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 the 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 skill-intensive technology, low barriers to knowledge spillovers and high degrees of redistribution characterize the industrial countries with a positive growth-inequality correlation. A negative correlation between growth and inequality arises for the group of non-industrial countries with the opposite characteristics.

JEL Classification Codes:
E1, General Aggregative Models
O4, Economic Growth and Aggregate Productivity Characteristics

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 of the growth-inequality correlation is empirically an 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; and Banerjee and Duflo (2000) 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. Barro (2000) reports a positive correlation between growth and income inequality among rich countries but a negative correlation for poor countries. This conflicting evidence on the direction of the growth-inequality correlation motivates us to probe deeper into the determinants of this growth-inequality correlation.

In this paper, we argue that the nature of technology and policy regimes for redistribution significantly influence the cross-country growth-inequality correlation. If these technology and policy parameters significantly differ between two subgroups of countries, this could give rise to a sign reversal in the growth-inequality correlation. Following this theoretical insight, we discern a similar sign reversal also in the cross-country data when we sort countries according to a key development indicator implied by the theory. This development indicator refers to the degree of industrialization of a country. We then calibrate a neoclassical model, and replicate the corresponding sign-reversal observed in the data. Based on this calibration experiment, we conjecture that the potential reasons why different studies find different growth-inequality correlations could be the use of different subsets of the world data.

In our model, everything else equal, the cross-country variation in growth and income inequality arises due to difference in the initial distribution of human capital. This gives rise to an endogenous cross-country correlation between growth and income inequality. Once one allows for changes in the structural and policy parameters, this correlation changes and could give rise to a sign reversal in the growth-inequality correlation consistent with cross-country data. The sign reversal in the growth inequality correlation occurs when we switch from the group of industrial to non-industrial countries. Our calibrated model provides an explanation for why the cross-country correlation between growth and inequality is negative for non-industrial countries and positive for industrial countries. This sign reversal is also consistent with Barro's (2000) finding that the same cross-country correlation differs between rich and poor countries.

Our model builds on a recent stream of literature in which the initial inequality of endowments shapes a country's occupational structure and growth.[1] The model combines the features of Lucas's (1988) endogenous growth model with the Lucas's (1978) span of control model. Moreover, following Benabou (2002) our model excludes a credit market which allows path dependence.[2] The main results of this paper also hold when we introduce a credit market with a borrowing constraint.

The second distinguishing feature of the model is 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 usability of knowledge. The 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 innovators in the economy, and therefore determines both the stock and the usability of knowledge.

Finally, in our model, as in Alesina and Rodrik (1994), the government redistributes income from the owners of reproducible input to the owners of a non-reproducible input. A tax on the implicit rental income from human capital is a vehicle of redistributive policy in our model. The tax proceeds are rebated to adults who supply raw labor. This redistributive tax policy impacts the cross-country growth-inequality relationship via influencing the occupational distribution and turns out to be an important determinant of the sign reversal of the growth-inequality correlation.

In a calibration exercise, we group 61 countries into industrial and non-industrial (or agricultural) categories by using the share of agriculture as the sorting device. Industrial countries, by definition, have a low share of agriculture. The low share of agriculture in the industrial countries is a reflection of a relatively skill biased technology. After sorting countries into these two categories, we explore the reasons for the sign reversal of the growth-inequality correlation based on our calibration experiment. Given the same preferences and the common frontier for the non-rival component of the world technology, this sign reversal is explained by agricultural countries having a greater degree of barriers to knowledge diffusion and lower redistributive tax rate vis-à-vis industrial countries.

The sign reversal occurs because of the interaction between barriers to knowledge spillover and redistributive tax regimes, and their joint influence on the marginal contribution of an innovator. In our model, an innovator generates two opposing effects on the growth rate of per capita output: a positive effect due to externality from knowledge spillover and a negative effect due to diminishing returns to innovation caused by the relative scarcity of labor. The growth rate is maximized when these two effects offset each other. On other hand, the steady state proportion of innovators has an upper bound that balances the steady state value of work with that of innovation. The relative magnitudes of the growth maximizing proportion of innovators and the upper bound for the steady state determine the sign of the growth inequality correlation for any group of countries. We now elaborate the intuition in three steps.

First, note that the inequality and the proportion of innovators negatively correlate because a greater proportion of innovators heightens the relative scarcity of workers and lowers the skill premium. The Gini-coefficient of income, a popular measure of income-inequality, moves one-to-one with this skill-premium in our model.

Second, we document evidence to claim that non-industrial countries have a greater barrier to knowledge spillover than industrial countries. A relatively large barrier to knowledge spillover raises the private return to innovations. Since growth rates and returns to innovations are positively related, the growth maximizing proportion of innovators in non-industrial countries exceeds that in industrial countries. Due to history dependence the non-industrial countries remain trapped below this growth maximizing proportion more frequently than the industrial countries. Consequently, among the group of non-industrial countries, we observe that a country with a greater proportion of innovators grows faster and has a lower degree of income inequality. This implies a negative cross-country growth inequality correlation within this group. For the group of industrial countries, a relatively low barrier to knowledge spillover pushes the growth maximizing proportion of innovator to a sufficiently low level such that most countries in this group sit above it. Consequently, among these countries, lower growth is associated with lower income-inequality making the growth-inequality correlation positive.

Third, we provide direct evidence to claim that industrial countries tend to have a larger public welfare system and hence a greater redistributive tax-transfer scheme than non-industrial countries. A higher redistributive tax rate in the industrial countries reinforces the positive growth-inequality correlation because it lowers both inequality and the incentive for innovation, and hence the growth rate. For non-industrial countries, the negative effect of knowledge barriers on the magnitude of the growth-inequality correlation outweighs the positive effect of redistributive taxes. Consequently, the cross-country growth-inequality correlation turns out to be negative for this group of countries.

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 and examines how they change if we allow a borrowing constraint. Section 4 examines the long run growth-inequality relationship arising from the model and reports some calibration results regarding the growth-inequality correlation. Section 5 concludes.

2. The Model

There is a continuum of infinitely lived dynasties with measure one. At each date t, an adult with one unit of labor, h_t units of human capital and a child represents one dynasty. The economic environment consists of a single perishable consumption good, variable human capital, raw labor, and a technology that is partly determined by the distribution of human capital among the adults. The adult faces a discrete occupational choice between management and work. She then divides her income between consumption and investment in her child's education. The child becomes an adult in the following period, and represents her dynasty. Preferences display intergenerational altruism, and so the adult maximizes the present discounted utility value of the consumption stream 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. History specifies the initial distribution Ψ_0.

Following Lucas's (1978) span of control model we assume that production is organized by groups of adults each consisting of a leader and one or more workers. The leader manages production by carrying out innovative activities and then by laying out a set of tasks for the workers to implement her plan. We call the leader the manager and innovator for the group or, in short, the manager. 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. At date t, the TFP depends on: (i) the proportion m_t of adults who are the managers and (ii) the average human capital H_t in the economy. This idea combines the insights of Lucas (1988) regarding knowledge externality with Prescott's (1998) notion of usability of knowledge.[3] In particular, we assume that at each date t:

$$A_t = Am_t^{\theta} H_t^{b},\ 0 \le \theta < \infty, 0 \le b \le a < 1. \tag{1}$$

Note that a larger value of θ lowers the value of TFP in the economy. The parameter θ, therefore, proxies various barriers to the spillover of information facilitated by the managers, and hence determine how far innovative activities inside a country can increase its TFP. If θ equals zero then 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.[4] In such a case, the production function reduces to a technology similar to Lucas (1988).[5] To summarize, at each date $t \geq 0$ the output q_t of a manager is given by:

$$q(h, n_t^d, H_t, m_t) = Am_t^{\theta} H_t^b h^{1-a} (n_t^d)^a, \qquad t=0, 1, 2.... \tag{2}$$

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

At each date t 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

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

The Government

The rich by definition possess sufficient human capital to operate as a viable manager while the poor do not. At any date t, the government levies proportional tax at a constant rate τ on the income of the managers and makes a lump-sum redistributive transfer, z_t to each worker. Let $\Pi_{mt}(h)$ denote the maximal profit income of a manager who has h units of human capital and Π_{mt} denote the average maximal profits of all managers at date t. Then the budget constraint of the government can be written as:

$$z_t = \frac{\tau m_t \Pi_{mt}}{(1-m_t)}, \tag{4}$$

The parameter τ represents the degree of fiscal redistribution, which we calibrate. The higher the value of τ, the greater is the degree of redistribution.[6]

The occupational choice is endogenous in this model and it is driven by the relative rewards from work and management. Let the discrete occupational choice by an adult be denoted by an indicator function n_t. At each date t, if she chooses to be a worker then $n_t = 1$, otherwise, if she chooses to be a manager then $n_t = 0$. It follows, therefore, that each date $t \geq 0$, the disposable income $y_t(.)$ of an adult as a function of her human capital h is given by:

$$y_t(h) = n_t \cdot (w_t + z_t) + (1-n_t)\cdot(1-\tau)\Pi_{mt}(h). \tag{5}$$

In the absence of a viable credit market the adult divides her income $y_t(h)$ between consumption c_t and investment s_t in her child's schooling such that

$$c_t + s_t \leq y_t(h) \quad t=0, 1, 2, \ldots \tag{6}$$

The evolution of human capital within the dynasty satisfies,

$$h_{t+1} = (1-\delta)h_t + s_t, \qquad 0<\delta<1, \quad t=0,\ 1,\ 2,\ \ldots.. \tag{7}$$

where δ is the rate of intergenerational spillover of knowledge in the tradition of Benabou (2000), and Mankiw et al. (1992).

Following Barro (1974) we assume intergenerational altruism parameterized by the discount factor β. 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,

$$v_t = V(c_t, v_{t+1}) = u(c_t) + \beta v_{t+1}. \tag{8}$$

where $u(c)=lnc$ and $0<\beta<1$, such that by recursion, $v_0 = \sum_{t=0}^{\infty} \beta^t \ln c_t$.

At date zero, the adult with $h \geq 0$ units of human capital chooses a sequence $\{c_t \geq 0, s_t \geq 0, n_t \in \{0,1\}\}_{t=0,1,2......}$, so as to

$$Maximize \ \sum_{t=0}^{\infty} \beta^t \ln c_t \ \text{ subject to (1)-(7)}, \ t=0,\ 1,\ 2,.... \tag{9}$$

Equilibrium

The definition of equilibrium ensures individual optimization and a set of aggregate consistency conditions. First, given a sequence of $\{m_t, H_t, w_t\}_{t=0,1,2,..}$ a redistributive tax rate $0<\tau<1$ and the initial distribution Ψ_0 of human capital, the initial adult of each dynasty with $h \geq 0$ units of human capital chooses a set of decision rules $\{c_t(h), s_t(h), n_t(h)\}_{t=0,1,2,\ldots}$ so as to satisfy the optimization exercise described by (9). Second, the conjectured sequence $\{m_t, H_t, w_t\}_{t \geq 0}$ coincides with the same generated by the distribution of these decision rules for the investment and the occupational choices, which are represented by the sequence of functions $\{s_t(h),\ n_t(h):\ h \geq 0\}_{t=0,1,2,..}$, such that at each date t,

$$m_t = \int_{\{h:n_t(h)=0\}} d\Psi_t(h)\,, \tag{10}$$

$$H_{t+1} = (1-\delta)\int h d\Psi_t(h) + \int s_t(h) d\Psi_t(h),\ H_0 = \int h d\Psi_0(h)\,, \tag{11}$$

the labor market clears,

$$\int_{\{h:n_t(h)=0\}} n_t^d(h, w_t; H_t, m_t) d\Psi_t(h) = 1 - m_t\,, \tag{12}$$

where,

$$n_t^d(h, w_t; H_t, m_t) = \left(\frac{aA\ m_t^{\boldsymbol{\theta}} H_t^a}{w_t}\right)^{\frac{1}{1-a}} h\,,\quad t=0,\ 1,\ 2.... \tag{13}$$

the maximal profit of a manager satisfies,

$$\Pi_{mt}(h)=r_t h, \text{ where, } r_t = (1-a)Am_t^{\theta} H_t^a (aAm_t^{\theta} H_t^a / w_t)^{a/(1-a)},\ t=0,1,\ 2,.... \tag{14}$$

The goods market clears,

$$\int_{h\geq 0} (c_t(h) + s_t(h)) d\Psi_t(h) = \int_{\{h:n_t(h)=0\}} q(h, n_t^d(h); H_t, m_t) d\Psi_t(h)\,. \tag{15}$$

This completes the definition of equilibrium.

All equilibrium sequences converge to a state characterized by dynasties of workers and dynasties of managers, where there is balanced growth. The rationale goes as follows. By the production technology (2), a manager needs a positive amount of unskilled labor to produce output. Consequently, in equilibrium there must be some workers at every date t. At the same time, the optimal investment in human capital is non-decreasing in the adult's human capital stock.[7] The equilibrium sequences of human capital thus preserve the initial ranking of dynasties such that the distribution of human capital evolves as:

$$\Psi_{t+1}((1-\delta)h + s_t(h)) = \Psi_t(h) . \qquad (16)$$

Starting from any arbitrary initial distribution of human capital, adults of dynasties with a sufficiently low initial stock of human capital would not invest in their child's education and specialize to form a dynasty of workers while the rest would invest and specialize to form a dynasty of managers.[8] Our primary interest is in analyzing and calibrating such a dynastic steady state to which we now turn.

3. Balanced Growth Path

The steady state of the model is characterized by dynasties of managers and dynasties of workers, and a balanced growth rate γ which preserves the initial distribution of human capital.[9] We call this steady state a balanced growth path.[10] In such a state, the managerial proportion, m_t, in the labor force, the implicit post tax rental price of human capital, $\bar{r}_t$, after tax wage rate, $\bar{w}_t$, the average human capital, H_t, and the cumulative distribution of human capital, ψ_t satisfy:

$$m_t = m , \qquad (17)$$

where, m denotes the initial proportion of adults with h_0 units of human capital.

$$\bar{r}_t = (1-\tau)r(m) ,$$

where, $r(m) = (1-a)Am^{\theta}(1-m)^{a}$, (18)

$$\bar{w}_t = w(m, h_0)(1+\gamma)^t ,$$

and, $w(m, h_0) = (a(1-a)^{-1} + \tau) r(m) m h_0 (1-m)^{-1}$, (19)

$$H_t = m h_0 (1+\gamma)^t, \tag{20}$$

$$\Psi_t((1+\gamma)^t h) = \Psi_0(h), \ \ h \geq 0 \tag{21}$$

The per capita national income Y_t satisfies:

$$Y_t = Y_0 (1+\gamma)^t, \text{ where } Y_0 = (1-m) w(m, h_0) + m(1-\tau) r(m) h_0 \tag{22}$$

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

$$i_t(h) = 0 \quad \text{if} \quad h = 0 \tag{23}$$

$$= i(m) = \beta[(1-\tau) r(m) + 1 - \delta] - 1 + \delta, \text{ if } h = h_0 \tag{24}$$

The balanced growth rate γ: $m \rightarrow R$ is given by:

$$\gamma(m) = i(m) - \delta \tag{25}$$

Figure 1 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 when $m = \theta/(\theta + a)$. Let us denote this growth maximizing managerial proportion by m^*.

<Figure 1 comes here>

It follows from Figure 1 that a necessary condition for the existence of a non-negative balanced growth state is given by:

$$i(m^*) \geq \delta \tag{26}$$

Bandyopadhyay and Basu (2001) have shown that along such a balanced growth path, it is not optimal for workers to invest in schooling, while it is so for the managers. For a given combination of parameters there is a continuum of steady states indexed by the initial proportion m of dynasties with positive human capital. In the steady state, a dynasty with positive human capital turns out to be a dynasty of managers. However, not any arbitrary value for m can be an admissible managerial proportion in the steady state. If m is too high then it increases the relative scarcity of raw labor. This drives down the skill premium to a level too low to compensate the managers for undertaking investment in human capital. Thus, there exists a critical proportion of managers (which we call m_c hereafter) above which the model does not admit a steady state.[11] In other words, given (26), our model allows a unique set of steady state equilibria given by:

$$0 < m < m_c \quad , \tag{27}$$

Since each steady state defined over (27) preserves the initial proportion of adult owners of human capital, the steady state in this model is *path-dependent*. The conditions (26) and (27) together constitute the necessary and sufficient conditions for the existence of a unique and connected set of steady states for our model. [12]

Borrowing Constraint

In this section we informally discuss the implications when there is limited opportunity to borrow at a fixed world interest rate to meet the adult's investment need. Suppose that the economy is initially on a balanced growth path without borrowing. For illustration, consider only the case when workers need to invest a lump-sum amount for just one period before switching to a managerial dynasty. If $w<h^*$, then workers cannot just invest once and switch.[13] However, once a borrowing option becomes available some workers could borrow and invest in their child so that the grown-up child is able to switch to a managerial dynasty in the next period.[14]

In particular, if we allow imperfect borrowing as in Degregario (1986) then the adult would have access to a multiple ψ >1 of her current income when she invests in her child's education. When such a borrowing option is available, some workers would borrow and switch to a managerial dynasty if the value for such an action dominates the value from not switching. The appendix formulates the value functions and the decision rules for such a switch.

We have simulated the value functions for switching and not switching for plausible parameter values, which we report in the appendix. There exists a threshold ψ for which such a switch using the credit market is worthwhile. However, we find the value of this threshold implausibly high in our calibrated model. The upshot of this exercise is that when limited borrowing opportunity is available, it is unlikely that adults will avail of it to invest in education. The reason is that the production technology requires non-zero raw labor to be viable. Some people need to specialize in unskilled activity, and therefore choose not to invest in children's education even if limited borrowing opportunity is available. For the empirical exercises, we ignore the credit market, meaning we set ψ equal to unity.

4. Growth-Inequality Relationship

Based on the model's steady state properties, 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 the set defined by (27).

Denote the ratio of the steady state after-tax rental to wage income as $\omega(m)$, which one may call *skill premium*. Using (18) and (19), one obtains:

$$\omega(m) = \frac{(1-\tau)(1-a)(1-m)}{(a+\tau(1-a))m} \quad (28)$$

Based on (28), the Gini coefficient of the income distribution is given by:[15]

$$Gini = (1-a)(1-\tau) - m \quad (29)$$

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. The balanced growth rates in (25) and income-inequalities in (29) differ across countries because of differences in the initial proportion m of skilled adults in the population. To see the growth-inequality relationship clearly, use (18), (25) and (29) to obtain the following reduced form relationship between the balanced growth rate and the income inequality:

$$\gamma(m) = (\beta[(1-\tau)(1-a)Am^{\theta}(1-m)^{a} + 1 - \delta]) - 1, \quad (30)$$

where,

$$m = (1-a)(1-\tau) - Gini. \quad (31)$$

Equations (30) and (31) 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 (27). The upper bound m_c of the set of steady states depends on three critical parameters of interest, namely, τ, the degree of redistribution, a, the output elasticity of unskilled labor and θ, the extent of barriers to knowledge spillovers. A different τ implies a different growth-inequality relationship by altering the set of steady state values of the managerial proportion, defined by (27), via its direct effect on the post tax return on capital, and its indirect effect on the steady state occupational distribution. Similarly, the technology parameters a and θ would also influence the nature of the growth-inequality relationship. The growth-inequality relationship is defined over the following set $D(\tau, a, \theta)$ of steady state proportions of managers, m, such that:

$$D(\tau, a, \theta) = \{m: 0 \leq m \leq m_c(\tau, a, \theta)\}. \qquad (32)$$

An important feature of the model is that the sign of the growth-inequality correlation critically hinges upon the relative magnitudes of m_c and m^*, which in turn depend on the values of the crucial parameters, τ, a and θ.[16] By (31), the model's Gini coefficient decreases with m. However, one may notice from Figure 1 that the growth rate, $\gamma(m)$ in (30) increases with m if $m<m^*$, and it decreases with m if $m>m^*$. It follows, therefore, that *ceteris paribus*, the growth-inequality correlation is negative for the range of m values such that $m<m_c<m^*$, and it is positive for $m^*<m<m_c$. Thus the model has the potential of reproducing the heterogeneity in the growth-inequality correlation, which is the central theme of this paper. In the next section, we turn to a calibration exercise to check the predictive power of the model to reproduce the observed cross-country growth-inequality correlation.

Stylized Facts and Calibration

We focus on 61 countries for which a consistent series of income Gini (for the year 1985) and the share of agriculture in GDP are available. Data come from various sources. The per capita growth rate series are from the Summers and Heston Penn World Tables. An average per capita growth rate is computed for each country in the sample over the period

1960-2000. The world growth rate is proxied by the average growth rate of 2.38% for all countries in the sample, and likewise the world Gini is 41.29%. The growth-Gini correlation for all the countries in the sample is found to be –0.31. We use the proportion of higher secondary educated people (referred as HQ) in 1985 as a proxy for the managerial proportion *m*. The series for HQ came from the data set constructed by Barro and Lee (2001). The Appendix reports all our relevant data.

In the next step, we partition countries into agricultural and industrial groups by using the share of agriculture in GDP as a sorting device. Countries in the top quartile of the agricultural share are called agricultural or non-industrial countries, and the countries in the bottom quartile are labeled as industrial countries. In the next step, we compute the growth-inequality correlations, and some related statistics for these subgroups of countries. Table 1 reports basic statistics for the subgroups as well as the whole sample.

Table 1: Stylized Facts

Countries	Average Growth, 65-97	Average Gini, 1985	Growth-Gini Correlation	Average Share of Agriculture in GDP	Average Proportion of Educated People
World	2.38%	41.29%	-0.31	12.47%	8.20%
Agricultural	1.68%	44.75%	-0.5543	29%	2.25%
Industrial	2.92%	33.21%	0.33	2%	12.93%

The growth-inequality correlation shows sign reversal between agricultural and industrial countries. This sign reversal is robust even if we change the partition from quartiles to deciles. Thus to sum up the stylized facts: When one looks at the world distribution of human capital, the growth-inequality correlation is negative as found by Castello and

Domenech (2002) and others. However, as one starts grouping countries in terms of some structural feature (e.g. primary vs. secondary), one gets a reversal in the sign of this correlation. This sign reversal in the growth-inequality correlation is the central query of this paper to which we now turn in the following calibration exercise.

Calibration Methodology

For a given combination of parameters, our model admits a continuum of steady states. We exploit this property of the model for the purpose of calibration. We treat each steady state in the model's admissible range as a realization of a country's growth rate and Gini coefficient. Since the set of steady states changes as one varies the structural parameters, the model has the potential of explaining the sign reversal in the growth-inequality correlation.

For calibrating this model to the stylized facts, we proceed as follows. In the first step, we perform a baseline calibration, which could reproduce the growth-inequality correlation and the related attributes of all countries in the sample as shown in Table 1. Next, we use these calibrated parameter values from the baseline calibration as a benchmark to calibrate the growth-inequality correlations and other related statistics for the subgroups of countries.

Baseline Calibration

The model involves six parameters: A, β, a, τ, θ, δ. We first exploit the fact that the Gini in equation (29) only involves a, τ and m. This provides an opportunity to exactly calibrate the average Gini without involving other equations in the model. We proceed as follows. We use the labor intensity parameter, a as a proxy for the average share of agriculture in GDP as shown in Table 1.[17] Then we calculate the baseline τ by plugging the world average Gini, and the world average proportion of educated people (as shown in Table 1) into equation (29). Using this procedure, the world redistributive tax rate τ is found to be 43.45%. Note that this procedure exactly replicates the average Gini in the sample.

In the next step, we proceed to calibrate the four remaining parameters, A, β, θ, and δ. The immediate challenge here is to calibrate these four parameters in such a way that the following three conditions are met: (i) the world average growth rate is replicated; (ii) the world growth-inequality correlation is reproduced; (iii) the range of m to calculate these two summary statistics is consistent with the model's steady state range of m, as well as the world range of m as in the Barro-Lee data set. We resort to a trial-and-error process as follows to search for the appropriate parameters values.

(i) Calculate four quartiles of the proportions of educated people in the sample. Call these four quartiles, mq_1, mq_2, mq_3, m_{max}.

(ii) Draw m from four rectangular distributions over the ranges, [m_{min}, mq_1], [mq_1, mq_2], [mq_2, mq_3], [mq_3, m_{max}], where $m_{\min}$ and m_{max} are respectively the minimum and maximum proportions of educated people in the sample.

(iii) By construction, a draw from any of these intervals is equally likely (meaning the probability is 25%). Thus one may calculate the model's average growth rate, and the growth-inequality correlation assuming that the probability of m belonging to any of these subintervals is 25%.[18] This ensures that the random draws of m obey the empirical distribution of m.

(iv) The model's average growth rate, and the growth-inequality correlation are then computed for 1000 replications by fixing these four parameters at suitable initial values.

(v) We then start searching for these four parameters A, β, θ, and δ, in the parameter space until two conditions are met: (a) the 95% confidence intervals for the relevant two statistics, average growth rate, and the growth-inequality correlations embrace the sample counterparts; (b) the maximum value of m in the sample, $m_{\max}$, is less than the theoretical upper bound, m_c, of the admissible steady state set of m defined in (27). [19]

Table 2 reports the relevant results for the baseline calibration. Note that the confidence interval of the growth rate and the growth-inequality correlation embraces the sample counterparts reported in Table 2. Also, the $m_{\max}$ for the world is less than the model's admissible upper bound m_c.

Table 2: Baseline Calibration Results

A	0.57
β	0.83
τ	0.4345
θ	0.0170
δ	0.0316
a	0.1247
m_c	0.3541
Maximum Admissible Steady State Value of m	$m_{\max}$ in the Sample: 0.337
95% Confidence Interval for the Growth-Gini Correlation	[-0.3247, -0.1905] Sample Correlation: -0.30
95% Confidence Interval for the Average Growth Rate	[2.3065, 2.3805] Sample Growth Rate: 2.38%

Calibration for Agricultural and Industrial Countries

We repeat the same experiment for the sample of agricultural and industrial countries as follows. Fixing all parameters except θ at the baseline levels, we allow variation in θ to see at what range of values the growth-inequality correlation comes close to observed values for agricultural and industrial countries.[20] Table 3 reports the results.

Table 3: Comparative Statics Exercises with respect to θ

	Industrial Countries	
Values of θ	Growth-Gini Correlation: 95% Confidence Interval	Growth Rate 95% Confidence Interval
0.000	(.99,.99)	(2.15, 2.15)
.0010	(.99, .99)	(2.14, 2.15)
.0012	(.75,.80)	(2.08, 2.08)
.0014	(.59, .72)	(2.06,2.07)
.0016	(.41,.57)	(2.05,2.05)
.0018	(.20,.40)	(2.04,2.04)
.0020	(.016,.211)	(2.03,2.03)
.0022	(-.14,-.04)	(2.01,2.02)
.0024	(-.26,-.11)	(2.00,2.00)

	Agricultural Countries	
Values of θ	Growth-Gini Correlation: 95% Confidence Interval	Growth Rate: 95% Confidence Interval
0.00	(.99,.99)	(1.90,1.95)
0.01	(.96,.97)	(1.29,1.34)
0.02	(.73,.82)	(.70,.74)
0.03	(.23,.42)	(.12,.17)
0.04	(-.21,-.05)	(-.42,-.38)
0.05	(-.44,-.34)	(-.96,-.91)
0.06	(-.57,-.51)	(-1.48,-1.43)

Note: The entries in the second and third column are rounded off to two decimals. θ values are exact.

The growth-Gini correlation is sensitive to θ values and it decreases as the value of θ increases.[21] For the industrial countries a sign reversal occurs at a value of θ within (0.002, .0022), while for the agricultural countries, it occurs at a range of values within

(.03, .04). For industrial countries, the sample correlation of .33 is matched for a θ value of .0018. For the agricultural countries, the sample correlation of -.55 is reproduced for a θ value of .06. However, for these θ values we are unable to replicate the observed growth rates. Rather than being a weakness, this is indeed the strength of our model because although the growth-inequality correlation is sensitive to change in θ, its variation alone cannot explain all the relevant stylized facts.

We are, therefore, left with an option to vary β or δ to match the growth rates.[22] It turns out that given the other parameter values, the variation of β matches the growth rates better than δ. If we allow variation of δ, for agricultural countries δ takes an implausibly small value close to 0. We, therefore, vary β to match the growth statistics. Table 4 summarizes the final calibration results. Notice that the calibrated value of β is higher in agricultural countries than in industrial countries. Despite their higher saving propensity, agricultural countries end up growing less than industrial countries because of a greater barriers to technology implied by a larger calibrated value of the parameter θ and lower skill intensity in the technology implied by smaller value of *(1-a).*

Table 4: Calibration Results for Subgroup of Countries

	Agricultural Countries	Industrial Countries
A	0.57	0.57
β	0.851	0.8371
τ	0.3380	0.5292
δ	0.0316	0.0316
θ	0.048	0.0017
a	0.29	0.02
Average Growth Rate (95% Bounds	(1.67%, 1.73%)	(2.92%, 2.92%)
Observed Growth Rate	1.68%	2.92%
Growth Gini Correlation (95% Bounds)	(-.58,, -.50)	(0.25, 0.36)

Note: The entries in the last four rows are rounded off to two decimals.

Our model thus explains the frequently observed stylized fact that the growth-inequality correlation is generally negative when one looks at the overall world distribution of human capital (as in Castello and Domenech, (2002)). However, in addition, it can also explain why partitioning countries by structural features like industrial vs. non-industrial could make a striking difference in the growth-inequality correlation.

An important clarification is in order now. Given a theoretical U shaped relationship between growth and Gini implied by (30) and (31) (referred to as the growth Laffer curve hereafter), how does the model generate a negative or a positive relationship between growth rate and income Gini for any given sample? This happens because the data and the resulting structural parameters may be such that the rising or falling part of the growth Laffer curve could dominate the scenario for any subgroup of countries. An econometrician without correcting for heterogeneity across countries can come up with a negative growth-inequality correlation for the world population. However, this may hide the fact that growth-inequality correlation may differ and even reverse sign across subgroups of countries differing in structural characteristics.

Some Direct Evidence to Support Calibrated Values of the Crucial Parameters

In Table 4, the calibrated value of θ for the agricultural countries is about 28 times higher than the industrial countries. Since the difference in the value of θ is crucial for the sign reversal of the cross-country growth-inequality correlation, the issue arises whether such a difference in the magnitude of θ is empirically plausible. To this end, we look at some broad proxies of communication facilities such as the use of telephones, televisions and the Internet.[23] The cross-country average telephone mainlines per thousand people (over the sample period 1978-2000) is 12 for agricultural countries and 412 for industrial countries. The same average for the number of television sets per 1000 (over the sample period 1975-2000) is 36 for agricultural countries and 434 for industrial countries. The cross-country average number of Internet users in the year 2000 is 1785425 for the non-industrial countries and 13300004 for industrial countries.[24] These three measures of communication facilities provide ample evidence to the fact that the informational barriers in the agricultural countries are about 7 to 35 times higher than the industrial countries. In light of this evidence our estimates of θ as a measure of informational barrier appear reasonable.

Our calibration indicates that the redistributive tax rate τ is greater in industrial countries than in agricultural countries. Because of the highly aggregative nature of the redistributive tax parameter τ, it is difficult to find direct evidence of it from the data. We examine a some broad proxies for τ as follows. First is the top marginal income tax rate, which may be interpreted as a measure of progressiveness in the tax structure. For the year 2000 for which no missing data are present in our sample, the cross-country average top marginal tax rate is 37% for the non-industrial and 42% for the industrial countries in our sample. Second, the share of consumption taxes in total tax revenue may also be deemed as possible measure of the degree of redistribution of a country. Because consumption tax is usually regressive in nature, a higher share of consumption taxes in the total tax revenue would reflect lesser degree of redistribution. For the year 1999 (for which there are relative less missing data) the cross-country average share of taxes on goods and services in total tax revenue is 36.5% for the non-industrial countries, and it is

22.3% for the industrial countries.[25] Finally, looking at the welfare benefits, one gets a similar picture about the difference in redistributive policy between agricultural and industrial countries. The recent Human Development Report (2003) raises several concerns about a failing welfare system in poor countries. In the year 2000, the share of health expenditure in public spending is about 5.78% for our sample of industrial countries and it is 2% for our sample of agricultural countries.[26] Likewise, the share of education spending is 5.58% and 3.36% for the respective groups during 1998-2000. This evidence corroborates that the industrial countries have a greater degree of redistribution than agricultural countries.

Nonlinearity in the Growth Rate

As evident from Figure 1 and equation (30), the model admits a non-monotonic relationship between growth rate, $\gamma(m)$ and the initial inequality of human capital characterized by m. Does this nonlinear relationship hold up with the data? To this end, we performed the following calculations. Setting the parameters at the baseline levels, we calculated the growth rates based on equation (30) using the proportion of higher secondary educated people as a proxy for m. Figure 2 plots the actual and the model growth rates after dropping four outliers from the sample.[27] The model growth rate shows a clear inverted U shaped relationship that predicts the nonlinear central tendency of the actual growth rates reasonably well. The mean squared errors of the forecasts turn out to be .01%. The correlation coefficient between m and the error of the forecast is 1.08% implying no obvious heteroskedasticity in the fitted relationship.

Figure 3 presents the model and the actual growth plots for a different set of parameter values. The model growth rate performs better now in terms of matching the cross-country diversity of the growth rates. The model growth rate now ranges from about 1.5% to nearly 3.25%. It is important to reiterate here that the purpose of this paper is not to match the cross-country volatility of the growth rates; it is rather to match the cross-country sign reversal in the growth inequality correlation. Given this central goal of this paper, as a side implication we find that the model has also the potential to replicate some degree of cross-country volatility of the growth rates. It is noteworthy that we can achieve this in terms of a simple deterministic non-monotonic relationship between the growth rate and the proportion of innovators.[28]

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 the 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 relationship derived from our model helps explain why the growth-inequality correlations differ between industrial and agricultural countries. Based on the calibration results, we infer that poorer countries are likely to have a greater barrier to knowledge spillovers, a lower degree of income redistribution and low skill intensity in technology.

Our calibration results that agricultural countries have a lower degree of redistribution and a higher barrier to technology diffusion may not be a coincidence. One may speculate here, subject to future research, that as a country goes through different stages of development its political structure changes in such a way that the society optimally moves towards a more equitable society. Moreover, as the economy makes a transition towards an industrial society, its communication infrastructure develops to expedite the diffusion of technology.

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 greater degree of redistribution, which we observe in our calibration. Second, a possible extension would be to understand the within-country growth-inequality dynamics using this framework. Third, one could also extend the model to analyze the wide diversity in the long run growth rates that has perplexed the growth theorists for so long.

Appendix

DATA

Country	1985 Gini (%)	% Growth Rate (1960-2000)	%HQ (1960)	% Share of Agriculture in GDP (1998)
Australia	37.6	2.201048	21.8	3
Austria	23.1	2.972214	5.7	1
Bangladesh	36	1.17029	1.7	22
Belgium	26.2	2.833316	10.7	1
Botswana	54.2	5.296692	0.7	4
Brazil	61.8	2.811787	6.4	8
Cameroon	49	0.488557	0.7	42
Canada	32.8	2.408737	19.3	2
Central African Republic	55	-2.04745	0.4	55
Chile	53.2	2.393899	8.3	8
China	31.4	4.353067	1.1	18
Colombia	51.2	1.905696	5.7	13
Costa Rica	47	1.318737	11.6	15
Denmark	31	2.235654	18.6	4
Dom. Rep	43.3	2.877098	6.4	12
Ecuador	44.5	1.380737	13.6	12
Egypt	34	2.636108	4.6	17
El Salvador	48.4	0.73444	3.4	13
Finland	30.8	2.931237	13.8	4
France	34.9	2.65952	10.5	2
Ghana	35.9	1.116894	0.8	37
Greece	39.9	3.187037	8.7	8
Guatemala	58.3	1.290063	3.5	21
Honduras	54.9	0.468652	3.3	23
India	38.1	2.720568	3.7	29
Indonesia	39	3.455032	0.6	20
Iran	42.9	2.044144	2.6	25
Ireland	34.6	4.175669	9.6	4
Italy	33.2	2.919363	6.7	3
Jamaica	43.2	0.743303	2.8	7
Japan	35.9	4.320426	16	2
Jordan	36.1	1.341806	11	3
Kenya	57.3	1.123722	0.7	29
Korea	34.5	6.084182	11.7	5
Lesotho	56	2.081319	0.5	11
Malawi	59.9	1.580678	0.4	39
Malaysia	48	3.934199	2	13
Mexico	50.6	1.992323	7.3	5
Nepal	30.1	1.582777	1.5	40
Netherlands	29.1	2.446493	13.8	3
New Zealand	35.8	1.229817	30.3	8
Norway	31.4	3.017212	13.5	2

Country	1985 Gini	Growth Rate (1960-2000, %)	HQ(%) (1960)	% Share of Agriculture in GDP (1998)
Pakistan	39	2.927103	2	26
Panama	47.5	2.427036	11.1	7
Peru	49.3	0.883243	12	7
Philippines	46.1	1.335597	17.8	17
Portugal	36.8	3.91347	4.5	6
Romania	23.4	3.607066	6	15
Singapore	42	7.03046	4.3	0
South Africa	51	1.052055	2.3	4
Spain	31.8	3.455831	7	3
Sri Lanka	45.3	2.291855	1.4	21
Sweden	31.2	2.130871	16.9	2
T&T	41.7	2.375157	3.3	2
Thailand	41.7	4.702397	5	11
Tunisia	49.6	3.188625	2.8	12
Turkey	44	2.359622	4.1	18
UK	27.1	2.097119	12.8	2
Uraguay	41.23	1.241224	8.1	8
US	37.3	2.526298	33.7	2
Venezuela	42.8	-0.49845	10	5

Source: The series HQ is the proportion of population with higher secondary education. These data came from Barro and Lee (2001). The series for the average per capita growth rates of real GDP for the sample period 1960-2000 was computed from the latest Penn World Tables 6.1. The share of agriculture in GDP for the year 1998 (for which data for all countries in our sample are available) came from the World Bank Development Indicators. The Gini coefficients for 1985 are obtained from Forbes (2000) and Deininger and Squire (1996). 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 a large number of missing 1990 Gini data, we did all our computations based on the 1985 Gini series.

Appendix

Suppose that a worker could borrow $(\psi - 1)$ times their current income at a one period gross interest rate *R* by promising to repay a multiple $\mathrm{R}(\psi - 1)$ of her current income in the next period. If an investment *h*'* is just enough for them to merge into the optimal growth path of a managerial dynasty then their consumption in the first two periods, c_1 and c_2, and the new steady state investment rate *i'* must satisfy:

$$c_1 + h^{*\prime} = \psi w \quad , \tag{A1}$$

$$c_2 + (\psi - 1)wR = (r' - i')h^{*\prime}, \tag{A2}$$

where *r'* denotes the new steady state value of the implicit price of human capital. Let V_ψ denote the value function of a worker who switches as above such that

$$V_\psi = \max_{h^{*\prime}} \begin{bmatrix} \ln(\psi w - h^{*\prime}) + \beta \ln((r' - i')h^{*\prime} - (\psi - 1)wR) \\ + \dfrac{\beta^2}{1-\beta}\left\{\ln(1 + i' - \delta) + \ln h^{*\prime} + \ln(r' - i')\right\} \end{bmatrix} \tag{A3}$$

Given any arbitrary value of $\psi > 1$ we can solve for the optimal amount $h^{*\prime}$ of investment in education such that

$$f(h^{*\prime}) = \frac{\beta^2}{1-\beta} \tag{A4}$$

where the function, $f(.)$, is given by

$$f(h^{*\prime}) \equiv \frac{h^{*\prime}}{\psi w - h^{*\prime}} - \frac{\beta(r' - i')h^{*\prime}}{(r' - i')h^{*\prime} - (\psi - 1)wR} \tag{A5}$$

Note that $f(0) = 0$, $f' > 0$ for all $h^{*\prime} < \psi w$, provided $h^{*\prime} > h_0$; otherwise, $h^{*\prime} = 0$. We thus have:

Lemma 1. There is always a unique solution for $h^{*\prime} < \psi w$.

Lemma 2. The optimal value of $h^{*\prime}$ increases if ψ increases.

Let V_w be the value function of a worker who does not switch given that some other workers switch. Since other workers switch, the proportion of managers from the next period changes to m', and thus the worker who does not switch enjoys the benefit of a higher wage growth due to other workers' switching. Thus the value function V_w of such a non-switching worker is:

$$\begin{aligned} V_w &= \ln w + \sum_{t=1}^{\infty} \beta^t \ln w(m')(1+\gamma(m'))^t \\ &= \ln w + \frac{\beta \ln w'}{1-\beta} + \frac{\beta}{(1-\beta)^2} \ln(1+i'-\delta) \end{aligned} \qquad \text{(A6)}$$

If $V_\psi > V_w$ then some workers would switch. We calculated $h^{*\prime}$, V_w, and V_ψ for alternative values of ψ setting the other parameter values at the baseline levels as in Table 2 and the world interest rate at 3%.[29] Results are reported in Table A.1. By Lemma 2, $h^{*\prime}$ increases, if ψ increases. Observe that $V_w > V_\psi$ until ψ exceeds a threshold value around 5.[30] Thus, a worker adult would not invest in human capital even if some limited borrowing opportunity is available.[31]

Table A.1

ψ	$h^{*\prime}$	V_ψ	V_w
1.5	.22	-11.74	-7.57
2.0	.36	-10.16	-7.55
2.5	.46	-9.20	-7.54
3.5	.65	-7.89	-7.52
4.0	.75	-7.41	-7.50
5.0	.95	-6.67	-7.57

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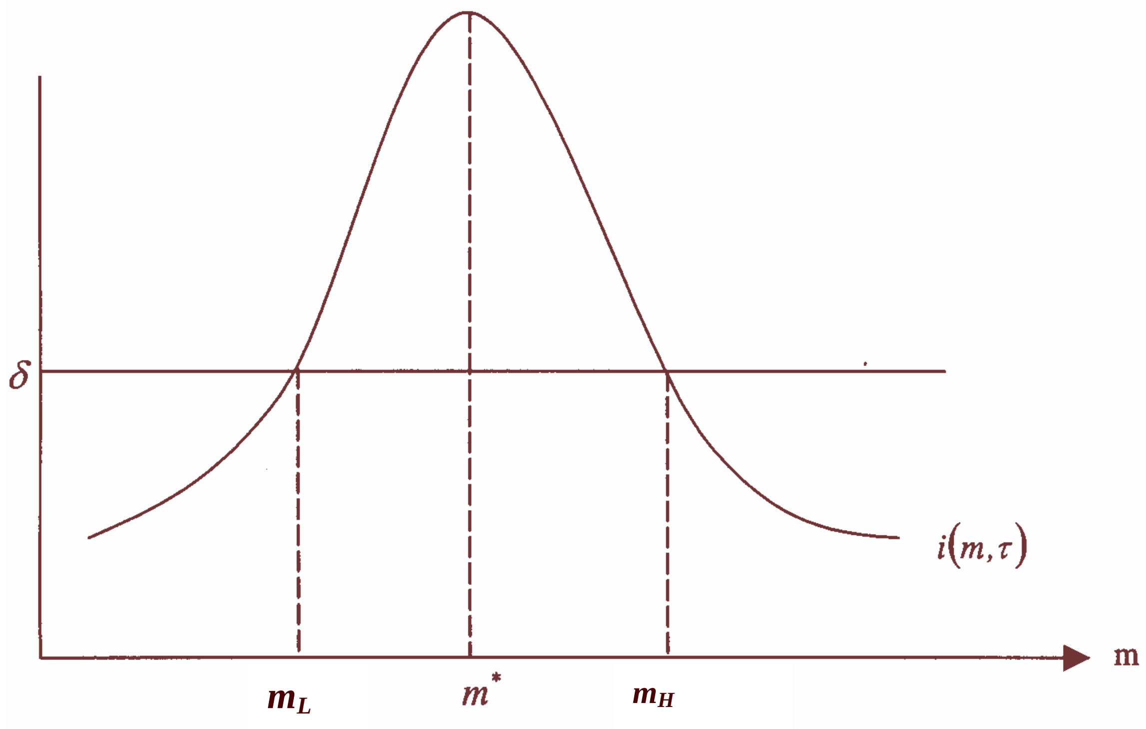
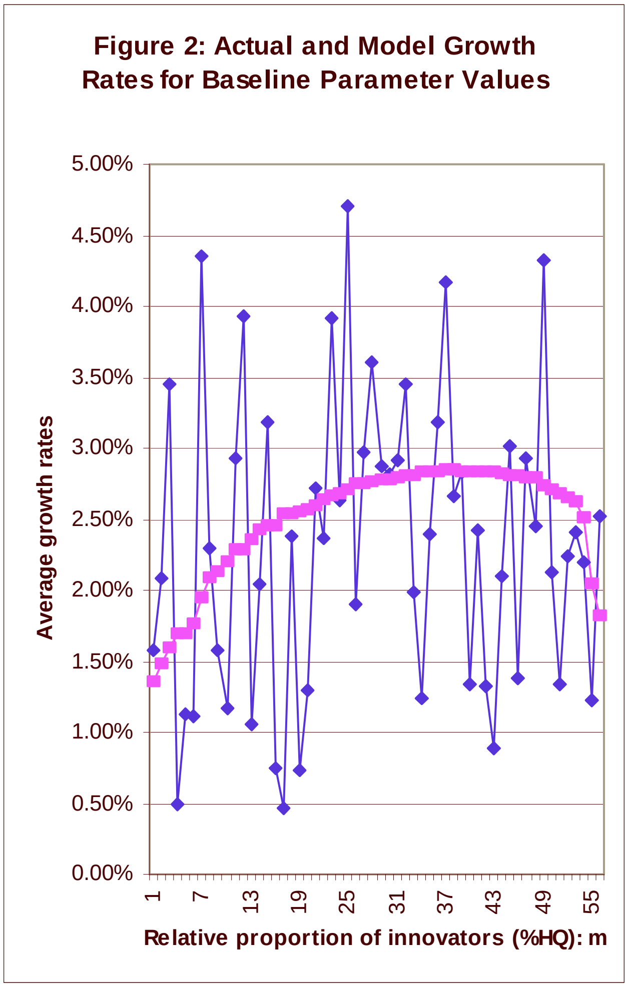
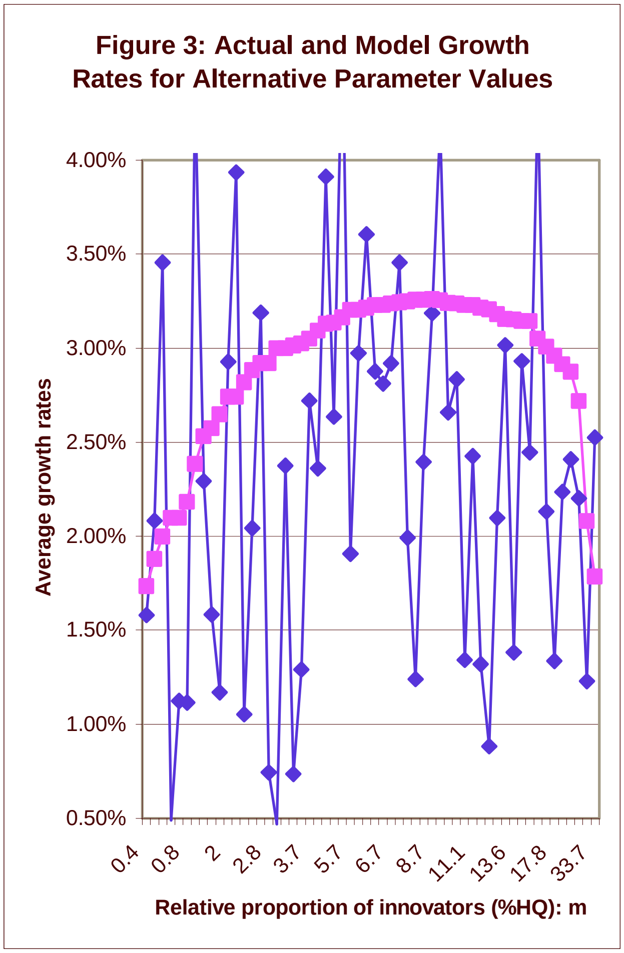
Figure 1





Note: The smooth curve with boxes is the model growth rate. The choppier curve with diamonds is the actual growth rates. The root mean squared error of the forecasts is .01%



Note: Same as F*igure 2. The parameter values are: A*=.55, τ=.2, δ=.0314,θ=.0356,a=.3813,β=.85. The root mean squared error is .01%

Footnotes

Lead footnote

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

[2] There are two distinct branches of literature dealing with long run inequality. In the models of Alesina 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 (1997), 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 a credit market does not exist. Mookherjee and Ray (2003) 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 the relationship between endogenous growth and income inequality.

[3] Prescott (1998) argues that the cross-country disparity in income is better explained by how much non-rival knowledge a country could exploit rather than by 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.

[4] 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 a regulatory system as in Parente and Prescott (2002, pp. 81-89) with an important difference. In their model, a larger barrier implies that each firm (or a group led by a manger) 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.

[5] Through interaction, a manager gets the same external benefit from a large group of managers with low average human capital as from a small group of managers with sufficiently high average human capital. This interaction is parameterized by *b*.

[6] In principle, τ can also 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.

[7] See Bandyopadhyay (1993) for a proof.

[8] Depending upon the initial distribution of human capital, however, we may observe a strictly non-increasing or a strictly non-decreasing sequence of managers. The corresponding sequence of income inequality and growth may give rise to wealth mobility within a country, and a Kuznets curve as a part of transitional dynamics. This issue is beyond the scope of this paper.

[9] Bandyopadhyay and Basu (2001) have characterized the steady state by showing that in the above environment there are two constants $0<m<1$, $h_0>0$ and a time invariant function $\gamma : m \to R$ such that a competitive equilibrium with an initial distribution Ψ_0 with $\Psi_0(h) = 1-m$, for $0 \le h < h_0$ and $\Psi_0(h) = 1$, for all $h \ge h_0$, describes a balanced growth state.

[10] Hereafter, we use the phrases balanced growth path and steady state interchangeably.

[11] We provide the details of the characterization of m_c in Bandyopadhyay and Basu (2001).

[12] In our calibration exercise we impose suitable restrictions on the parameters to ensure that these conditions hold.

[13] This leaves open the possibility of workers undertaking incremental investment from an earlier period and eventually becoming a manager. We proved in Bandyopadhyay and Basu (2001) that the concavity of the utility function rules out this option.

[14] Because of the public good property of knowledge, not all workers prefer to switch like this in response to a borrowing opportunity. A worker could free-ride by not switching and enjoying the benefit of higher wage growth when other workers switch. The appendix describes the details.

[15] To obtain the expression for the Gini in (29), define $\bar{a}$ as the worker's steady state post tax share in income. Note that using (28), $\bar{a} = [1+m(1-m)^{-1}\omega(m)]^{-1}$. 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 (G*ini*) is, therefore, given by: G*ini* $= 1-\bar{a} - m$, which after simplification yields (29).

[16] See Figure 1 and footnote 11.

[17] The fact that agriculture has low skill intensity justifies this choice.

[18] Note that we do not need to compute the average Gini because it is exactly replicated. Recall τ is calibrated to exactly replicate the average Gini in the very first step of the calibration.

[19] This second condition ensures that the draws of m in each replication are admissible by the model's steady states.

[20] We also adhere to the same baseline steady state distribution of human capital assuming that each sub-sample is drawn from the same baseline distribution.

[21] This happens because a change in θ via its effect on m^* shifts the growth curve. It also impacts the critical proportion m_c of managers above which the model does not admit a steady state. The sign of the growth-Gini correlation thus depends on the magnitude of m_c relative to m^*.

[22] Since A is nonrival knowledge, we cannot change it across countries. The parameter a is, however, chosen separately for each group to match the average share of agriculture in GDP. Likewise, the value of τ is chosen for each group to replicate the Gini coefficient.

[23] All these data came from World Development Indicators (2002) (referred as WDI hereafter).

[24] The choice of the sample period is constrained by missing values. For telephone lines there are more missing values before the year 1978. Since the use of the Internet is a relatively a recent phenomenon, we choose the year 2000 which is the terminal year in our dataset and for which there is no missing data.

[25] The data for the marginal tax rate and taxes on goods and services came from WDI (2002). There are several missing data for the period before 1999, which constrained our choice of years.

[26] See Table 17 of the Human Development Report (2003).

[27] These outliers are Korea, Singapore, Central African Republic and Venezuela.

[28] We also recalibrated the model using the parameters in Figure 3 as a new baseline. We were able to match again the observed sign reversal of the Gini-growth correlation, average growth rates and Gini for industrial and non-industrial countries. The relative ordering of the three critical parameters, a, τ and θ remain the same for these two subgroups as reported in Table 4. Details are not reported here for brevity but available from the authors upon request.

[29] A world interest rate of 3% is merely taken as an estimate for illustrative purpose. We varied the rate around this, and the qualitative results stay the same. A lower interest rate is qualitatively similar to a lower ψ.

[30] We set m at 8.2% which is the average proportion of educated people for the world (see Table 1). When some workers switch in response to borrowing opportunity, m will increase to m'. Since it is difficult to obtain an analytical expression for m', we perform a

sensitivity analysis with different values of *m'* above *m*. Qualitative results remain the same.

[31] If some workers switch, it will have an effect on the set of the admissible proportion of managers. The lower bound is likely to increase because of the new entry of managers. As mentioned in footnote 30, this effect is taken into account while simulating the value functions (A.3) and (A.6). The upper bound m_c will not change unless an adult with positive initial human capital gets cheap loans from abroad to find it optimal to invest in their children's education.