= x_t, \end{aligned} \quad (9)$$

and

$$y_t(h) = n_t(h) \cdot \bar{w}_t + (1 - n_t(h)) \cdot \bar{r}_t h. \quad (10)$$

Figure 1 illustrates how the breakeven skill level divides the adults into two occupational groups, workers and managers, according to their individual stock of human capital.

<Figure 1 comes here>

At date $t+1$, an adult's human capital h_{t+1} is positively related to her parent's human capital h_t and the investment s_t in her schooling made by her parent at date t . In particular, the human capital is updated by using the following technology:

$$h_{t+1} = (1 - \delta)h_t + s_t, \quad 0 < \delta < 1 \quad t=0, 1, 2, \dots \quad (11)$$

The above investment technology presumes a positive externality $\delta < 1$ associated with family upbringing in the tradition of Benabou (1996). It also assumes $\delta > 0$ such that without a positive investment in schooling the current generation can transfer only a fraction $(1 - \delta)$ of existing knowledge to the future generation. Consequently, knowledge is maintained or accumulated

only if a generation acquires them through investment in schooling. This feature is similar to Mankiw et al. (1992).

Following Barro (1974) we assume intergenerational altruism. At each date t , the utility v_t of the adult is a function of her family's consumption c_t and her child's utility v_{t+1} as a grown-up adult. In other words,

$$v_t = V(c_t, v_{t+1}) = u(c_t) + \beta v_{t+1}. \quad (12)$$

where $u(c) = \ln c$ and $0 < \beta < 1$, such that

$$v_0 = \sum_{t=0}^{\infty} \beta^t \ln c_t.$$

The adult with h units of human capital chooses a suitable occupation $n_t(h)$ following (9) and divides her income $y_t(h)$, given by (10), between consumption c_t and investment s_t such that

$$c_t + s_t \leq y_t(h) \quad t=0, 1, 2, \dots \quad (13)$$

Note the absence of a viable credit market is implicit in the above budget constraint. At $t=0$, the optimization problem of the adult with $h \geq 0$ units of human capital is to choose a sequence $\{c_t(h) \geq 0, s_t(h) \geq 0, n_t(h) \in \{0,1\}\}_{t=0,1,2,\dots}$, so as to

$$\text{Maximize } \sum_{t=0}^{\infty} \beta^t u(c_t) \text{ subject to (9), (10), (11) and (13). } t=0, 1, 2, \dots \quad (14)$$

Characteristics of Equilibrium

The set of sequences $\{c_t(h), s_t(h), n_t(h), n_t^d(h): h \geq 0; x_t, r_t, m_t, H_t, w_t, \tau\}_{t=0,1,2,\dots}$ and the initial distribution Ψ_0 describe the model's *equilibrium* such that at each $t \geq 0$, the labor demand $n_t^d(\cdot)$ satisfies (4), the implicit rental price r_t of human capital satisfies (5), the breakeven skill x_t satisfies (8), the sequence $\{c_t(h), s_t(h), n_t(h)\}_{t=0,1,2,\dots}$ satisfies (14), and $\{H_t, m_t\}_{t \geq 0}$ coincides with the same generated by the optimal sequence $\{s_t(h), n_t(h)\}_{t=0,1,2,\dots}$, such that

$$m_t = \int_{\{h:n_t(h,\tau)=0\}} d\Psi_t(h), \quad (15)$$

$$H_{t+1} = (1-\delta) \int h d\Psi_t(h) + \int s_t(h) d\Psi_t(h), \quad H_0 = \int h d\Psi_0(h), \quad (16)$$

and the labor market clears such that at each date $t=0, 1, 2, \dots$,

$$\int_{\{h:n_t(h,\tau)=0\}} n_t^d(h, w_t; H_t, m_t) d\Psi_t(h) = 1 - m_t \quad (17)$$

Notice that the labor demand function, n_t^d does not depend on the redistributive tax rate because the tax is based on indirect profit and not on the output of the firms. On the other hand, the labor supply or, equivalently, occupational choice as characterized in (8) and (9) depends on the after tax wage rate. Nevertheless, the market clearing wage does not depend on the tax rate τ because the profit maximizing firm equates the before tax real wage to the marginal product of labor. Figure 2 illustrates the labor market equilibrium in a situation where subsidy z_t is positive.¹¹

<Figure 2 comes here>

The goods market clears such that at each date $t=0, 1, 2, \dots$,

$$\int_{h \geq 0} (c_t(h) + s_t(h)) d\Psi_t(h) = \int_{\{h:n_t(h,\tau)=0\}} q(h, n_t^d(h); H_t, m_t) d\Psi_t(h). \quad (18)$$

¹¹ Note that because of the discrete occupational choice, the aggregate labor supply curve (called L^s schedule) is a step function. At $\bar{w}_t = 0$, the breakeven skill, x_t equals zero which means L^s equals zero, because everybody chooses to be a manager. As \bar{w}_t increases x_t increases as seen from (8) and Figure 1. There exists a \bar{w}_t^* such that for all w_t greater than \bar{w}_t^* , h_t is less than x_t meaning everybody wants to become a worker. At $x_t = h_t$, an adult is indifferent between the two occupations. This explains horizontal segment BC of the labor supply function over the range $1 - m_t \leq L^s \leq 1$. The labor market equilibrium condition (17) holds at the point where the MPL schedule intersects the labor supply schedule corresponding to $L^s = 1 - m_t$, as shown in Figure 2.

The distribution of human capital evolves as

$$\Psi_{t+1}((1-\delta)h + s_t(h)) = \Psi_t(h). \quad (19)$$

This completes the definition of equilibrium.

III. Balanced Growth State

For the purpose of calibration, we compute now a parametric example with a logarithmic utility function, $u(c_t) = \ln c_t$. Bandyopadhyay and Basu (2001) have shown¹² that in the above environment, there are two constants $0 < m < 1$, $h_0 > 0$ and a time invariant function $\gamma : m \rightarrow R$ such that a competitive equilibrium with an initial distribution Ψ_0 with $\Psi_0(h) = 1-m$, for $0 \leq h < h_0$, $\Psi_0(h) = 1$ for all $h \geq h_0$, describes a balanced growth state. In such a state, the managerial proportion, m_t , in the labor force, the implicit net rental price of human capital, \bar{r}_t , net wage rate, \bar{w}_t , the average human capital, H_t , and the cumulative distribution of human capital, Ψ_t satisfy:

$$m_t = m, \quad (20)$$

$$\begin{aligned} \bar{r}_t &= (1-\tau)r(m), \\ \text{where, } r(m) &= (1-a)A_0m^\theta(1-m)^a, \end{aligned} \quad (21)$$

$$\begin{aligned} \bar{w}_t &= w(m, h_0)(1+\gamma)^t, \\ \text{where, } w(m, h_0) &= (a(1-a)^{-1} + \tau)r(m)mh_0(1-m)^{-1}, \end{aligned} \quad (22)$$

$$H_t = mh_0(1+\gamma)^t, \quad (23)$$

$$\Psi_t((1+\gamma)^t h) = \Psi_0(h), \quad (24)$$

$$\text{with } h \geq 0$$

The per capita national income Y_t satisfies:

$$Y_t = Y_0(1+\gamma)^t, \text{ where } Y_0 = (1-m)w(m, h_0) + m(1-\tau)r(m)h_0 \quad (25)$$

¹² For a detailed derivation of the following results, see the appendix of Bandyopadhyay and Basu (2000).

The optimal investment rule $s_t(h)$ in (11) satisfies, $s_t(h) = i_t(h)h$ such that

$$i_t(h) = 0 \quad \text{if} \quad h = 0 \quad (26)$$

$$= \beta[(1-\tau)r(m) + 1 - \delta] - 1 + \delta \quad \text{if} \quad h = h_0 \quad (27)$$

It follows, therefore, that the balanced growth rate $\gamma: m \rightarrow R$ is given by:

$$\gamma(m) = \beta[(1-\tau)r(m) + 1 - \delta] - 1 \quad (28)$$

Bandyopadhyay and Basu (2001) also show that if (20)-(24) hold, then there exists a constant $h^* > 0$ such that adults with h^* units of initial human capital remain indifferent between investing and not investing in schooling, and h^* satisfies:

$$h^* = \xi(m).B(m).h_0. \quad (29)$$

where

$$\xi(m) = \frac{\left[\frac{am}{(1-a)(1-m)} + \frac{\pi m}{1-m} \right]}{\left[(1-\beta)(1-\tau) + (1-\beta)(1-\delta)r(m)^{-1} \right]}, \quad (30)$$

$$B(m) = \left(\frac{1-\delta+i(m)}{1-\delta} \right) \left(k(m, \tau) - \frac{\beta(1-\beta^{k(m)})}{1-\beta} \right), \quad (31)$$

$$k(m) = \frac{\ln \left[1 + \frac{(1-\beta)\ln((1-i(m))/(1-\tau)r(m))}{\beta[\ln(1+i(m)-\delta) - \ln(1-\delta)]} \right]}{\ln \beta}, \text{ and} \quad (32)$$

$$i(m) = \beta[(1-\tau)r(m) + 1 - \delta] - 1 + \delta. \quad (33)$$

A sufficient condition for the existence of such a dynastic steady state where all managers invest in schooling and no workers do so is that $h_0 > h^*$, or equivalently by use of (29),

$$\xi(m).B(m) < 1 \quad (34)$$

A few points of clarification are in order. First, the net implicit rental price of human capital in (21) is a time invariant, hump shaped function $r(\cdot)$ of the steady proportion m of adults who are managers. A new manager generates external benefits to other managers with her innovative activities. She, however, adds to the relative scarcity of workers and hence boosts the wage rate or, equivalently, the cost of production for all managers. For a low value of m , additional benefits are higher than additional costs and, therefore, returns to schooling increases with additional managers in the economy. A high value of m , however, turns the balance in the opposite direction. If the value of m equals $\theta/(\theta+a)$ (called m^* hereafter), the return to schooling reaches its maximum. Second, the growth rate γ in (28) is directly related to the steady state rate of investment of managers. To see this, note that the balanced growth rate, $\gamma(m)$, is simply $i(m) - \delta$ where $i(m)$ is given by (33). Growth is thus driven by the rate of investment, $i(m)$, which in turn depends positively on the after tax return on schooling. It follows, therefore, that for a given tax policy τ the growth rate γ also attains its maximum at the same m^* . Figure 3 illustrates how the growth rate varies with the relative proportion m of managers by drawing $i(m)$ and δ schedules. The steady state growth rate is the difference between $i(m)$ and δ , which reaches its maximum at $\theta/(\theta+a)$.

<Figure 3 comes here>

Clearly, it follows from Figure 3 that if $i(m^*, \tau) > \delta$, there are two real numbers $m_L^1 > 0$ and $m_L^2 > 0$ that solve the equation $i(m, \tau) = \delta$ for any given $0 < \tau < 1$. Consequently, we can ensure a non-negative balanced growth state in this model only if

$$i(m^*, \tau) > \delta \text{ and } m_L^1 \leq m \leq m_L^2 \quad (35)$$

We next explore the range of initial proportion m of adults with positive human capital over which such a dynastic steady state holds.

If (29) through (35) hold, we have a continuum of initial states characterized by the initial proportion m of adults with positive stock of human capital that persists in the steady state. In other words, there are multiple steady states and each steady state is path-dependent because it preserves the initial distribution of human capital.¹³

The issue arises whether or not the set of steady states that satisfy inequality (34) is connected.¹⁴ To put it in formal terms, define m_c as the value of m that solves (34) as equality. To ensure a connected set of steady states, one requires that the solution for m_c to be unique. The steady states with non-zero balanced growth rates can then be defined as a function of the initial proportion m of skilled adults in the labor force over the range:

$$m_L^1 < m < \min\{m_c, m_L^2\}.$$

A sufficient condition for a unique solution to (34) is that $\xi(m)$ intersects $B(m)$ only once. It is easy to verify from (30) that $\xi(m)$ is monotonic increasing in m .¹⁵ However, no such monotonicity can be analytically established for the function $B(m)$ specified in (31). We have extensively simulated $B(m)$ and $\xi(m)$ and found that for a wide range of parameter values, $B(m)$ shows little variation. Figure 4 provides an illustration.¹⁶ The dotted curve plots $B(m)^{-1}$ and the solid curve is $\xi(m)$. The value of m_c at which these two schedules intersect is around 0.34 for this simulation.

<Figure 4 comes here>

The following proposition summarizes a sufficient condition for a steady state with a non-negative growth rate:

¹³ This idea of a continuum of steady states is similar but not quite the same as the concept of club convergence as in Galor (1996) and Quah (1994). Countries with different initial skill distributions converge to different steady states. In this paper, we do not, however, look at the short run dynamics of this convergence.

¹⁴ To avoid numerical complexity for calibration, we only focus on a connected set of steady states.

¹⁵ To see this note that the partial derivative of $\xi(m, \tau)$ with respect to m is:

$$\xi_m = \frac{\xi(m)}{m(1-m)} \left[1 - (1-\delta) \frac{am}{(1-\tau)r(m) + 1 - \delta} + (1-\delta) \frac{\theta(1-m)}{(1-\tau)r(m) + 1 - \delta} \right].$$

Note that since $0 < a < 1$ and $0 < m < 1$, the second term in the square bracket is less than unity. Since $\theta > 0, a > 0, 0 < m < 1, r(m) > 0$ and $\xi(m) > 0$ it follows that $\xi_m > 0$.

¹⁶ For the purpose of this simulation we set $a=0.1, \delta=0.1, A=1.0, \theta=0.5, \beta=0.9$ and $\tau=0.2$.

Proposition 1: *The equilibrium with the initial distribution Ψ_0 of human capital such that $\Psi_0(0) = \Psi_0(h^*) = 1 - m$, $h_0 > h^*$ and $\Psi_0(h_0) = 1$ describes a balanced growth path with a strictly positive rate of growth as defined above in (28), if and only if the following conditions hold:*

$$i(m^*, \tau) > \delta \quad (36a)$$

and

$$m_L^{-1} < m < \min\{m_c, m_L^2\}. \quad (36b)$$

4. Growth-Inequality Relationship

As described in Proposition 1, the model's steady state is path dependent in the sense that it depends on the initial proportion of adults with human capital. We now compute a measure of income inequality that remains time invariant in a steady state. We then compute the growth-inequality correlation across steady states that lie within that set defined by (36b).

Let us denote the ratio of the after-tax factor income as $\alpha(m)$, which is the measure of income inequality in the present context. In other words,

$$\alpha(m) = \frac{(1 - \tau)r(m)h_0}{w_0 + z_0} \quad (37)$$

Plugging (20) through (24) into (37), one obtains,

$$\alpha(m) = \frac{(1 - \tau)(1 - a)(1 - m)}{(a + \tau(1 - a))m} \quad (38)$$

Based on (38), the gini coefficient of the income distribution (call it gini hereafter) is given by:¹⁷

¹⁷ To obtain the expression for the gini in (39), define \bar{a} as the worker's steady state post tax share in income. Note that using (38), $\bar{a} = [1 + m((1 - m)^{-1}\alpha(m))]^{-1}$. Next, note that in the steady state, the initial inequality of human capital perpetuates, which means $(1 - m)$ fraction of the population have \bar{a} fraction of total income and m fraction the population have $(1 - \bar{a})$ fraction of total income. The Lorenz ratio for income (*gini*) is, therefore, given by: $gini = 1 - \bar{a} - m$, which after simplification yields (39).

$$gini = (1-a)(1-\tau) - m \quad (39)$$

Notice that the model's income gini coefficient depends on the initial proportion, m of adults with human capital, the degree of redistribution measured by τ , and the skill intensity measured by a .¹⁸ Steady state growth rate in (28) and income-inequality in (39) differ across countries because of differences in the initial proportion (m) of skilled adults in the population.

To see the growth-gini relationship clearly, use (21), (28) and (39) to obtain the following reduced form relationship between the balanced growth rate and the income-gini:

$$\gamma(m) = (\beta[(1-\tau)(1-a)Am^\theta(1-m)^a + 1 - \delta]) - 1, \quad (40)$$

where

$$m = (1-a)(1-\tau) - gini. \quad (41)$$

Equations (40) and (41) together represent the central result of this paper: an endogenous relationship between growth and income inequality driven by the initial proportion m of adults with human capital.

The above growth-inequality relationship holds across the range of steady states defined by (36b) and the parameters of the model. Note that the lower and upper bounds of the set of steady states depend on three critical parameters of interest, namely, the degree of redistribution, τ , the skill intensity in technology, a and the extent of barriers to knowledge spillovers, θ . A different τ implies a different growth-inequality relationship by altering the set of steady state proportion of managers in the labor force in (36b) via its direct effect on the post tax return to capital and its indirect effect on the steady state occupational distribution. Similarly, technology parameters a and θ that proxy the skill intensity and barriers to knowledge spillovers respectively, would also influence the nature of the growth-inequality relationship. The growth-gini relationship is defined over the following set $D(\tau, a, \theta)$ of steady state proportions of managers, m such that

$$D(\tau, a, \theta) = \{m: gini=(1-a)(1-\tau)-m \text{ and } m_L^1 \leq m \leq \min\{m_c, m_L^2\}\}. \quad (42)$$

An important feature of the model is that the sign of the growth-gini correlation critically hinges upon the relative magnitudes of m_L^1 , m_c and m^* , which in turn depend on the values of the crucial parameters, τ , a and θ . By (39), the model's gini coefficient decreases with m . However, one may notice from Figure 3 that the growth rate, $\gamma(m)$ in (28) increases with m if $m < m^*$, and it decreases with m if $m > m^*$. It follows, therefore, that *ceteris paribus*, the growth-gini correlation is negative for the range of m values such that $m < m_c < m^*$, and it is positive for $m^* < m < m_c$.

We next report the comparative statics properties of the model in terms of simulation of the model's steady states. The baseline parameter values are chosen to match the average growth rate of 1.96%, the average gini coefficient of 40.21% , and a growth-gini correlation of -0.09 for a sample of 66 countries for the period 1960-90. The appendix presents the data and documents the sources. The baseline parameter values thus obtained are $a=0.3$, $\tau=.3$, $\theta=.0221$, $\delta=0.1$, $A=.385$, $\beta=.95$.

In order to perform comparative statics, we simulate the model's steady states using the following steps. First, fixing the parameters at the baseline levels, we compute the growth-gini correlation over the set of steady states. Second, we compute the average growth rate and average gini over the same set of steady states. Finally, we change the parameters around the baseline values to ascertain how the average growth rate, average gini, and the growth-gini correlation change.

Table 1 reports the growth-gini correlation for grids of τ for the steady state sets of managers that satisfy (42) around the baseline value of 30%.¹⁹ Not surprisingly, the average growth rate and average income gini fall as τ increases. The set of steady state proportion of managers shrinks as τ increases. This happens because the post tax return on capital is lower, and the distribution of income shifts away from the owners of human capital to workers. This aspect of the model is similar to Bertola (1993) who finds that a redistributive policy in favor of workers taxes accumulated factors of production. The new element in our model is the effect of a change

¹⁸ It is straightforward to verify that as long as $\alpha(m) > 1$, the gini coefficient is positive.

¹⁹ Mendoza, Razin and Tesar (1994) find that the effective capital income tax rates (which may be a crude proxy for τ) range from 25% to 60% across major OECD countries. Our baseline value is not off the range they find.

in τ on the growth-inequality correlation itself. The growth-inequality correlation falls as τ increases. It turns from positive to negative when τ reaches a high level (above 30%).

To gain further intuition for the above result note that an increase in τ raises the threshold level of human capital, h^* given by (29) at which the manager is indifferent between investing and not investing in schooling. To ensure managers with h_0 units of initial human capital to continue investing in a steady state, the value of m_c that solves (34) as equality must fall when τ rises. By (33) and Figure 3, an increase in the tax rate τ decreases the maximum proportion m_L^2 of adults that can invest in human capital in a non-negative balanced growth state. Consequently, the upper bound of the set of steady states decreases, which is reflected by shrinkage of the steady state set of managers. On the other hand, a change in τ has no effect on the growth maximizing proportion of managers in the labor force, m^* . Thus as τ rises, the difference between the upper bound of the set of steady states and m^* decreases (see the last two columns of Table 1). This makes the negative association between growth and inequality stronger. The sign of the correlation depends on how small the gap between m_c and m^* is.

<Table 1 comes here>

Table 2 reports the comparative statics properties of the model with respect to variation of the parameter a . There are two noteworthy features in Table 2. First, countries with a more unskilled labor-intensive technology (a larger a) experience a lower growth rate and lower degree of income inequality. Second, the simulated cross-country correlation coefficient between the growth rate and the gini-coefficient increases when we increase the common value of the parameter a shared by our artificial group of countries. Note, in particular, that the correlation changes sign from negative to positive when the value of the parameter a exceeds 0.33. We conclude that countries with sufficiently low skilled labor-intensive technology would display a positive correlation between income inequality and the rate of growth.

To find intuition for the above result, we make the following observation from our model: a larger value of a corresponds to a lower implicit price of human capital in (21) and thus by (33) generates a lower rate of investment in schooling by the managers. Consequently, by Figure 3, the required minimum proportion m_L^1 of adults who must maintain skill in a steady state increases, while the maximum proportion m_L^2 of adults who can maintain skill in a steady state decreases. A larger a , on the other hand, lowers m_c because a lower skill intensity requires a

larger threshold of human capital that must be possessed by each manager in a steady state required by (29). Given h_0 , a lower value of m_c thus solves (34) with equality.²⁰ Consequently, the region, $m_L^1 \leq m \leq \min(m_c, m_L^2)$ where the growth-gini correlation is negative, shrinks. This is confirmed by the numbers in the fourth row of Table 2. This explains why the growth-gini correlation increases in a .²¹

<Table 2 comes here>

The comparative statics properties of the growth-inequality correlation with respect to θ is reported in Table 3. Note that countries with a higher θ tend to have a lower growth-inequality correlation and lower average growth rate. For $\theta=0$, the production technology reduces to Lucas (1988), in which case a near perfect positive relationship is obtained between growth and gini due to elimination of barriers to knowledge spillovers. If $\theta=0$, the implicit price of human capital $r(m)$, the investment rate $i(m)$, and the growth rate decrease with respect to m . With instantaneous knowledge spillovers, the owners of human capital cease to gain additional benefit from interaction with other managers. This fact decreases the value of a manager, $r(m)$. It thus changes the non-linear relationship (21) between the implicit price of human capital, r and the proportion of managers in the labor force, m into a strict negative relationship.

<Table 3 comes here>

The growth-gini correlation is very sensitive to a change in the value of θ which suggests that a very small departure from the Lucas-Uzawa type production technology could make a big difference in the magnitude and sign of the growth-gini correlation. The model's average gini is less sensitive to change in θ . Recall that a larger value of θ represents a greater degree of barriers to knowledge spillovers. A large such barrier to knowledge spillovers raises both m^*

²⁰ Following a previous discussion, note that the left hand side of the equation (34) increases monotonically with m .

²¹ Since the reported gini coefficient is an average gini computed over the steady state range of m , it may not necessarily satisfy the monotonicity property with respect to a as per equation (39).

and m_c starting from the benchmark levels where m_c exceeds m^* .²² The distance between m_c and m^* decreases as θ rises, making the inverse association between growth and gini stronger.

Table 4 summarizes the comparative statics properties of the model with respect to τ , a and θ .

<Table 4 comes here>

Calibration

The model thus admits various relationships between growth and income inequality across different partitioning of the set of steady states. Both the magnitude and the sign critically depend on the degree of redistributive tax rate, τ , the skill intensity in technology measured by $1-a$, and the barrier to knowledge spillovers as measured by θ .

Cross-country growth-inequality relationship may significantly vary across samples of countries differing in terms of these three crucial parameters. These three parameters are, however, unobservable in the sample. In the following calibration experiment, our goal is to explain the observed differences in correlation between the developed and the developing countries. Presuming that these two groups of countries differ in terms of the above three critical parameters, we calibrate these parameters for each group of countries and compare them. We provide a rationale from our model for the differences in stylized facts regarding their key economic indicators namely, the average growth rate, the average gini-coefficient and the growth-gini correlation. This way, we assess the empirical implications of our model for the observed diversities in the growth-gini correlation for country groups differing in terms of important economic development indicators.

While partitioning the sample of countries in terms of economic indicators, the immediate issue arises about the choice of suitable economic development indicators. Although economic development is a broad concept, we focus here on two specific indicators of economic development, which have some direct implications for our model. The first indicator is the proportion of educated adults in the population, measured by the proportion of labor force with at least a secondary level of education. The rationale behind this choice is based on numerous

²² A larger θ is analogous to an implicit tax on output via its adverse effect on the total factor productivity. As a result, when θ rises, the labor demand schedule shifts down. The labor supply schedule does not change because the

studies including De Meulemeester and Rochat (1995), Bruck (1969) and Shuanglin (1997) which document a direct association between the level of higher education and economic development. Our second indicator of economic development is the share of agriculture in GDP. It is also well documented that as the economy develops, it produces a smaller share of primary output (Rostow, 1960). Based on these two economic indicators, we label countries with a low agricultural share in GDP and a high proportion of educated people as advanced or rich, and the remaining group of countries as developing or poor.

Table 5 reports the growth-gini correlations for the bottom and top 25% countries in terms of education and the share of agriculture. The appendix presents the data and the sources. Both these economic indicators give remarkably similar numbers for growth-inequality correlation. The growth-gini correlation thus ranges between 0.22 to 0.27 for rich countries, and -0.12 and -0.16 for poor countries. This is consistent with Barro's (2001) finding that poor countries have negative correlation between growth and inequality in contrast with rich countries. It is also noteworthy that in our sample, the average growth rate is lower and the average gini is higher for poor countries compared to rich countries.

<Table 5 comes here>

The last column of Table 5 presents the numbers for the three relevant variables based on the model's prediction. We calibrated three key parameters, τ , a and θ around the baseline estimates. The calibrated values of these three parameters are also reported in Table 5.

While contrasting the calibrated parameter values of the advanced with the developing countries, we get the following insights: the developing countries use a technology that has a lower skill intensity than the technology used by their developed counterpart. In particular, Table 5 reports the share $(1-a)$ of skilled labor's income in national income is only 67% (meaning $a=0.33$) in developing countries while it is 78% ($a=0.22$) in the developed countries. The measured barrier to spillovers of knowledge reflected by θ appears to be almost twice as large in developing countries as in the developed countries. We can make sense of these numbers as follows. If the primary producing sector is less skill intensive than the rest of the economy, developing countries with a predominant agricultural sector are likely to have a lower skill intensity than developed countries, or equivalently, a larger value of a than the developed countries. Also, if an agrarian economy proxies for a shortage of information and

basic skill level, x_t as shown in Figure 1 is independent of θ . Therefore, the skill premium rises lowering the

communication technology then developing countries with a larger share of agriculture in GDP would imply a larger barrier to knowledge spillovers than their developed counterpart.

Regarding the degree of redistribution, we find that countries with a lower skill intensive technology and lower levels of education also have a lower redistributive tax rate than the benchmark τ . Developed countries have a higher rate of redistributive tax rate than developing countries.²³ Using (22) and (25), it is straightforward to verify that the steady state rate of transfer (z_t/w_t) is equal to $((1-a)/a)\tau$. Based on the calibrated values of a and τ from Table 5, the rate of redistributive subsidy to workers is 1.17 for developed countries while it is 0.53 for developing countries. Along a balanced growth path, the rate of redistributive subsidy is more than double for developed countries compared to developing countries. The calibration results thus give rise to a testable hypothesis that developing countries have a lower degree of redistribution than developed countries.²⁴

5. Conclusion

This paper examines the role of three important determinants of the relationship between income inequality and the rate of growth across countries. It does so in a general equilibrium growth model where the initial distribution of human capital persists in the steady state. Countries experience different long run growth and income inequality due to differences in the initial distribution of human capital. The long run correlation between the growth rate and income inequality depends crucially on the extent of barriers to knowledge spillovers, the skill-intensity in technology, and the degree of income redistribution. The model provides a purely neoclassical explanation for how technology and policy differences may imply a qualitatively different growth-inequality relationship.

The steady state relationships derived from our model help explain why the growth-inequality correlation differs between rich and poor countries. Based on numerical examples and calibration results, we infer that poorer countries are likely to have a greater barrier to knowledge spillovers, a lower degree of income redistribution, and a low skill intensity in technology.

threshold h^* in (29). This explains why m_c rises when θ rises.

²³ This may be contrasted with our earlier comparative statics reported in Table 1 that the growth-gini correlation reverses sign from positive to negative as τ alone increases. After calibrating the model by allowing variation of all three parameters, τ , a and θ one obtains the full story.

Our work could be extended in several directions. First, we abstracted from the issue of optimal redistribution while calibrating the growth-inequality correlation. A future extension could explore the issue of whether the observed difference in growth-inequality correlation between rich and poor countries is optimal. This would help explain why richer countries find it optimal to have a better redistributive policy, which we observe in our calibration. Second, we have abstracted from short run dynamics in this paper because our goal is to understand the long run relationship between growth and inequality. A future extension could explore the short run dynamics of the model and attempt to provide insight into *club convergence* as in Galor (1996) and Quah (1994).

²⁴ The issue arises: why do developed countries have a higher growth rate when it is well known that a higher tax on reproducible factor like human capital adversely impacts growth (Bertola, 1993)? Recall from our calibration that rich countries have a greater skill intensity and lesser barriers to knowledge. This could potentially compensate for the loss of growth due to redistributive tax on savings.

Appendix

DATA

Country	1985 Gini(%)	PCI growth rate, 65-97 (%)	HQ+SQ, 1985(%)	Share of Agrl in GDP(%)
C. African Rep.	55	-1.2	3	55
Malawi	59.9	0.5	5.2	39
Lesotho	56	3.1	5.7	11
Nepal	30.1	1.1	5.7	40
Kenya	57.3	1.3	5.9	29
Cameroon	49	1.3	6.1	42
Botswana	54.2	7.7	6.2	4
Guatemala	58.3	0.7	9.7	21
El Salvador	48.4	-0.4	10	13
Indonesia	39	4.7	10.9	20
Thailand	41.7	5	11.1	11
Brazil	61.8	2.2	11.4	8
Pakistan	39	2.7	12.3	26
Turkey	44	2.1	14.3	18
Tunisia	49.6	2.7	14.8	12
Honduras	54.9	0.6	15.2	23
Bangladesh	36	1.4	15.8	22
Portugal	36.8	3.2	15.9	6
Ghana	35.9	-0.8	16.1	37
Dom. Rep	43.3	2.3	16.7	12
India	38.1	2.7	16.9	29
Iran	42.9	-1.2	18.3	25
Mexico	50.6	1.5	19	5
Egypt	34	3.5	19.4	17
Costa Rica	47	1.2	21.8	15
Colombia	51.2	2	22.1	13
Singapore	42	6.4	24.4	0
Ecuador	44.5	1.8	24.5	12
Spain	31.8	2.3	24.6	3
Jamaica	43.2	-0.4	24.7	7
Malaysia	48	4.1	25.3	13
China	31.4	6.8	26.7	18
T & T	41.7	2.6	28.4	2
South Africa	51	0.1	29	4
Jordan	36.1	-0.4	29.4	3
Venezuela	42.8	-0.8	30.5	5
Peru	49.3	-0.3	30.8	7
Greece	39.9	2.4	31.3	8

Hungary	21	2.2	31.8	6
Panama	47.5	0.7	33	7
Chile	53.2	1.9	33.9	8
Bulgaria	23.4	-0.3	34.8	19
Philippines	46.1	0.9	35.1	17
France	34.9	2.1	36.1	2
Sri Lanka	45.3	3	36.3	21
Italy	33.2	2.5	36.9	3
Uruguay	41.23	1.2	37.3	8
Poland	25.3	1.8	42	5
Norway	31.4	3	42.9	2
Romania	23.4	-0.4	44.2	15
Finland	30.8	2.4	44.4	4
Belgium	26.2	2.3	46.2	1
UK	27.1	1.9	48.5	2
Ireland	34.6	3	51.1	4
Austria	23.1	2.6	53.2	1
Denmark	31	1.9	54	4
Korea	34.5	6.6	57	5
Japan	35.9	3.5	57.9	2
Netherlands	29.1	1.9	58.7	3
Israel	30.9	2.4	59	
Sweden	31.2	1.4	59.9	2
Switzerland	34.7	1.2	64.7	
Australia	37.6	1.7	70.2	3
Canada	32.8	1.8	78.8	2
New Zealand	35.8	0.7	85.6	8
US	37.3	1.6	91.1	2

Source: The series HQ+SQ is the proportion of population with secondary and higher secondary education. These data came from Barro and Lee (1997). The series for the average per capita growth rates (PCI) and the share of agriculture in GDP came from the World Bank Development Indicators. The Gini coefficients for 1985 are obtained from Forbes (2000) and Deininger and Squire (1998). There are two available series for the gini coefficients for our sample: one for the year 1985 and the other for the year 1990. Because of large number of missing 1990 gini data, we did all our computations based on 1985 gini series.

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Table 1: Model's Prediction for Alternative Redistributive Tax Rates τ

τ	Growth-Gini Correlation	Average Growth Rate(%)	Average Gini (%)	Steady State Set of Managers $[m_L^1, \min(m_c, m_L^2)]$	m^*
0.25	0.1165	3.1206	43.65	$[3.02 \times 10^{-6}, 0.167]$	0.068
0.27	0.0352	2.65	42.5	$[1.02 \times 10^{-5}, 0.162]$	0.068
0.29	-0.05	2.19	41.35	$[3.61 \times 10^{-5}, 0.160]$	0.068
0.31	-0.11	1.72	40.15	$[0.0001, 0.15]$	0.068
0.33	-0.20	1.25	39.00	$[0.0005, 0.15]$	0.068
0.35	-0.26	0.79	37.8	$[0.002, 0.14]$	0.068

Note: Other parameter values are fixed at the benchmark levels: $a=.3$, $\theta=.0221$, $\delta=.1$, $A=0.385$, $\beta=0.95$.

Table 2: Model's Prediction for Alternative Values of a , the Output Elasticity of Unskilled Labor

	$a=.25$	$a=.27$	$a=.29$	$a=.31$	$a=.33$	$a=.35$
Growth-Gini Correlation	-0.36	-0.26	-0.14	-0.02	-0.09	0.19
Average Growth Rate	3.20%	2.70%	2.20%	1.71%	1.21%	0.72%
Average Gini	43.7%	42.55%	41.35%	40.15%	30.95%	37.75%
Steady State Set of Managers $[m_L^1, \min(m_c, m_L^2)]$	$[3.02 \times 10^{-6}, 0.16]$	$[1.02 \times 10^{-5}, 0.16]$	$[3.61 \times 10^{-5}, 0.16]$	$[.0001, 0.158]$	$[.0005, 0.157]$	$[0.002, 0.149]$
m^*	0.08	0.07	0.07	0.07	0.06	0.06

Note: $\tau=0.3$ and the other parameter values are fixed at the benchmark levels as in Table 1.

Table 3: Model's Prediction for Alternative Values of θ , the Barriers to Knowledge Spillovers

θ	0.000	0.015	0.017	0.019	0.023	0.027	0.031	0.035
Growth-Gini Correlation	0.99	0.76	0.89	0.33	-0.19	-0.50	-0.66	-0.74
Average Growth Rate	2.97%	2.27%	2.18%	2.09%	1.92%	1.74%	1.57%	1.4%
Average Gini	40.95%	40.85%	40.8%	40.8%	40.7%	40.7%	40.7%	40.65%
$[m_L^1, \min(m_c, m_L^2)]$	Not Defined	$[7.34 \times 10^{-7}, .15]$	$[3.61 \times 10^{-5}, 0.15]$	$[3.86 \times 10^{-5}, 0.15]$	$[1.43 \times 10^{-5}, 0.15]$	$[9.98 \times 10^{-5}, 0.16]$	$[.0004, 0.16]$	$[.002, 0.16]$
m^*	0.00	0.05	0.05	0.06	0.07	0.08	0.09	0.10

Note: $\tau=.3$ and the other parameters are fixed at the benchmark levels as In Table 1.

Table 4: Summary of the Model's Comparative Statics

	Average Growth Rate	Average Gini Coefficient	Growth-Gini Correlation
When a rises	Decreases	Decreases	Increases
When θ rises	Decreases	Changes very little	Decreases
When τ rises	Decreases	Decreases	Decreases

Table 5: Summary of Calibration Results**Developed Countries**

	Top 25% Countries in terms of education	Bottom 25% Countries in terms of the share of agriculture	Model's Prediction
Growth-Gini Correlation	0.22	0.27	0.25
Average Growth Rate	2.14%	2.32%	2.22%
Average Gini	31.52%	33.2%	40.36%

Note: We calibrated τ , a and θ to match the characteristics of the sample setting other parameters at the bench mark levels as in Table 1. The calibrated values of τ , a and θ are 0.38, 0.22 and 0.014 respectively.

Developing Countries

	Bottom 25% Countries in terms of Education	Top 25% Countries in terms of the share of agriculture	Model's Prediction
Growth-Gini Correlation	-0.16	-0.12	-0.14
Average Growth Rate	2.08%	1.79%	1.92%
Average Gini	49.07%	42.9%	41.04%

Note: The parameters τ , a and θ are calibrated to match the observed characteristics of the sub-sample of countries setting other parameters at the benchmark levels as in Table 1. The calibrated values of τ , a and θ are 0.265, 0.328 and 0.025 respectively.

The graph illustrates the determination of the optimal level of human capital investment. The vertical axis represents the wage rate w_t and the return to human capital $r_t h_t$. The horizontal axis represents the level of human capital h_t . A 45-degree line, labeled $r_t h_t$, originates from the origin. A horizontal dotted line, labeled \bar{w}_t , represents the wage rate. The intersection of the 45-degree line and the horizontal line determines the optimal level of human capital investment, x_t , which is marked on the horizontal axis. The area to the left of x_t is labeled 'Workers' and the area to the right is labeled 'Managers'.

Figure 3

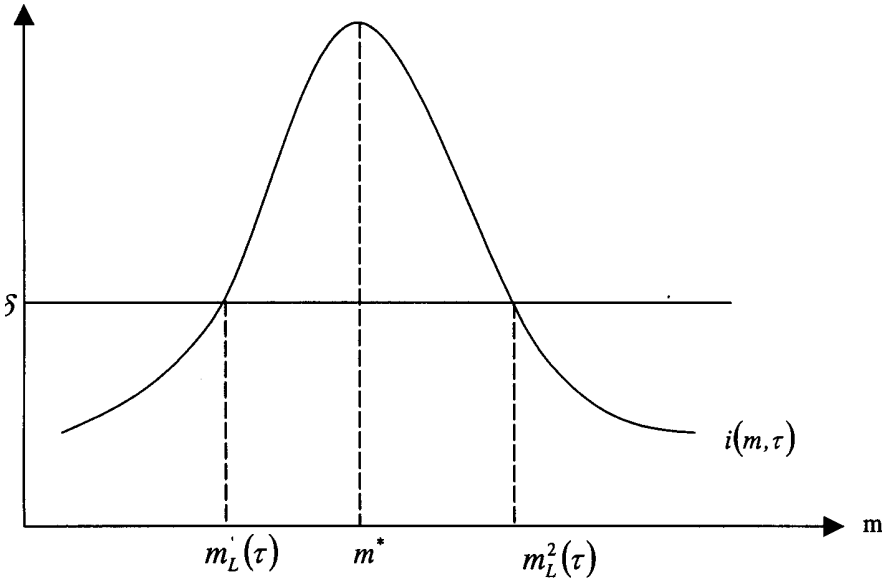


Figure 4
Plots of $\xi(m, \tau)$ and $B(m, \tau)^{-1}$

