Education, Economic Growth and Personal Income Inequality Across Countries*

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Abstract

This paper offers a supply-side explanation of the cross-country variation in long-run growth and inequality. In the model education simultaneously affects growth and income inequality. More human capital may increase or decrease growth but also measured inequality. In contrast to some recent contributions the paper uses consistently defined data showing that higher (within-country) inequality is associated with lower growth, even when controlling for initial income, education or fertility. Furthermore, countries with a more productive education sector appear to have lower inequality. It is argued that institutions and policies which generate more high-skilled people or enhance the productivity of the education sector may affect long-run income equality and growth in a positive way.

KEYWORDS: Human Capital, Education, Growth, Inequality, Policy

JEL Classification: O4, I2, D31, H2

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1 Introduction

For a long time economists have been interested in the question of how income inequality and growth are associated. Recent results indicate that there does not seem to be a robust relationship between inequality and growth within countries over time.[1] However, based on compilations of inequality data from household surveys as e.g. by Deininger and Squire (1996), it has been found that inequality varies substantially across countries.

This paper argues that the cross-country variation can be explained well by different education policies or institutions. These links are first analyzed in a theoretical model whose implications are then confronted with empirical evidence.

One issue for the theory part is that *human capital* and *education* explain long-run patterns of *growth* very well. See, for instance, Lucas (1988), Barro (1991), Mankiw, Romer and Weil (1992), Benhabib and Spiegel (1994), or Fernandez and Rogerson (1995), (1996).

Secondly, the link between *distribution* and *growth* is considered which has been analyzed in a vast number of contributions.[2] Just to name a recent few suffice it to mention Galor and Zeira (1993), Bertola (1993), Alesina and Rodrik (1994), Persson and Tabellini (1994), or Perotti (1996). The consensus emerging from these studies is that inequality negatively affects growth.

However, based on Deininger and Squire's data set the consensus has recently been challenged by Deininger and Squire (1998), Forbes (1998), Barro (2000) and others who find non-robust or even positive associations, suggesting that income inequality might be good for growth, especially in rich countries.

[1] For instance, Li, Squire and Zou (1998) show for many countries that there is little variation in within country income dispersions over time. In contrast, Atkinson (1998) finds that for the G7 countries the income dispersions have changed significantly over time.

[2] That literature is surveyed by e.g. Bénabou (1996), Bertola (1999), or Aghion, Caroli and García-Peñalosa (1999).

Clearly, any study of the relationship between inequality and growth has to address important methodological issues. For instance, is inequality referring to gross or net concepts of wealth or income? How is inequality measured and what properties does a measure (e.g. the often used Gini coefficient) have? Furthermore, one has to tackle causality and endogeneity problems. For instance, does inequality affect the composition of human capital which in turn affects growth? Or does the composition affect inequality and/or growth? These sometimes difficult issues are discussed by all the empirical contributions mentioned but no clear consensus on methodology seems to hold.

In this context the present paper makes the following points: First, it is assumed that education *simultaneously* affects growth and (income) inequality. Second, within a macro framework it is shown that the often used Gini coefficient generates certain predictions by *construction* which has adverse effects for testing any 'true' relationship. Third, using *consistent* income concepts for the measurement of inequality no positive association between (measured) income inequality and growth is found in the data used in this paper. Fourth, the paper discusses some sources of the cross-country differences in the composition of human capital.

In the model education simultaneously determines growth and inequality by assuming that human capital is '*lumpy*' and can be identified with 'degrees'. People are hired as high-skilled workers in the labour market only if they have obtained a degree. The source of income inequality lies in the production process, because high and low-skilled people are imperfect substitutes in production.

The government finances education by raising a tax on the resources (wealth) of all individuals and the percentage of high-skilled people in the population is directly related to the tax rate.[3] Ex ante all agents are identical so that innate

[3]Thus, even those who have not received education contribute to financing it. That is

ability or initial wealth differences are not important in the set-up. The model ignores problems arising from the time spent receiving education by assuming that education is provided as a public good and that all people spend the same time in school, but attend different courses leading to different degrees.[4]

In equilibrium growth is positively related to human capital only up to a certain point, since the government takes resources away from the private sector in order to finance education, which reduces growth. On the other hand it generates more high-skilled people which exert a *positive* effect on production and income equality (in the sense of Generalized Lorenz Curve Dominance). However, for high growth taxes and so the number of high-skilled people must not be too high.

Equality in long-run incomes as well as growth (for a given human capital mix) are shown to depend positively on the productivity of the education sector. An important feature of the model is that differences in human capital generally lead to *ambiguous* rankings of income inequality when the latter is *measured* by the often used Gini coefficient.

The model predicts for the long-run that (a) countries with relatively more high-skilled people have higher initial income and less gross income inequality, and (b) less inequality is associated with higher growth.

These predictions are then confronted with empirical evidence for the period 1960-90. In contrast to recent contributions the paper focuses on data from Deininger and Squire (1996) and the Luxembourg Income Study (LIS) which

realistic in most public education systems and may be in the low-skilled people's interest as is e.g. shown by Johnson (1984) or Creedy and Francois (1990). Furthermore, governments have fiscal and institutional instruments other than direct provision of education at their disposal which have a significant bearing on the working of private education systems. For a discussion of public vs. private education see, for instance, Glomm and Ravikumar (1992) or Fernandez and Rogerson (1998).

[4]Opportunity costs of education might easily be introduced into the model by subtracting a fixed amount of happiness from a high-skilled person for having spent time in school. The paper's results would not change in that case.

are based on *consistent* concepts for inequality measurement. The consistency requirement reduces sample sizes significantly so that each observation assumes great importance in any qualitative analysis.

Simple correlations reveal that across countries income inequality as measured by the (within-country, time-average) Gini coefficient covaries *positively* (D/S 96) or *negatively* (LIS) with the long-run growth rate of real GDP per capita. Both correlations are relatively weak, but they would suggest that in the long run and for the typical country an increase in inequality might be positively associated with growth.

In both samples the composition of human capital covaries *negatively* with long-run growth. That appears to be at odds with what many people have found in cross-country studies. There it has usually been reported that human capital is positively associated with growth. However, recent contributions have also found non-robust or negative associations between them. This difference in results is investigated in more detail in the main text.

Next, the model's predictions are discussed in the context of *simple* cross-country growth regressions.[5] It turns out that when controlling for various factors including initial income, fertility or the composition of the labour force, income inequality as measured by the Gini coefficient is negatively associated with growth in all of this paper's regressions. Furthermore, when controlling for various factors including initial income, inequality, or fertility an increase in the percentage of high-skilled people increases long-run growth across countries.

These results raise the question what forces determine the labour force mix in

[5]Following e.g. Caselli, Esquivel and Lefort (1996) the results should investigated in terms of *dynamic* panel data methods. These methods seem superior when analyzing growth, but, as argued by Barro (1997), p. 37, or Temple (1999), p. 132, they may have their own problems. For that reason the paper discusses simple statistics whose properties may also be relevant for those methods.

production. Tinbergen (1975), chpt. 6, has argued that there is a race between technological development and education so that differences in the human capital composition may be caused by the *demand* side of an economy (e.g. skill-biased technological change).[6] However, contributions such as Katz and Murphy (1992) or Murphy, Riddel and Romer (1998) provide evidence that the dominating forces at work are more likely to be *supply* driven. Therefore, in this paper the supply of education is taken to win Tinbergen's race in the long-run.

The data suggest that differences in the supply of human capital may account well for the observed differences in long-run performance and income inequality. These differences may be due to political decisions such as how the school system is organized (elitist or egalitarian), or how it is financed (fee structure), but also factors such as history, labour market conditions and other institutional arrangements.

The paper is organized as follows: Section 2 presents the theoretical model and derives testable predictions. Section 3 confronts the model with empirical evidence. Section 4 provides concluding remarks.

2 The Model

Consider an economy that is populated by N (large) members of two representative dynasties of infinitely lived individuals. The two dynasties are *high-skilled* workers, L_h, and *low-skilled* workers, L_l, where L_h, L_l denote the total numbers of the respective agents in each dynasty. The difference between high and low-skilled labour is "lumpy", that is, *either* an individual has received education

[6] Thus, the paper abstracts from the important phenomenon of skill-biased technological change and should, therefore, be viewed as complementary to recent models along the lines of, for instance, Galor and Tsiddon (1997), Acemoglu (1998), or Caselli (1999).

certified in the form of a degree and is then considered high-skilled *or* it has no degree and remains in the low-skilled labour pool.

By assumption the population is stationary with $L_h \equiv xN$ and $L_l \equiv (1-x)N$ where x denotes the percentage of high-skilled people in population. Each worker supplies one unit of either high or low-skilled labour inelastically over time. All agents initially own an equal share of the total capital stock, which is held in the form of shares of many identical firms operating in a world of perfect competition. Thus, all agents receive wage and capital income and make investment decisions. Furthermore, aggregate output is produced according to

$$Y_t = A_t\ K_t^{1-\alpha}\ H^\alpha,\ H^\alpha = \left[(L_h + L_l)^\alpha + L_h^\alpha\right], \qquad 0 < \alpha < 1, \tag{1}$$

where K_t denotes the aggregate capital stock including disembodied technological knowledge, H measures effective labour in production, and A_t is a productivity index. The production function is a *reduced form* (see Appendix A.1) of the following relationship: By assumption *effective labour* depends on tasks requiring *basic skills* and tasks requiring *high skills.* These tasks are *imperfect substitutes* in production. On the other hand it is assumed that *low and high-skilled people* are *perfect substitutes* in performing *basic* tasks. Thus, high-skilled people always perform the tasks of low-skilled people in the model, but low-skilled people can never execute tasks that require a degree. Thus, each type of labour alone is *not* an essential input in production.[7]

The government runs a balanced budget, uses its tax revenues to finance public education and maintains a constant ratio of expenditure G_t to its tax

[7]Modelling production in this way relates to work that distinguishes between tasks performed for a *given* educational attainment of the labour force and education mixes for *given* tasks. See e.g. Tinbergen (1975), chpt. 5, and Lindbeck and Snower (1996) .

base.[8] It taxes the agents' wealth holdings at a constant rate τ. The capital stock (wealth) of the representative agent is $k_t = \frac{K_t}{N}$ so that $G_t = \tau k_t N = \tau K_t$ and $\frac{G_t}{K_t} = \tau$ for all t. Thus, real resources are taken from the private sector and used to finance public education, which generates high-skilled agents.[9]

In general, public education is 'produced' using government resources and other factors such as high-skilled labour itself. That is captured by the following *reduced form* of the education technology

$$x = \tau^{\epsilon} \quad \text{where} \quad 0 < \epsilon \leq 1 \ , \quad x_{\tau} > 0, \quad \text{and} \quad x_{\tau\tau} \leq 0. \tag{2}$$

Thus, if the government channels more resources into education, it will generate more high-skilled people. However, doing this generally becomes more difficult at the margin, as more resources provided to the education sector lead to a decreasing marginal product of those resources due to congestion or other effects.

The parameter ϵ measures the productivity of the education sector.[10] If $\epsilon < 1$, the education sector is productive and a marginal increase in taxes increases education output substantially. Underlying that is the description of an education sector with spillovers from, for instance, high-skilled to new high-skilled people or where the capital equipment such as computers makes the education technology very productive. For a justification of the set-up see Appendix A.2.

[8]Capital taxes keep the analysis simple and are supposed to capture a broad class of tax arrangements, the aim of which is to channel public resources into education. For a similar approach in a different context see Alesina and Rodrik (1994). Constancy is imposed in order to focus on long-run, time-consistent equilibria with steady state, balanced growth.

[9]In the model agents are endowed by the same *basic* ability and receive basic education which is produced and provided costlessly. Education is always meant to be higher education. *Ex ante* everybody is a candidate for receiving (higher) education and once chosen to be *in* the education process will complete the degree. The education process is taken to be sufficiently productive in converting no skills into high-skills.

[10]The reduced form directly relates the percentage of high-skilled people (x) to the percentage of resources (wealth) going into the education sector (τ). Let pr denote the productivity of the education sector. Then $pr = \frac{x}{\tau} = \tau^{\epsilon - 1}$, which is decreasing in ϵ for given policy.

The Private Sector. There are as many identical firms as individuals and the firms face perfect competition and maximize profits. By assumption they are subject to knowledge spillovers, which take the form $A_t = \left(\frac{K_t}{N}\right)^\eta = k_t^\eta$ with $\eta \geq \alpha$. Thus, the *average* stock of capital, which includes disembodied technological knowledge, is the source of a positive externality.[11] Then simplify by setting $\eta = \alpha$ which allows one to concentrate on steady state behaviour. For a justification see Romer (1986). As the firms cannot influence the externality, it does not enter their decision directly so that

$$\begin{aligned} r &= (1-\alpha)k_t^\alpha K_t^{-\alpha} H^\alpha, \\ w_h &= \alpha k_t^\alpha K_t^{1-\alpha}\left[(L_h + L_l)^{\alpha-1} + L_h^{\alpha-1}\right], \\ w_l &= \alpha k_t^\alpha K_t^{1-\alpha}\,(L_h + L_l)^{\alpha-1}. \end{aligned} \tag{3}$$

The workers have logarithmic utility and own all the assets which are collateralized one-to-one by capital. A representative worker takes the paths of r, w_h, w_l, τ as given and solves

$$\max_{c_i} \int_0^\infty \ln c_i \; e^{-\rho t}\; dt \tag{4}$$

$$s.t. \qquad \dot{k} = w_i + (r-\tau)k - c_i \qquad i = l, h \tag{5}$$

$$k_0 = \text{given}, \;\; k_\infty = \text{free}.$$

The worker's problem is standard and involves the following growth rate of the average high or low-skilled worker's consumption

$$\gamma = \frac{\dot{c}_l}{c_l} = \frac{\dot{c}_h}{c_h} = (r-\tau) - \rho. \tag{6}$$

[11]Here the assumption is that regardless of the source of new ideas or blueprints production is undertaken so that all agents are affected relatively equally from knowledge spillovers. The results would not change if the externality depended on the *entire* capital stock instead.

Thus, consumption of all workers grows at the same rate in the optimum and depends on the after-tax return on capital. As the agents own the initial capital stock equally and have identical utility functions, their investment decisions are the same. But then the wealth distribution will not change over time and all agents continue to own equal shares of the total capital stock over time.

Market Equilibrium. For the rest of the paper normalize by setting $N = 1$ so that the factor rewards in (3) are given by

$$r = (1-\alpha)(1+x^{\alpha}) \ , \qquad w_h = \alpha k_t (1 + x^{\alpha-1}) \qquad \text{and} \qquad w_l = \alpha k_t . \tag{7}$$

The return on capital is constant over time and wages grow with the capital stock. As $w_h = w_l\,(1 + x^{\alpha-1})$, high-skilled labour receives a premium over what their low-skilled counterpart gets. That reflects the fact that the high-skilled may always perfectly substitute for low-skilled labour so that both types of labour receive the same wage w_l for routine tasks and that performing high-skilled tasks is remunerated by the additional amount $w_l\,x^{\alpha-1}$. The premium depends on the percentage of high-skilled labour in the population, grows over time at the rate γ and is decreasing in x for a *given* capital stock.[12]

From the production function one immediately gets $\gamma_y = \gamma_k$ so that per capita output and the capital-labour ratio grow at the same rate. With constant N total output also grows at the same rate as the aggregate capital stock. From (6) the consumption of the representative agent grows at γ. Each worker owns $k_0 = \frac{K_0}{N}$ units of the initial capital stock. Equation (5) implies $\dot{k} = w_i + (r - \tau)k - c_i$ so

[12]Thus, the wage premium depends negatively on the number of high-skilled people, which captures an important and realistic aspect in the explanation of wage inequality. See, for instance, Bound and Johnson (1992), Katz and Murphy (1992) or Autor, Krueger and Katz (1998). Notice that w_l depends on k_t and so x in equilibrium.

that $\gamma_k = \frac{w_i - c_i}{k} - (r - \tau)$ for $i = l, h$ where $(r - \tau)$ is constant. In steady state, γ_k is constant by definition. But $\frac{w_i}{k}$ is constant as well, because from (7)

$$\frac{w_h}{k_t} = \frac{\alpha k_t (1 + x^{\alpha-1})}{k_t} = \alpha(1 + x^{\alpha-1}) \quad \text{and} \quad \frac{w_l}{k_t} = \alpha,$$

which implies $\gamma_k = \gamma$. Thus, the economy is characterized by *balanced growth* in *steady state* with $\gamma_Y = \gamma_K = \gamma_y = \gamma_k = \gamma_{c_h} = \gamma_{c_l}$.

Furthermore, from equation (5) and using $\gamma_k k = \dot{k}$ and $\gamma_k = \gamma_{c_h} = \gamma_{c_l}$ in steady state one obtains $(r - \tau - \rho)k_t = w_i + (r - \tau)k_t - c_i$. Thus, $c_i = w_i + \rho k_t$ $(i = h, l)$ are the instantaneous consumption levels of a representative agent in steady state. Notice that $c_h > c_l$ for positive x. From (6), (7) and $\tau = x^{\frac{1}{\epsilon}}$ one obtains $\gamma = (1 - \alpha)(1 + x^\alpha) - x^{\frac{1}{\epsilon}} - \rho$ and verifies that

$$\hat{x} = [\epsilon\alpha(1 - \alpha)]^{\frac{\epsilon}{1-\epsilon\alpha}}, \quad \text{and} \quad \hat{\tau} = [\epsilon\alpha(1 - \alpha)]^{\frac{1}{1-\epsilon\alpha}}$$

maximize growth, which is concave in x since for $\epsilon \leq 1$ and any x

$$\frac{d^2\gamma}{(dx)^2} = -\alpha(1 - \alpha)^2 x^{\alpha-2} - \frac{1}{\epsilon}\left(\frac{1}{\epsilon} - 1\right) x^{\frac{1-2\epsilon}{\epsilon}} < 0.$$

Thus, in the model it is possible that an economy has high-skilled workers, but does not do better than another economy with no high-skilled people. The effect of a change in the productivity of the education sector for a given $x \in (0, 1)$ is given by $\frac{d\gamma}{d\epsilon} = \frac{\ln(x)\ x^{\frac{1}{\epsilon}}}{\epsilon^2} < 0$. Hence, a reduction in ϵ, that is, making the education technology more productive, raises growth.

Lemma 1 *The long-run growth rate γ satisfies the following properties:*

1. γ is concave in x. *2. $\frac{d\gamma}{d\epsilon} < 0$ for $x \in (0, 1)$.*

Income Inequality. In the model all income differences are due to differences in wage income. As growth is often related to measures of gross income inequality, the paper concentrates on the distribution of gross (of tax) income. When one relates growth to income inequality one should look at an average of personal incomes over time. If the agents sold their income stream in a perfect capital market, they would discount their income stream by $r-\tau$, that is, by the after-tax market rate of return on assets. As their gross income at any point in time is $y_{it} = w_{it} + rk_t$, the present value of their lifetime incomes is

$$\int_0^\infty y_{it}\, e^{-(r-\tau)t} dt = \int_0^\infty y_{i0}\, e^{\gamma t}\, e^{-(r-\tau)t} = \frac{y_{i0}}{\rho} \equiv y_i^d \quad \text{where} \quad i = l, h.$$

Thus, y_i^d denotes the sum of an individual's gross incomes discounted by the after-tax market rate of return on assets.[13] Notice $y_{i0} = w_{i0} + rk_0$ where

$$w_{l0} = \alpha k_0 \quad \text{and} \quad w_{h0} = \alpha k_0 (1 + x^{\alpha-1})$$

and that the mean of the discounted sum of incomes is

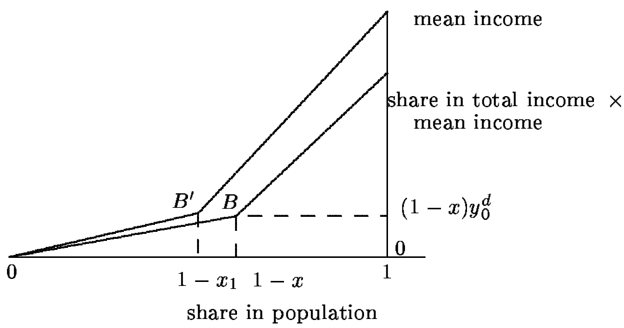
$$\mu^d = \frac{(1-x)w_{l0} + xw_{h0} + rk_0}{\rho} = \frac{(1+x^\alpha)k_0}{\rho}. \tag{8}$$

implying $\frac{dw_l^d}{dx} = 0$, $\frac{dw_h^d}{dx} < 0$ and $\frac{d\mu^d}{dx} > 0$ so that the mean of the PV of lifetime gross incomes is increasing in x. In order to compare any two cumulative income distributions of discounted lifetime income assume $x_1 > x$. Then the different values of x will give rise to two cumulative distribution functions, $F(y_i^d(x_1))$ and $G(y_i^d(x))$ with unequal means.

[13]Other income variables one may want to use are (gross) current income y_{it}, detrended initial incomes y_{i0}, or capital adjusted incomes $\frac{y_{it}}{k_t}$. All of these concepts suffer from the problem that they do not fully reflect the path incomes follow.

If F dominates G in the sense of *Second Order Stochastic Dominance* (SOSD), then F will be preferred to G by any increasing, concave social welfare function according to Atkinson (1970).[14] Second Order Stochastic Dominance is equivalent to *Generalized Lorenz Curve* (GLC) dominance. (For a proof see, for example, Lambert (1993), pp. 62-66.) A GLC is obtained by multiplying the values of the y-axis of an ordinary Lorenz Curve, which relates the share of the population (x-axis) to the share in total income (y-axis) which that population share receives, by mean income, i.e. (share of total income) $\times$ (mean income).

Figure 1: Generalized Lorenz Curve



A GLC *dominates* another one if the two curves do not cross and one is completely above the other one. In the figure the income distribution associated with $x_1 > x$ GLC-dominates the income distribution for x, because an increase in x raises μ^d and shifts the kink at B to B' which is to the left and above GLC(x).

According to a theorem by Shorrocks (1983) every individualistic additively separable, symmetric, and inequality-averse social welfare function would prefer the GLC dominating income distribution. Hence, according to the GLC dominance criterion there exists a *unanimous* preference for the income distribution

[14]Formally and for non-negative incomes, *Second Order Stochastic Dominance* requires $\int_0^c F(y)dy \leq \int_0^c G(y)dy$. Geometrically, a distribution $F(y)$ dominates another distribution $G(y)$ in the sense of SOSD if over every interval $[0, c]$, the area under $F(y)$ is never greater (and sometimes smaller) than the corresponding area under $G(y)$.

with the higher GLC. Even the high-skilled would prefer the distribution with a higher x under a veil of ignorance.[15]

Let $I(x)$ be any inequality measure reflecting that a higher x leads to a GLC dominating income distribution. Then $I(0) = I(1) = 0 < I(x)$ and $\frac{dI}{dx} < 0$ for $x \in (0, 1)$. Thus, according to $I(x)$ and for the PV of lifetime gross incomes there is no measured inequality if all agents get the same wage and they are all either equally high or low-skilled. When there is any skill heterogeneity, producing more skills reduces inequality. Furthermore, as $x = \tau^{\epsilon}$, a decrease in ϵ for a given policy would lower $I(x)$.

Proposition 1 *If there is heterogeneity in skills, an increase in the percentage of high-skilled people or an increase in the productivity of the education technology for given policy reduce inequality in the present value of lifetime (gross) incomes in the sense of Generalized Lorenz Curve Dominance.*

Taking the Model to Data. In practice it is very difficult to calculate an agent's PV of lifetime gross income. Furthermore, it is usually difficult to find or to choose inequality measures satisfying certain desirable properties. One inequality measure that is frequently reported and employed in empirical research is the Gini coefficient, which measures the area between the Lorenz Curve and the 45^o degree line as a fraction of the total area under the 45^o degree line. A Gini coefficient of 0 (1) reports perfect equality (inequality).

In the model the Gini coefficient for the PV of lifetime gross income, but also

[15]Exactly the same holds for the distribution of detrended (initial) incomes y_{i0} and capital adjusted incomes $\frac{y_{it}}{k_t}$. It also holds if one works with current incomes y_{it} and $x \leq \hat{x}$. In that case an increase in x causes the new GLC to be everywhere above the old GLC for $t > 0$, because the capital stock would be higher at each date and mean income would rise. However, if $x > \hat{x}$ it does not necessarily hold.

for current and capital adjusted gross income is given by

$$G^g(x) = \frac{\alpha(1-x)x^\alpha}{1+x^\alpha} \tag{9}$$

and is not unambiguously decreasing in x, because for low (high) x an increase in human capital increases (decreases) G^g. See Appendix A.3. That raises three issues which merit comment for any empirical analysis.

First, equation (9) is derived under the assumption of equal capital ownership and income. In reality, the capital income component of the distribution of total personal gross incomes affects (often reduces) measured inequality. However, the model's Gini coefficient captures that empirically the main source of inequality stems from wage inequality. (See e.g. Atkinson (1998), p. 19).

Second, households may consist of people with different educational backgrounds. However, when household surveys are based on observations of individual units, the Gini coefficient would not change its informational content if there was a rearrangement of persons into high or low-skilled groups.

Third, ambiguity in Gini coefficients reflects the well-known fact that Lorenz curves often intersect so that clear rankings of income distributions with equal or unequal means would not be possible by simple Lorenz curve comparisons. See Atkinson (1970) and, in particular, Fields (1987) or Amiel and Cowell (1999), chpt. 6, who show that the Gini coefficient usually generates a Kuznets curve *by construction*, when incomes are rising. However, changes in income (e.g. real GDP per capita) is what growth is all about. Thus, measurement issues such as the choice of inequality measures are important and may not have received enough attention in the macroeconomics and growth literature.

For the model that raises an important point. Suppose the economies were identical except for their composition of human capital. Then countries with a higher x should have a higher mean and lower inequality in time-average incomes. Proposition 1 was derived from the general notion of GLC Dominance. If one employs a measure like the Gini coefficient, one may find that countries with a higher x show up higher measured inequality, although long-run income inequality in those countries may actually be lower than in other countries.

In the model growth is a complicated non-linear function of x. However, part of this non-linearity can be separated out as

$$\gamma(x, G^g(x)) = (1-\alpha)\left[\frac{\alpha(1-x)x^{\alpha}}{G^g}\right] - x^{\frac{1}{\epsilon}} - \rho. \tag{10}$$

This is a useful expression for linear operationalizations of the model.[16] A simple linear approximation $d\gamma = \frac{\partial\gamma}{dx}\, dx$ would require information on x only. However, given that the 'true' relationship is highly non-linear, one may use the additional information on the overall non-linearity contained in the non-linear part $G^g(x)$

$$d\gamma = \left(\frac{\partial\gamma}{\partial x}\right)_{|G^g} dx + \left(\frac{\partial\gamma}{\partial G^g}\right)_{|x}\left(\frac{\partial G^g}{\partial x}\right) dx.$$

It is not difficult to verify that $\left(\frac{\partial\gamma}{\partial x}\right)_{|G^g}$ first increases and then decreases in x. Notice the difference in interpretation of $\left(\frac{\partial\gamma}{\partial x}\right)_{|G^g}$ and $\left(\frac{\partial\gamma}{\partial x}\right)$. The former says that for *given* inequality growth would be a concave function of human capital. Furthermore, one verifies $\left(\frac{\partial\gamma}{\partial G^g}\right)_{|x} < 0$ which says that higher inequality reduces

[16]Other operationalizations may follow from $\gamma(x(\tau,\epsilon),\alpha,\rho)$. However, policies differ widely across countries and α, ϵ or ρ are difficult to measure so that x may be a good proxy for the underlying differences. As regards endogeneity Caselli et al. (1996) argue that at a more abstract level, "*... we wonder whether the very notion of exogenous variables is at all useful in a growth framework (the only exception is perhaps the morphological structure of a country's geography).*" However, there may be other exceptions one may think of such as differences in willful actions, social fabrics, languages, or historical incidents. In the logic of this model such differences lead to different policies (τ) and so human capital and growth.

growth for a *given* stock of human capital. Finally, it has already been shown that $\left(\frac{\partial G^g}{\partial x}\right)$ first increases and then decreases in x. Now $dG(x) = \left(\frac{\partial G^g}{\partial x}\right) dx$ so that $d\gamma = \left(\frac{\partial \gamma}{\partial x}\right)_{|G^g} dx + \left(\frac{\partial \gamma}{\partial G^g}\right)_{|x} dG^g(x)$. As part of the information of the non-linearity in $\gamma(x)$ is contained in G^g, it is useful to use data for that variable, because one would get a more informative linear approximation of $\gamma(x)$.

In general, one would *not* know whether the Data Generating Mechanism for G^g was driven by x or some other process. Thus, assuming inequality depends on x or not would be observationally equivalent. Of course, there is a difference in interpreting the coefficients in growth regressions. Suppose one finds a significantly negative coefficient on G^g. Then this is often taken as evidence that 'inequality *causes* low growth'. Of course, '*causes*' only really means '*correlates with*'. From the model the same coefficient on $G^g(x)$ would have to be interpreted as a '*spurious*' correlation between inequality and growth.

However, most people believe that education affects inequality and still they include G^g in growth regressions. Also, '*spurious*' does not necessarily mean unimportant. The coefficient on $G^g(x)$ would reveal valuable information on how x works through inequality on growth.

For these reasons 'spurious' correlations are analyzed and it is left an open question whether inequality as such has any independent 'causal' impact on growth. However, the present study also relates to work where G^g is assumed not to be explained by x. With that in mind growth regressions of the form $\gamma_i = \beta_0 + \beta_1 x_i + \beta_2 G^g(x_i) + \beta_3 \tilde{y}_0(x_i) + \sum_j^N R_{ji} + u_i$, are analyzed where G^g, x, and $\tilde{y}_0 \equiv \ln Y_0$ are taken to be the main regressors, R_{ji} denotes exogenous variables, included or not included in the regression, and u_i is a disturbance term.[17]

[17]For the linear operationalization of the model the latter would in general be a complicated, non-linear function of some underlying normally distributed error term, which one would have to know for hypothesis testing. However, here the focus is on the signs of point estimates and

3 Empirical Evidence

The theoretical model implies that countries with relatively more high-skilled people have higher initial income and less gross income inequality over time. Less income inequality is in turn predicted to be (spuriously) associated with higher long-run growth. These implications are checked by analyzing simple correlations and simple cross-country growth regressions.

In the paper human capital is measured by the percentage of the *labour force* from 25 to 64 years of age which have attained at least upper secondary education. Data for that variable are provided by the OECD for 1996 and 34 countries. It collapses the time series dimension into a single number by attaching weights to the human capital composition of different generations of all those who are economically active at a particular point in time and is taken to represent a long-run process which is approximated by its time-average over the sample period.[18]

Comparable data on income distributions for large samples of countries are rare and often do not satisfy minimum quality requirements.[19] Two valuable sources that are often used are the data set compiled by Deininger and Squire (1996) (henceforth, D/S 96) and the Luxembourg Income Study (LIS). Although D/S 96 is a secondary data set which covers more countries than LIS, it has many problematic features that are discussed in detail by Atkinson and Brandolini (1999). But in order to relate to research based on D/S 96 and since the focus here is on consistency, the Gini coefficients from both sources are used.

not on significance levels or other test statistics.

[18]See Table A1.1, p. 36. Notice the binary nature of the variable. Breaking it down by age cohorts reveals for the *population* as a whole that in almost all countries the percentage of the population that has attained at least upper secondary education has risen over time. (See Table A1.2a on p. 37.)

[19]For instance, D/S 96 require as (minimum) standards of quality that the data be based on (1) actual observation of individual units drawn from household surveys, (2) a representative sample covering all of the population, and (3) comprehensive coverage of different income sources as well as population groups.

In an intertemporal framework one should measure inequality in long-run incomes. That would require calculating some form of time-average of incomes. Gini coefficients of such averages for large samples of countries do not exist. As an approximation one may take averages of Gini coefficients over time and interpret that average as the Gini coefficient of an average of income distributions at different dates. Here averages of Gini coefficients for each country are taken for the period 1960-90 and are meant to reflect long-run within-country inequality.[20]

The income and recipient concept employed here is gross income per household and it is strictly adhered to. The strict adherence results in small samples. In contrast, Deininger and Squire (1998), Forbes (1998), Barro (2000) and others construct *unadjusted* inequality measures from D/S 96, that is, they construct 'average' Gini coefficients by taking averages of Gini coefficients based on gross or net income or adjusted (add 6 percentage points) Gini coefficients based on expenditure, each for individual or household income recipients, for each country and year according to some data quality criteria. That procedure may yield large samples, but a lot of important information is lost, making it very likely that their coefficients on inequality are biased upwards.[21]

Finally, long-run growth rates were calculated using the Penn World Table (Mark 5.6) from Summers and Heston (1991). All the other data are taken from Barro and Lee (1994). Together with the other sources this yields two small samples comprising of 21 countries based on D/S 96, resp. 13 countries based on LIS. Both samples consist of relatively rich countries.

[20] Deininger and Squire (1998) also run their regressions on an average of Gini coefficients for the whole sample period. For the justification, which is satisfied here as well, see p. 268 of their paper. Most researchers restrict attention to initial positions and regress growth on a measure of initial income inequality. Notice, however, that in contrast to neo-classical growth theory, the income distribution usually determines growth at each point in time in endogenous growth models. Thus, growth is not predicted to depend just on the initial income distribution.

[21] On the importance of income and recipient concepts in the measurement of inequality see, for instance, Lambert (1993), or Cowell (1995).

Simple summary statistics for the two samples are reported in Table 2. As one would expect the LIS sample, which consists of OECD countries only, features less variability than the sample based on D/S 96 which includes some important non-OECD countries. For example, in the D/S 96 sample the typical country has a time-average Gini value of 36.7 with a standard deviation (SD) of 7.9, has approximately 61 percent of the labour force who have at least upper secondary education (SD 22) and grows at 3.1 percent (SD 1.4). Thus, relatively there is not much variability in growth rates in that sample, but income inequality and the skill composition seem to differ widely across countries.

A difference of 1.1 percentage points in growth rates may, however, produce pronounced dynamic effects. If two economies started with the same initial income in 1960 and their growth rates differed by 1.1 percentage points, it would take the economy with the higher growth rate around 63 years to have twice the level of real GDP per capita of the other country.

For the period considered the intra-country variability in Gini values in both samples is low. For instance, the Gini coefficients reported in D/S 96 changed little in the United States and Germany (SD 1.42 and 0.76 percentage points, respectively) and seem to have changed most in France and Turkey (SD around 6 percentage points.) However, the D/S 96 Gini coefficients for the latter countries are problematic as they do not come from a consistent source.

One should bear in mind that small intra-country changes in Gini coefficients may reflect huge changes in welfare, that is, small variability in intra-country Gini coefficients may have drastic effects on some groups' income and overall welfare. However, the variability in inter-country, time-average Gini coefficients is far greater.

The simple correlations in Table 1 suggest the following interpretations: An increase in the percentage of workers with at least upper secondary or with tertiary education reduces growth across countries. (This effect is relatively small.) Countries with higher initial income have lower growth (relatively strong effect) and those with higher income inequality have higher growth (relatively weak effect). Economies operating with a more high-skilled labour force have less income inequality and higher initial income.

OECD countries appear to have lower long-run growth, operate their economies with a relatively higher skilled labour force and have higher initial income, and lower income inequality. Interestingly and in relative terms, countries granting citizens more civil rights seem to have *lower* growth, but have higher initial income, spend more on education, have a more qualified labour force, and lower income inequality. The OECD dummy shares all the features of CVLIB when interpreting more civil rights as being a member country of the OECD.

What is of interest here is that in the samples growth covaries *ambiguously* with measured income inequality and *negatively* with the human capital composition and the education finance variable. The latter property seems odd, as many studies find that human capital and more public resources for education affect long-run growth in a significantly positive way. See e.g. Barro (2000), Table 1. However, there are interesting exceptions. For example, Benhabib and Spiegel (1994), Caselli et al. (1996), or Forbes (1998) sometimes report negative coefficients for the effect of (male) education on growth.

This model suggests that in samples with relatively high x's one may be on the downward sloping side of a concave relation between (costly) education and growth. Furthermore, the positive association between AIHG and growth in the D/S 96 sample may be due to the problems associated with their data.

Table 1: Simple Correlations

Deininger and Squire (1996)

	G60-90	SECL	AIHG	LY60	TERL	OECD	GEDU	LAFERT	CVLIB
SECL	-0.366	1.000							
AIHG	0.146	-0.716	1.000						
LY60	-0.790	0.789	-0.640	1.000					
TERL	-0.117	0.644	-0.486	0.453	1.000				
OECD	-0.659	0.570	-0.632	0.832	0.307	1.000			
GEDU	-0.393	0.733	-0.507	0.639	0.493	0.459	1.000		
LAFERT	0.469	-0.805	0.866	-0.867	-0.477	-0.764	-0.577	1.000	
CVLIB	0.766	-0.701	0.631	-0.940	-0.365	-0.803	-0.676	0.799	1.000
EDUPR	0.332	-0.970	0.727	-0.784	-0.648	-0.583	-0.640	0.734	0.838

Luxembourg Income Study

	G60-90	SECL	LIS.ORG	LY60	TERL	OECD	GEDU	LAFERT	CVLIB
SECL	-0.347	1.000							
LIS.ORG	-0.274	-0.148	1.000						
LY60	-0.865	0.626	-0.094	1.000					
TERL	-0.208	0.266	-0.146	0.286	1.000				
GEDU	0.072	0.132	-0.371	0.064	0.531	0	1.000		
LAFERT	0.442	-0.651	0.601	-0.628	-0.029	0	-0.162	1.000	
CVLIB	0.487	-0.219	-0.324	-0.382	-0.425	0	-0.465	-0.073	1.000
EDUPR	0.365	-0.992	0.131	-0.643	-0.191	0	-0.026	0.669	0.158

Variable Definitions:

G60-90	Average growth rate of real GDP per capita for the period 1960-90
SECL	Percentage of the labour force from 25 to 65 years of age who have attained at least upper secondary education, 1996. (Source: OECD)
TERL	Percentage of the labour force from 25 to 65 years of age who have attained tertiary education, 1996. (Source: OECD)
AIHG	Average Gini coefficient for gross income of households for the period 1960-1990. (Source: Deininger/Squire)
LIS.ORG	Average Gini coefficient for gross income of households (adjusted for household size by the square root of the number of household members) for the period 1960-1990. (Source: Luxembourg Income Study)
LY60	Natural logarithm of the level of real GDP per capita in 1960.
GEDU	Government expenditure on education as a fraction of GDP for the period 1960-85.
LAFERT	Natural logarithm of the average fertility rate (children per woman) for the period 1960-84. (Source: Barro-Lee).
CVLIB	Gastil's index of civil liberties (from 1 to 7; 1 = most freedom).
OECD	Dummy for OECD countries.
EDUPR	Imputed productivity index of the education technology (from 0 to 1; 0 = most productive) for the period 1960-85.

An interesting feature of both samples is that fertility relatively strongly correlates negatively with SECL and positively with income inequality. That may suggest that countries where fertility is higher have less educated people and higher inequality. Of course, one may just as well take this as an indication that more education 'causes' lower fertility and less inequality.

Despite the fact that the required consistency for the inequality data yields small samples making statistical inferences very difficult, one might argue that simple correlations present a misleading picture of any 'true', cross-country relationship between long-run growth and other economic variables and that growth of GDP per capita is influenced by many different factors which should be controlled for.

For this reason the paper investigates simple growth regressions, but due to the few data points it concentrates on parsimonious models. Tables 3 to 6 indicate that, when controlling for upper secondary education, income inequality, initial income or fertility, tertiary education (TERL) and being a member country of the OECD would not significantly add to the 'explanation' of long-run growth. Therefore, the paper focuses on measured inequality, SECL, LY60 and LAFERT.

Initial GDP is always found to be negatively associated with growth, which would corroborate the hypothesis of conditional convergence according to which initially poorer economies tend to have higher subsequent growth. From the model initially poorer countries have less human capital, a prediction that appears to be borne out by the data. (The simple correlations between LY60 and SECL are relatively strong in both samples.) Thus, LY60 depends positively on SECL and this endogeneity is usually ignored in growth regressions.

Furthermore, it turns out that when controlling for various factors including initial income or fertility

1. an increase in the human capital of the labour force typically *raises* an average economy's rate of growth.[22]

2. more gross income inequality is *negatively* correlated with long-run growth in *all* regressions, that is, the point estimates measuring the association between income inequality and growth are negative, although usually only weakly so.

The linear models investigated appear to 'explain' growth rather well. As an indication notice the relatively high R^2s for most regressions which, as must be recalled, are based on rather small samples.

The second result is interesting because recent findings show that after controlling for many variables, including human capital and fertility, income inequality, measured by the Gini coefficients from DS/ 96, is negatively associated with subsequent growth in countries with low initial income, whereas the association is *positive* for high initial income countries. See, for instance, Barro (2000). As fertility is taken to be a robust control variable it is concluded that inequality is good for growth in rich countries.

In this paper both samples consist of relatively rich countries and adding fertility as a control variable does *not* change the *negative* sign of the point estimate on measured income inequality. Of course, fertility need not be viewed as exogenous. Indeed there may good reasons to believe that education is a determining factor of fertility. See e.g. Becker, Murphy and Tamura (1990) or Rosenzweig (1990) and notice the relatively strong negative correlation between fertility and SECL in Table 1.

[22]The few negative coefficients found on SECL can easily be attributed to an omitted variable bias. If one thinks inequality should play an in dependent role and any 'true' model should include LY60 as an explanatory variable and if the 'true' effect of initial income on growth is negative as most studies assume and show, then the estimated coefficient on SECL should be biased downwards.

Summarizing: Using data which are based on *consistent* measurement concepts it turns out that when controlling for factors such as initial income or fertility countries with a more skilled labour force or lower income inequality have higher long-run growth. This happens to be the case in *all* the regressions run. Thus, countries with lower inequality than the typical one *appear* to be doing better in terms of growth.

That raises the question why some economies have a more skilled labour force than others. One answer may be that they possess more productive education technologies or spend more on public education.

In this context the simple correlations in Table 1 provide some descriptively suggestive evidence: EDUPR proxies how productive public resources have been in generating more high-skilled people.[23] In both samples countries with relatively unproductive education technologies (higher EDUPR) also seem to be those that have higher income inequality. This appears to be especially true for the non-OECD countries in the D/S 96 sample. Furthermore, there is an indication that countries that spend more on education (higher GEDU) have lower income inequality.

4 Concluding Remarks

The experience of high growth economies suggests that there is a link from education to income equality and growth. The paper provides a supply-driven explanation of how that link may operate across countries.

In the model education directly affects income inequality and growth. Due to

[23]Clearly, not all resources channelled into education are targeted at secondary education. But given the binary nature of SECL, and given data for GEDU, EDUPR may be a reasonable approximation to measure the (long-run) productivity of the education technologies.

technology, market imperfections or institutional restrictions, high-skilled workers contribute more to effective labour in production than their unskilled counterpart and they receive a wage premium which depends on how many of them are present in the economy. The government provides public education which produces human capital in the form of high-skilled people. It is shown that the productivity of the education sector positively affects growth and income equality. Furthermore, the model implies that countries with a more high-skilled labour force should exhibit lower inequality.

Using data, which are based on *consistent* concepts for the measurement of inequality, it is found that, when controlling for various factors such as initial income or fertility, long-run growth is higher for countries that (a) had a relatively more high-skilled labour force or (b) had lower income inequality as measured by the (time-average) Gini-coefficient. The data also suggest that countries with a more productive, public education technology exhibit lower income inequality. Therefore, the paper does not find an indication that higher income inequality good for growth in rich countries.

Cross-country differences in education may be due to many things such as policy, history, labour market conditions, physical and human capital equipment used in schooling, laws, school financing (fees) etc. Furthermore, the differences may also reflect different demand conditions.

Untangling the precise demand-supply relationships between human capital, technology and institutions in the explanation of growth or inequality is interesting ongoing research and has been beyond the scope of this paper. These and other problems are left for future research.

A Technical Appendix

A.1 Technology

By assumption $Y_t = A_t H_t^{\alpha} K_t^{1-\alpha}$, where the index of effective labour H depends on labour requiring *basic skills* (B) and labour requiring *high skills* (S). *Labour* requiring basic skills is performed by high and low-skilled *persons*, $B = B(L_l, L_h)$, whereas high-skilled labour is only performed by high-skilled persons, $S = S(L_h)$. High and low-skilled people are perfect substitutes to each other when performing basic skill (routine) tasks, i.e. $B(L_l, L_h) = L_l + L_h$. Thus, high-skilled people also perform those routine tasks a low-skilled person may do.[24] On the other hand, only high-skilled people can perform high-skilled tasks (labour) and for simplicity let $S(L_h) = L_h$. To capture the relationship between labour inputs assume $H = [B^{\rho} + S^{\rho}]^{\frac{1}{\rho}} = \left[(L_h + L_l)^{\rho} + L_h^{\rho}\right]^{\frac{1}{\rho}}$. For $\rho < 1$ labour requiring basic skills (B) and labour requiring high skills (S) are imperfect (less than perfect) substitutes. For ease of calculations let $\rho = \alpha < 1$ which yields equation (1).

A.2 Discrete Time Justification for $x = \tau^{\epsilon}$

Equation (2) is compatible with many models that also use high-skilled labour as an input generating education. For instance, let h_t denote the *total* stock of human capital in the economy in a discrete time model. Assume that human capital evolves according to $h_{t+1} = f(G_t, K_t, h_t)\, h_t$ where new human capital h_{t+1} is produced by non-increasing returns. Here human capital formation would depend on the level of the stock of knowledge h_t, government resources provided for education G_t and the tax base K_t. The function $f(\cdot)$ governs the evolution of human capital. Assume that it is separable

[24] For instance, Lindbeck and Snower (1996) show that firms may organize production so that people perform one particular task (Tayloristic organization) or various tasks (holistic organization). In the model only high-skilled people are capable of performing several tasks and firms use a mixture of Tayloristic and holistic organization.

in the form $f(g(G_t, K_t), h_t)$. Let $g = c\left(\frac{G_t}{K_t}\right) = c(\tau)$ and for simplicity

$$h_{t+1} = c(\tau)\ h_t^{\beta}, \quad \text{where} \quad c \geq 0,\ c' > 0,\ c'' \leq 0,\ 0 < \beta < 1.$$

where β measures the productivity of the education sector and $c(\tau)$ captures the efficiency or quality of education, depending on the government resources channelled into education. For a similar expression see, for example, eqns. (1), (2) in Glomm and Ravikumar (1992).

In the model human capital is carried discretely so $h_t = x_t N$. Normalize population by setting $N = 1$. Then total human capital at date t is given by x_t. In steady state $\bar{x} = x_t = x_{t+1}$ and so $\bar{x} = c(\tau)^{\frac{1}{1-\beta}}$. Next suppose that the efficiency of the education sector is described by $c(\tau) = \tau^{\mu}$ where $0 < \mu < 0$. For non-increasing returns to scale it is necessary that $\mu + \beta \leq 1$. Let $\frac{\mu}{1-\beta} \equiv \epsilon$ then the more explicit set-up would be equivalent to (2) in steady state. As $\bar{x}_{\epsilon} < 0$, any increase ϵ would mean that less human capital is generated in steady state. From non-increasing returns to scale it follows that $\mu \leq 1 - \beta$ so that $\epsilon \leq 1$. Hence, $\epsilon = 1$ would represent a relatively unproductive human capital formation process.

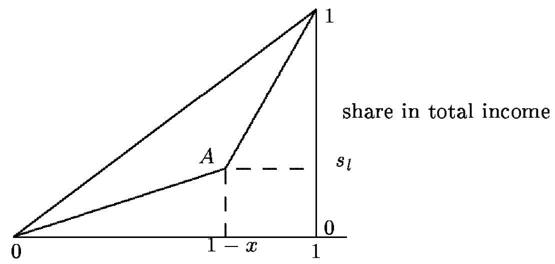
A.3 The Gini Coefficient

A Lorenz Curves (LC) relates population shares to income shares. In the model total gross income is μN. Furthermore, $L_l = xN$, $L_h = xN$ and mean income μ is increasing in x. The share of total gross income going to the low-skilled is $s_l \equiv \frac{w_l L_l + r k_t L_l}{\mu N}$ so that the Lorenz curve looks like Figure 2 below.

The LC has a kink at the point A at which $(1-x)$ percent of the population receive s_l percent of total income. From this one may calculate the Gini coefficient as

$$G = 1 - 2\left[\frac{(1-x)\,s_l}{2} + x s_l + \frac{(1-s_l)\,x}{2}\right] = 1 - (s_l + x)$$

Figure 2: Ordinary Lorenz Curve



where the expression in square brackets represents the area under the LC. Recall that $w_l = \alpha k_t$ and $w_h = \alpha k_t(1 + x^{\alpha-1})$ so that gross mean income is given by $\mu = (1 - x)w_l + xw_h + rk_t = (1 + x^{\alpha})k_t$. Then $s_l = \frac{\alpha(1-x)}{1+x^{\alpha}} + (1 - \alpha)(1 - x)$ so that

$$G^g = (1 - x) - (1 - \alpha)(1 - x) - \frac{\alpha(1 - x)}{1 + x^{\alpha}} = \frac{\alpha(1 - x)x^{\alpha}}{1 + x^{\alpha}} \tag{A1}$$

Then the effect of an increase in x on G^g depends on

$$\begin{aligned} sgn(G^g_x) &= \left[\alpha^2 x^{\alpha-1}(1 - x) - \alpha x^{\alpha}\right](1 + x^{\alpha}) - \alpha^2 x^{\alpha-1} x^{\alpha}(1 - x) \\ &= \alpha x^{\alpha-1}\left(\left[\alpha(1 - x) - x\right](1 + x^{\alpha}) - \alpha x^{\alpha}(1 - x)\right). \end{aligned}$$

For low x an increase in x raises G^g, whereas for higher values of x a higher x reduces it. Hence, the Gini coefficient does not produce unambiguous rankings of the (gross) income distribution.

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B Data Appendix

Data Sources

- Barro and Lee (1994). Web site: *www.nber.org/pub/barro.lee/ZIP/.*
- Summers and Heston (1991): Penn World Table (Mark 5.6). Web site: *www.nber.org/pwt56.html.*
- OECD Education Database. Web site: *www.oecd.org//els/edu/EAG98/list.html.*
- Deininger and Squire (1996). Web site: *www.worldbank.org/html/prdmg/grthweb/dddeisqu.html.*
- Luxembourg Income Study. Web site: *lissy.ceps.lu.*

Definition of variables[25]

G60-90	Average growth rate of real GDP per capita for the period 1960-1990 in percentage points, where G60-90 = $\frac{\ln y_T - \ln y_0}{T}$ and y_T denotes per capita GDP at final date T. (Source: Penn World Tables, Mark 5.6.)
SECL	Percentage of the labour force from 25 to 64 years of age who have attained at least upper secondary education, 1996. (Source: OECD)
TERL	Percentage of the labour force from 25 to 64 years of age who have attained tertiary education, 1996. (Source: OECD)
AIHG	Average Gini coefficient for gross income of households for the period 1960-1990 (Source: Deininger/Squire)
LIS.ORG	Average Gini coefficient for gross income of households (adjusted for household size by the square root of the number of household members) for the period 1960-1990. (Source: Luxembourg Income Study)
LY60	Natural logarithm of the level of real GDP per capita in 1960. (Source: Penn World Tables, Mark 5.6; Variable: RGDPL, i.e. real GDP per capita in 1985 international prices.)
AFERT	Average fertility rate (children per woman) for the period 1960-84. (Source: Barro-Lee).
GEDU	Government expenditure on education as a fraction of GDP for the period 1960-1985 in percentage points. (Source: Barro-Lee)
CVLIB	Gastil's index of civil liberties (from 1 to 7; 1 = most freedom) for the period 1972-1989. (Source: Barro-Lee)
OECD	Dummy for OECD countries.
EDUPR	Imputed productivity index of the education technology (from 0 to 1; 0 = most productive) for the period 1960-1985.

[25] A detailed description of the data and how the paper's results were obtained is provided at: *http://www.tu-darmstadt.de/~rehme/gaac99/data.html.*

Table 2: Country Sample

	LIS.ORG	AIHG	G60-90	SECL	TERL	LY60	GEDU	AFERT	CVLIB	EDUPR
Belgium*	na	28.3	2.9	63.3	13.7	8.6	5.4	2.1	1.0	0.157
Italy*	na	28.7	3.3	45.8	11.5	8.4	3.8	2.2	1.6	0.238
Finland*	26.0	29.9	3.3	71.4	13.5	8.6	5.8	2.0	1.9	0.118
Norway*	26.9	30.8	3.3	85.0	17.2	8.6	6.3	2.3	1.0	0.059
Canada	32.3	31.2	2.9	81.6	19.6	8.9	6.8	2.4	1.0	0.076
Germany	29.2	31.4	2.6	86.3	15.4	8.8	4.0	1.9	1.6	0.046
Netherlands*	29.5	32.2	2.5	70.5	27.0	8.7	7.0	2.3	1.0	0.131
Sweden*	27.0	32.4	2.2	76.8	14.5	8.9	7.1	2.0	1.0	0.100
Denmark	28.0	32.5	2.4	71.2	17.2	8.8	6.3	2.0	1.0	0.123
United Kingdom*	32.0	33.6	2.2	81.3	14.7	8.8	5.2	2.3	1.0	0.070
New Zealand	na	34.4	1.2	65.5	12.9	9.0	4.7	2.9	1.0	0.138
Korea	na	34.5	6.7	62.3	20.9	6.8	3.7	3.9	5.2	0.144
Spain	na	34.6	3.7	38.3	16.9	8.0	1.9	2.6	2.9	0.242
United States	36.1	35.5	2.0	89.1	28.5	9.2	5.9	2.2	1.0	0.041
Australia	34.3	37.9	2.1	62.8	17.3	9.0	4.7	2.6	1.0	0.152
Ireland*	37.0	38.9	3.4	57.0	13.7	8.1	5.1	3.6	1.2	0.188
France	30.4	42.1	2.9	66.1	11.1	8.7	4.4	2.5	1.9	0.133
Thailand	na	45.5	4.4	14.2	6.5	6.8	3.0	5.0	3.8	0.557
Turkey	na	50.4	2.8	22.2	9.1	7.4	3.5	5.0	3.9	0.450
Malaysia	na	50.8	4.3	38.5	9.4	7.3	4.7	5.2	4.1	0.312
Brazil	na	56.1	2.7	28.3	11.0	7.5	2.8	4.8	3.4	0.353
Switzerland	34.4	na	1.9	83.0	10.4	9.2	4.5	2.0	1.0	0.062
Mean D/S 96		36.7	3.1	60.8	15.3	8.3	4.9	2.9	2.0	0.182
Mean LIS	31.0		2.6	75.5	16.9	8.8	5.6	2.3	2.0	0.100
SD D/S 96		7.9	1.1	21.8	5.5	0.7	1.4	1.1	1.3	0.135
SD LIS	3.6		0.5	9.9	5.4	0.3	1.0	0.4	1.3	0.045

EDUPR denotes the productivity of the education technology. It represents imputed values of ϵ of equation (2) in the text and has been proxied by $\frac{\ln(SECL/100)}{\ln(GEDU/100)}$. The starred countries' data are based on 'cs' and the unstarred ones are based on 'accept' Gini coefficients from Deininger and Squire (1996).

Table 3: Growth Regressions based on D/S 96

	(1)	(2)	(3)	(4)	(5)	(6)
Const.	21.722 (2.136) [0.000]	21.864 (2.060) [0.000]	22.155 (1.688) [0.000]	17.810 (1.786) [0.000]	21.246 (2.012) [0.000]	5.993 (2.430) [0.024]
SECL	0.020 (0.010) [0.051]	0.021 (0.008) [0.019]	0.022 (0.007) [0.007]	0.035 (0.009) [0.008]		− 0.028 (0.016) [0.100]
AIHG	− 0.066 (0.019) [0.003]	− 0.067 (0.018) [0.002]	− 0.065 (0.016) [0.008]		− 0.087 (0.017) [0.000]	− 0.034 (0.044) [0.450]
LY60	− 2.100 (0.316) [0.000]	− 2.107 (0.307) [0.000]	− 2.168 (0.194) [0.000]	− 2.030 (0.261) [0.000]	− 1.800 (0.184) [0.000]	
TERL	0.010 (0.022) [0.655]					
OECD	− 0.109 (0.462) [0.817]	− 0.118 (0.450) [0.796]				
R^2	0.901	0.900	0.900	0.801	0.844	0.162
No. of obs.	21	21	21	21	21	21

The dependent variable is the average growth rate of real GDP per capita over the period 1960-90. The estimation method is OLS. Standard errors are shown in parentheses and t-probabilities are reported in square brackets.

Table 4: Growth Regressions based on D/S 96, fertility control

	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Const.	23.781 (2.965) [0.000]	24.075 (2.554) [0.000]	4.144 (2.021) [0.056]	25.535 (2.573) [0.000]	23.533 (3.090) [0.000]	1.308 (2.158) [0.552]	4.028 (0.997) [0.001]
SECL	0.019 (0.009) [0.061]	0.022 (0.007) [0.009]	− 0.001 (0.015) [0.947]	0.024 (0.007) [0.004]		0.002 (0.018) [0.923]	
AIHG	− 0.044 (0.028) [0.136]	− 0.046 (0.025) [0.092]	− 0.150 (0.049) [0.008]		− 0.063 (0.029) [0.049]		− 0.150 (0.048) [0.006]
LY60	− 2.331 (0.391) [0.000]	− 2.377 (0.285) [0.000]		− 2.629 (0.264) [0.000]	− 2.055 (0.320) [0.000]		
TERL	0.013 (0.022) [0.575]						
OECD	− 0.084 (0.463) [0.858]						
LAFERT	− 0.919 (0.919) [0.334]	− 0.865 (0.863) [0.331]	4.404 (1.320) [0.004]	− 2.065 (0.578) [0.002]	− 1.021 (1.045) [0.343]	1.607 (1.136) [0.174]	4.451 (1.087) [0.001]
R^2	0.908	0.905	0.493	0.886	0.852	0.220	0.493
Obs.	21	21	21	21	21	21	21

Table 5: Growth Regressions based on L I S

	(1)	(2)	(3)	(4)	(5)
Const.	19.059 (2.707) [0.000]	18.976 (2.538) [0.000]	18.875 (2.534) [0.000]	17.404 (2.448) [0.000]	5.643 (1.799) [0.011]
SECL	0.014 (0.010) [0.211]	0.015 (0.010) [0.170]	0.017 (0.009) [0.099]		− 0.021 (0.015) [0.189]
LIS.ORG	− 0.020 (0.022) [0.382]	− 0.020 (0.021) [0.367]		− 0.028 (0.021) [0.216]	− 0.048 (0.040) [0.264]
LY60	− 1.930 (0.364) [0.000]	− 1.920 (0.342) [0.000]	− 1.998 (0.330) [0.000]	− 1.588 (0.275) [0.000]	
TERL	0.003 (0.015) [0.821]				
R^2	0.830	0.829	0.811	0.786	0.228
Obs.	13	13	13	13	13

The dependent variable is the average growth rate of real GDP per capita over the period 1960-90. The estimation method is OLS. Standard errors are shown in parentheses and t-probabilities are reported in square brackets.

Table 6: Growth Regressions based on LIS, fertility control

	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Const.	14.707 (4.809) [0.018]	14.805 (4.297) [0.009]	2.588 (1.442) [0.106]	19.251 (3.378) [0.000]	15.611 (4.833) [0.010]	2.053 (2.211) [0.375]	3.960 (0.832) [0.001]
SECL	0.019 (0.011) [0.131]	0.019 (0.010) [0.098]	0.016 (0.014) [0.277]	0.016 (0.011) [0.170]		− 0.005 (0.020) [0.791]	
LIS.ORG	− 0.043 (0.042) [0.328]	− 0.058 (0.038) [0.225]	− 0.138 (0.036) [0.004]		− 0.043 (0.042) [0.328]		− 0.121 (0.033) [0.005]
LY60	− 1.463 (0.559) [0.035]	− 1.474 (0.502) [0.019]		− 2.024 (0.374) [0.000]	− 1.375 (0.564) [0.038]		
TERL	− 0.001 (0.015) [0.947]						
LAFERT	1.335 (1.225) [0.312]	1.312 (1.103) [0.269]	3.727 (0.998) [0.005]	− 0.113 (0.627) [0.861]	0.501 (1.147) [0.673]	1.151 (1.138) [0.335]	2.906 (0.713) [0.002]
R^2	0.854	0.854	0.697	0.812	0.790	0.202	0.652
Obs.	13	13	13	13	13	13	13

Table A1.1
Distribution of the population and of the labour force 25 to 64 years of age by level of educational attainment (1996)

	Population					Labour force				
	Below upper secondary education	Upper secondary education	Non-university tertiary education	University-level education	Total	Below upper secondary education	Upper secondary education	Non-university tertiary education	University-level education	Total
Australia	43	32	10	15	100	37	35	11	17	100
Austria	29	63	2	6	100	23	68	2	7	100
Belgium	47	30	13	11	100	37	33	16	14	100
Canada	24	29	31	17	100	18	29	33	20	100
Czech Republic	16	74	x	10	100	12	76	x	12	100
Denmark	34	44	7	15	100	29	47	8	17	100
Finland	33	46	9	12	100	29	48	10	14	100
France	40	41	9	10	100	34	44	11	11	100
Germany	19	60	9	13	100	14	61	10	15	100
Greece	56	25	7	12	100	50	26	9	15	100
Hungary	37	50	x	13	100	24	59	x	17	100
Ireland	50	28	12	11	100	43	29	14	14	100
Italy	62	30	x	8	100	54	34	x	11	100
Korea	39	42	x	19	100	38	41	x	21	100
Luxembourg	71	18	x	11	100	63	21	x	16	100
Netherlands	37	40	x	23	100	29	43	x	27	100
New Zealand	40	35	14	11	100	35	38	15	13	100
Norway	18	55	11	16	100	15	56	12	17	100
Poland	26	61	3	10	100	21	64	4	12	100
Portugal	80	9	3	7	100	76	11	4	9	100
Spain	70	13	5	13	100	62	15	6	17	100
Sweden	26	47	14	13	100	23	48	15	14	100
Switzerland	20	58	12	10	100	17	58	14	10	100
Turkey	83	11	x	6	100	78	13	x	9	100
United Kingdom	24	55	9	13	100	19	57	10	15	100
United States	14	52	8	26	100	11	52	9	28	100
Country mean	**40**	**40**	**10**	**13**	**100**	**34**	**43**	**11**	**15**	**100**
WEI Participants										
Argentina	73	18	4	5	100	69	20	5	6	100
Brazil	75	16	x	9	100	72	17	x	11	100
India	92	3	1	5	100	m	m	m	m	m
Indonesia	81	15	2	2	100	m	m	m	m	m
Malaysia	67	26	x	7	100	62	29	x	9	100
Paraguay	67	19	3	11	100	64	21	3	13	100
Thailand	87	3	5	6	100	86	3	5	7	100
Uruguay	73	12	4	10	100	69	14	4	12	100

Poland: Year of reference 1995.
Turkey: Year of reference 1997.
Source: OECD Education Database. See Annex 3 for notes.

Table A1.2a

Percentage of the population that has attained a specific level of education, by age group (1996)

	At least upper secondary education					At least university-level education				
	Age 25-64	Age 25-34	Age 35-44	Age 45-54	Age 55-64	Age 25-64	Age 25-34	Age 35-44	Age 45-54	Age 55-64
Australia	57	62	60	54	46	15	16	18	14	8
Austria	71	82	75	67	53	6	7	7	5	4
Belgium	53	70	58	47	31	11	14	11	10	6
Canada	76	85	81	73	56	17	20	18	17	11
Czech Republic	84	92	87	84	71	10	11	12	10	8
Denmark	66	74	70	65	50	15	16	17	16	11
Finland	67	83	76	60	40	12	13	13	12	7
France	60	74	64	56	38	10	12	10	10	5
Germany	81	86	85	81	71	13	13	16	14	9
Greece	44	66	52	36	22	12	16	14	11	6
Hungary	63	80	75	62	28	13	14	15	15	9
Ireland	50	66	54	38	30	11	14	11	9	6
Italy	38	52	46	31	17	8	8	11	8	5
Korea	61	88	63	41	25	19	30	18	11	7
Luxembourg	29	32	33	28	20	11	11	14	12	6
Netherlands	63	72	66	57	47	23	25	25	21	16
New Zealand	60	65	64	56	49	11	14	13	10	6
Norway	82	91	87	78	62	16	19	17	14	8
Poland	74	88	82	68	47	10	10	10	12	8
Portugal	20	32	24	15	9	7	11	9	6	4
Spain	30	50	34	20	11	13	19	15	10	6
Sweden	74	87	80	70	53	13	11	15	16	10
Switzerland	80	87	82	78	71	10	11	10	9	6
Turkey	17	23	19	14	7	6	7	7	7	3
United Kingdom	76	87	81	71	60	13	15	15	12	8
United States	86	87	88	86	77	26	26	26	28	20
Country mean	**60**	**72**	**65**	**55**	**42**	**13**	**15**	**14**	**12**	**8**
WEI Participants										
Argentina	27	36	29	21	15	5	5	6	4	3
Brazil	25	31	27	19	11	9	9	11	9	4
India	8	11	9	6	3	5	6	5	3	2
Indonesia	19	28	17	13	7	2	3	2	1	1
Malaysia	33	48	32	18	8	m	m	m	m	m
Paraguay	33	43	31	26	19	11	13	11	9	6
Thailand	13	19	14	7	4	6	9	7	3	1
Uruguay	27	36	30	22	14	10	14	12	8	5

Poland: Year of reference 1995.
Turkey: Year of reference 1997.
Source: OECD Education Database. See Annex 3 for notes.