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Educational systems, growth and income distribution: a quantitative study

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Abstract

This study sets out to develop a dynamic model within an economy characterized by the coexistence of public and private schools, under imperfect credit market conditions, in an attempt to provide a clearer understanding of the evolution of economic growth and income inequality. We find that any government wishing to reduce income inequality should adopt policies aimed at increasing the enrollment rate in public schools. However, whilst high enrollment rates can be sustained in private schools, and thus create enhanced economic growth, this can only occur if accompanied by the liberalization of the credit markets.

JEL classification: E17; I28; O11; O15
Keywords: Income distribution; Imperfect credit markets; Mixed educational system

1. Introduction

Despite human capital being widely regarded as an extremely important determinant of economic growth, rather surprisingly, few studies within the literature have attempted to examine the structure of the educational system within an economy.[1] This study develops a dynamic model within an economy characterized by the coexistence of public and

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[1] The structure of the educational system of an economy is referred to as the composition of schools.

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private schools, under imperfect credit market conditions, in an attempt to provide a clearer understanding of the evolution of economic growth and income inequality.

In order to effectively study the impacts of educational policies on economic performance, a requirement of our model of coexisting public and private schools, is that students are allowed to switch; therefore, a prerequisite of all the countries selected for inclusion in this study is that they must be providers of both public and private schools. Details of private school enrollments, as a proportion of total secondary school enrollments, for the year 1985, are presented in Table 1 in respect of a wide range of high income (OECD and non-OECD) countries.

Details of private school enrollments for middle and low income countries, as a proportion of total secondary school enrollments in 1985, are presented in Table 2.

The deregulation of the financial sector normally takes place alongside the growth of an economy, with financial development in turn boosting economic growth as a result of additional financial resources being directed towards the most appropriate uses. Although, in explaining the linkage between financial development and growth, most of the literature on economic growth tends to focus on the role of physical capital, we aim to explore the ways in which financial development and economic growth are linked to human capital; we also adopt a human capital perspective to examine the impacts of financial reforms on income inequality.

We construct an overlapping generations (OLG) model within which agents differ in both their innate abilities and in the human capital possessed by their parents, and begin by studying a mixed educational system under perfect credit market conditions and no borrowing constraints, with governments providing public schools and support for the private sector.[2]

A government can subsidize private schools in one of two ways, either by a direct subsidy to the private school, or by subsidizing those households choosing to attend private schools through the reimbursement of tuition fees; such support is normally provided through voucher programs. We adopt the latter policy, assuming that households must choose between public and private schools, and that only those attending private schools will be eligible for vouchers. We find that the structure of the educational system is an important determinant of growth and income inequality. Under a public education regime, everyone has the same investment in education, therefore, income inequality is lower under a public education regime than under a private education regime; hence, for an economy with a mixed educational system, income inequality decreases (increases) as the size of the public sector increases (decreases).

We then introduce imperfect credit market conditions into our model in order to analyze the effects of credit constraints on education decisions.[3] We first consider an extreme case which assumes that no agents can borrow, a situation which may occur if there is no enforcement of punitive measures for defaulting; we refer to these as exogenous borrowing constraints. For agents attending public schools, credit constraints will only affect their

[2] Public schools are referred to as the ‘public sector’, and private schools as the ‘private sector’; we use the enrollment rate in public and private schools to represent the size of each sector.

[3] Carneiro and Heckman (2002) demonstrated that the relationship between family income and college enrollment can be explained by either long-run family effects, or short-run credit constraints.

Table 1
Private school enrollment as a proportion of total enrollment in secondary schools, high income countries, 1985

High income countries (OECD)	Enrollment rate (%)	High income countries (non-OECD)	Enrollment rate (%)
Australia	28.7795	Bahamas	23.6270
Belgium	64.8770	Bahrain	12.2448
Canada	6.5367	Cyprus	13.0283
Denmark	13.7139	Kuwait	13.7560
France	21.6396	Malta	31.1517
Ireland	64.0131	New Caledonia	38.1210
Italy	6.3332	Qatar	10.8256
Japan	13.0121	Reunion	6.5349
Luxembourg	8.0870	Saudi Arabia	2.9765
Netherlands	72.0570	United Arab Emirates	15.3827
New Zealand	4.5214		
Norway	2.8910		
Spain	34.7616		
Switzerland	5.8584		
UK	8.4712		
US	9.9055		

Sources: Figures for UNESCO (except Ireland and US) are obtained from the United Nations; figures for Ireland are obtained from the OECD Education Database, OECD Organization; figures for the US are obtained from the Annual Digest of Education Statistics, US National Center for Education Statistics (1994).

consumption and saving decisions; however, for agents attending private schools, credit constraints will directly affect their investment in education. Our work in relation to private school attendance with market imperfections is closely related to that of Galor and Zeira (1993), who showed that in the presence of credit market imperfections, and the indivisibility of human capital investment, the initial distribution of wealth will affect aggregate output and investment both in the short run and the long run. Here, unlike Galor and Zeira (1993), borrowing constraints not only ration poor agents, but also able individuals.

Exogenous credit constraints are, nevertheless, misleading, since people with higher potential future income are more likely to repay their loans, whilst it should also be easier for them to borrow. Lochner and Monge (2003) studied the lifecycle behavior of consumption, labor supply and human capital accumulation in an economy where credit constraints arise endogenously. Following their methodology, we make the assumption that agents will lose a fraction of their income if they default. Given the punishment for defaulting, an endogenous credit constraint is derived as a fraction of an agent's future income.[4] Fewer agents are rationed under endogenous credit constraints than under exogenous credit constraints.

In this paper, we are able to quantify the effects of educational policies and financial development on growth and income inequality through our model simulation. By allowing an economy to be transformed from one with exogenous credit constraints to one with

[4] Following Kehoe and Levine (1993), we study the case where households demonstrate indifference between repaying loans and defaulting.

Table 2
Private school enrollment as a proportion of total enrollment in secondary schools, middle and low income countries, 1985

Countries	Enrollment rate (%)
Middle income countries	
Argentina	29.6455
Botswana	50.4196
Brazil	28.2206
Cameroon	48.6366
Chile	38.6269
Colombia	42.3454
Costa Rica	9.1270
Cote d'Ivoire	28.9022
Fiji	88.0545
Gabon	39.4087
Greece	3.3341
Indonesia	49.7396
Jamaica	3.9756
Korea	39.4899
Mauritius	77.9608
Mexico	11.8432
Morocco	6.3304
Nicaragua	19.7232
Oman	0.5475
Panama	13.6075
Paraguay	23.3301
Peru	14.6107
Philippines	41.0035
Portugal	8.5942
Singapore	27.7426
St. Kitts and Nevis	3.5740
St. Lucia	9.2002
St. Vincent and the Grenadines	54.2311
Sri Lanka	2.3572
Swaziland	37.2468
Syrian Arab Republic	6.1702
Thailand	11.7490
Tonga	86.4490
Tunisia	9.4745
Turkey	2.5032
Uruguay	14.6687
Venezuela	24.8595
Zimbabwe	66.9242
Low income countries	
Bangladesh	93.0340
Burkina Faso	48.4858
Burundi	13.2623
Haiti	84.2507
Mali	8.7706
Niger	10.7273
Senegal	29.4094

Table 2 (*continued*)

Countries	Enrollment rate (%)
Tanzania	49.0686
Zambia	6.3299

Sources: UNESCO, United Nations.

perfect market conditions, through a stage of endogenous credit constraints, we find that although loosening credit constraints does improve economic growth, it nevertheless raises income inequality. The reason for this is that rich or able agents will benefit from the liberalization of credit markets and will invest more in education. The fiscal policies used by the government to change the structure of the educational system are the tax rate and the amount of vouchers; therefore, if the government wishes to reduce income inequality it should adopt policies that will expand the public sector. However, rapid economic growth will take place if the enrollment rate in private schools is high and the credit markets are liberalized.

There are several examples of analysis of long-run economic performance under public or private education.[5] Eckstein and Zilcha (1994) adopted an OLG model to show that compulsory schooling can increase growth whilst also reducing inequality. In their analyses of policy impacts on growth, welfare and inequality, Kaganovich and Zilcha (1999) and Glomm and Kaganovich (2000) assumed that governments could allocate tax revenues towards public investment in education and social security benefits. Epple and Romano (1998), Snipes (1998) and Caucutt (2002) have also provided further studies of school choices with peer effects.

A dynamic model with a mixed educational system was presented by Cardak (in press) as a means of exploring the relationship between growth and income distribution; however, in contrast to Cardak (in press), in this study we include credit markets in the model which enables us to study the impacts of financial development on growth and inequality through the role played by human capital. A theoretical model without human capital was constructed by Greenwood and Jovanovic (1990) to show the linkage between financial development and growth, whilst the empirical studies of Demetriades and Hussein (1996) and Luintel and Khan (1999) both found that there was bi-directional causality between financial development and economic growth.[6]

Although the relationship between financial development and growth is well documented, the linkage between financial development and income inequality is not so clear. Nevertheless, the quantitative evaluation undertaken in this study actually demonstrates financial liberalization will raise inequality. Under a mixed educational system, when an economy experiences financial reform through a process of transition from imperfect credit market conditions with exogenous constraints to perfect market conditions, then Gini coefficient at the end of the first period[7] right after financial reform will increase by 15.96%.

[5] Examples include Glomm and Ravikumar (1992), Zhang (1996) and Glomm (1997).

[6] Demetriades and Hussein (1996) examined 16 countries; Luintel and Khan (1999) examined 10 countries.

[7] In our model, one period equals 30 years.

The remainder of this paper is organized as follows. Section 2 presents the model of a mixed educational system. In Section 3, in order to study the impact of the structure of the educational system on economic growth and income distribution, we simulate equilibrium, followed by provision of the calibration of the parameters. The results of the simulation and the analysis of the impact of voucher programs are presented in Section 4. In Section 5, we examine a mixed educational system with imperfect credit markets. Section 6 presents the empirical support for the influence of the educational system on growth and inequality, with the final section providing the conclusions drawn from this study.

2. The model

We adopt an infinite-horizon, discrete time OLG model within which agents live for two periods, each period covering approximately 30 years, corresponding to childhood (young agents) and adulthood (old agents). Each adult gives birth to a single child, there is no population growth, and we normalize the population size to one. We assume that agents live in a small open economy, and that over their whole lifecycle, will have the same utility function, defined as:

$$\ln(c_t) + \beta \ln(c_{t+1}) \tag{1}$$

where $\beta \in (0, 1)$ is the discount factor, and c_t, c_{t+1} represent the consumption of the young and the old, respectively, for the cohort born at time $t>0$.

Let w_t represent the real wage rate per unit of human capital, then adult earnings are equal to their human capital, h_t, multiplied by the real wage rate per unit of human capital ($w_t h_t$). We assume that in this society, there is a social norm that parents give a fixed fraction (η) of their income to their children as endowments[8] and consume the remainder. Young agents will differ from one another by their endowments (or parental human capital if w_t is constant) and innate abilities (z_t). Both endowment and innate ability are public knowledge.

2.1. The production of goods

Using average physical capital (K_t) and average human capital (H_t) as inputs, the aggregate domestic output in period t is produced by a standard neoclassical production function:

$$Q_t = AF(K_t, H_t)$$

where A is total factor productivity (TFP). Assuming that the production function has constant returns to scale, then:

$$Q_t = A^* H_t^* F(K_t/H_t) = A^* H_t^* f(k_t), \text{ where } k_t = K_t/H_t.$$

[8] We thank one referee for providing the story of social norm to simplify the model setting.

Standard assumptions for neoclassical production functions are applied:

$$f'(k_t)>0 \quad \text{and} \quad f''(k_t)<0.$$

2.2. Factor prices

Market clearing prices for factors of production in every period satisfy:

$$R_t = A\frac{\partial F}{\partial K} - \text{depreciation rate} = A\,f'(k_t) - \text{depreciation rate} \tag{2}$$

$$w_t = A\frac{\partial F}{\partial H} = A(f(k_t) - k_t f'(k_t)) \tag{3}$$

The average human capital in this economy is:

$$H_{t+1} = \iint h_{t+1}\Gamma_{h,z}\mathrm{d}h\mathrm{d}z \tag{4}$$

where $\Gamma_{h,z}$ is a joint distribution of human capital and innate ability. If we assume that for a small open economy, there is no depreciation of physical capital and the global interest rate is constant ($R_t=R\ \forall t$), then the equilibrium value k^* of physical capital per unit of human capital is determined by Eq. (2) and is constant. Eq. (3) implies that w_t is constant ($w_t=w\ \forall t$).[9]

2.3. Human capital accumulation function

Following the literature,[10] we assume that human capital is accumulated according to a Cobb–Douglas learning technology:

$$h_{t+1} = z_t q_t(j)^{\gamma} h_t^{\delta} H_t^{1-\gamma-\delta}, \quad \gamma, \delta, 1-\gamma-\delta \in (0,1) \tag{5}$$

where j indicates the choice of school. Human capital in the next period depends on innate ability (z_t), school quality (q_t), the human capital possessed by the parents (h_t), and the average human capital for society as a whole (H_t). The parameters γ, δ, $1-\gamma-\delta$ are the corresponding elasticity of q_t, h_t, and H_t to future human capital. We restrict all factors devoted to the accumulation of human capital to exhibit diminishing returns.

Following Epple and Romano (1998), we assume the time invariant distribution of learning ability (Γ_z) to be log-normal with mean μ_z and variance σ_z^2 and the initial distribution of human capital (Γ_{h1}) to be log-normal with mean μ_{h1} and variance σ_{h1}^2. However, we assume that parental human capital does not affect the realization of innate ability.[11]

$$z_t \sim LN\left(\mu_z, \sigma_z^2\right), \quad h_1 \sim LN\left(\mu_{h1}, \sigma_{h1}^2\right).$$

[9] This allows us to use the dynamic transition in human capital to study the pattern of economic development, whilst also simplifying the process of simulation. Assuming that interest rate is endogenously determined in a closed economy will not change the results.

[10] Uzawa (1965), Lucas (1988), Glomm and Ravikumar (1992) and Glomm (1997).

[11] Epple and Romano (1998) assumed that there was a positive correlation coefficient between household income and innate ability.

2.4. School choice (j)

Under a mixed educational system, young agents can choose between public and private schools. Since a school (j) is characterized by its quality, we therefore make the following 'assumptions of schools' (AS):

(AS1) Schools cannot reject any students.
(AS2) Both public and private schools earn zero profit.
(AS3) For any level of educational expenditure chosen by a young agent, there always exists a private school to accept the agent.
(AS4) A private school will charge the same tuition fees for all types of students.
(AS5) School quality is measured by its expenditure per student [$q_t(j)$].[12]

Since public schools are provided by the government, entrance to them is free and unrestricted. From assumptions (AS1) and (AS2), q_{ut} is the same for all public schools.[13] Although young agents choosing to attend private schools need to pay tuition fees, they can nevertheless choose the quality of the school. Assumption (AS4) demonstrates that there is no price discrimination amongst students within a school; therefore, private schools can be perfectly segregated by their tuition fees.[14]

2.5. Government expenditure

Adults are required to pay income tax. We assume that the income tax rate is constant ($\tau_t = \tau \ \forall t$) and that the government maintains a balanced budget. Where there are voucher programs, the tax revenue is used for public school expenditure and vouchers (V_t) for agents attending private schools. The budget constraint for the government is therefore:

$$\tau w H_t = p_t q_{ut} + (1 - p_t) V_t$$

where p_t is the enrollment rate in public schools.

2.5.1. The maximization problem for households

We assume that vouchers can be used only for education. Given the endowments from their parents ($\eta w h_t$) and the amounts of vouchers, young individuals in cohort t choose the amount they wish to spend on consumption (c_t), the amount they wish to save (s_t), and

[12] We use q_{ut} and q_{rt} to denote expenditure per student in period t, for public and private schools, respectively.

[13] If there are several public schools in the economy, households will choose to attend the public school with the best quality; thus, the quality of public schools will begin to converge, and will eventually become identical.

[14] Caucutt (2002) considered a model where schools could engage in price discrimination amongst students. The results showed that rich individuals with lower abilities will subsidize poor but able individuals.

which type of school they wish to attend. Let e_t represent the expenditure on education by a household in period t. The budget constraint for a young agent is:

$$c_t + e_t(j) + s_t = \eta w h_t + \min\{e_t(j), V_t(j)\}, \quad \text{where} \quad e_t(j) = \begin{cases} q_{rt} & \text{if } j = \text{private} \\ 0 & \text{if } j = \text{public} \end{cases} \tag{6}$$

In Eq. (6), the term $\min\{e_t(j), V_t(j)\}$ demonstrates that vouchers can be used only for education; under this assumption, individuals attending private schools will never choose a level of educational expenditure, e_t, which is less than the amount of the vouchers. For agents born in period t, their human capital in period t+1 becomes h_{t+1}. Hence, the total income that an adult can earn in period t+1 is wh_{t+1}. They pay τwh_{t+1} in income tax and leave ηwh_{t+1} for their children.[15] The budget constraint for an adult is therefore:

$$c_{t+1} = (1 - \tau - \eta) w h_{t+1} + R s_t. \tag{7}$$

2.6. Equilibrium in a small open economy

Given the initial distribution of human capital Γ_{h1}, school preference, human capital accumulation technology, endowments (η), vouchers (V_t), a constant tax rate (τ), and a constant interest rate (R), equilibrium comprises of average capital stock $\{H_t, K_t\}$, the distribution of human capital Γ_{ht}, and individual decisions $\{s_t, e_t(j), c_t, c_{t+1}\}$, such that:

(1) Given $\{w, R, \tau, \eta\}$, the household maximization problem will be solved by $\{s_t, e_t(j), c_t, c_{t+1}\}$, maximizing the utility function subject to Eqs. (5), (6) and (7);
(2) The factor price equations, Eqs. (2) and (3), hold;
(3) Eq. (4) holds and K_t=(k*)H_t;
(4) Given Γ_{ht}, the distribution of human capital at t+1, Γ_{ht+1}, is determined by h_{t+1}=$z_t q_t(j)^\gamma h_t^\delta H_t^{1-\gamma-\delta}$; and
(5) The government maintains a balanced budget.

2.6.1. The case without vouchers

We first consider the case when there are no vouchers, in which case, all tax revenue is used for public school expenditure.

2.7. Private school attendance

Where agents choose to attend private schools, the optimal choices for private school tuition fees and savings are:

$$q_{rt} = \left(\frac{(1 - \tau - \eta) w \gamma}{R} z_t h_t^\delta H_t^{1-\gamma-\delta} \right)^{\frac{1}{1-\gamma}} \tag{8}$$

$$s_t = \frac{1}{\gamma(1 + \beta)} [\beta \gamma \eta w h_t - (1 + \beta\gamma) q_{rt}] \tag{9}$$

[15] We assume that τ<1$-\eta$.

Eq. (8) shows that investment in education increases along with any increase in parental human capital or innate abilities. By substituting q_{rt} within the human capital accumulation function of Eq. (8), the law of motion of human capital is:

$$h_{t+1} = \left[z_t \left(\frac{(1-\tau-\eta)w\gamma}{R} \right)^{\gamma} h_t^{\delta} H_t^{1-\gamma-\delta} \right]^{\frac{1}{1-\gamma}} \tag{10}$$

Eq. (10) represents the law of motion of human capital under a private education regime, and demonstrates that the human capital accumulation function is an increasing function of innate ability and parental human capital, all other things being held constant.

Let us now define g_{t+1} as the growth rate of average human capital from period t to period t+1 (g_{t+1}=H_{t+1}/H_t); with $\bar{z}$ representing the average learning ability, and b_t=h_t/H_t being the relative human capital. Following de la Croix and Doepke (2003), a balanced growth path is described by b_t=1, z_t^i=$\bar{z}$ $\forall t$ (i.e. the difference between agents vanishes).

Proposition 1. Under a private education regime without vouchers, a balanced growth path (b_t=1, z_t=$\bar{z}$ $\forall t$) will exist, with a constant growth rate (g^*), g^* being equal to $[\bar{z}((1-\eta)w\gamma/R)^{\gamma}]^{1/(1-\gamma)}$.

Proof. See Appendix A. □

2.8. Public school attendance

We assume that the government maintains a balanced budget; hence, with no voucher programs, the expenditure per student in public schools will be equal to the total tax revenue:

$$q_{ut} = \tau w H_t / p_t$$

An agent attending a public school will accumulate human capital in accordance with:

$$h_{t+1} = z_t q_{ut}^{\gamma} h_t^{\delta} H_t^{1-\gamma-\delta} \tag{11}$$

The optimal choices of savings and consumption for households are:

$$s_t = \frac{1}{(1+\beta)R} \left[\beta R \eta w h_t - (1-\tau-\eta) w h_{t+1} \right] \tag{12}$$

$$c_t = \eta w h_t - s_t \tag{13}$$

Note that under a public education regime (p_t=1), the law of motion of human capital is:

$$h_{t+1} = z_t (\tau w)^{\gamma} h_t^{\delta} H_t^{1-\delta} \tag{14}$$

Proposition 2. Under a public education regime, a balanced growth path (b_t=1, z_t=$\bar{z}$ $\forall t$) will exist, with a constant growth rate (g^*), g^* being equal to $\bar{z}(\tau w)^{\gamma}$.

Proof. See Appendix A. □

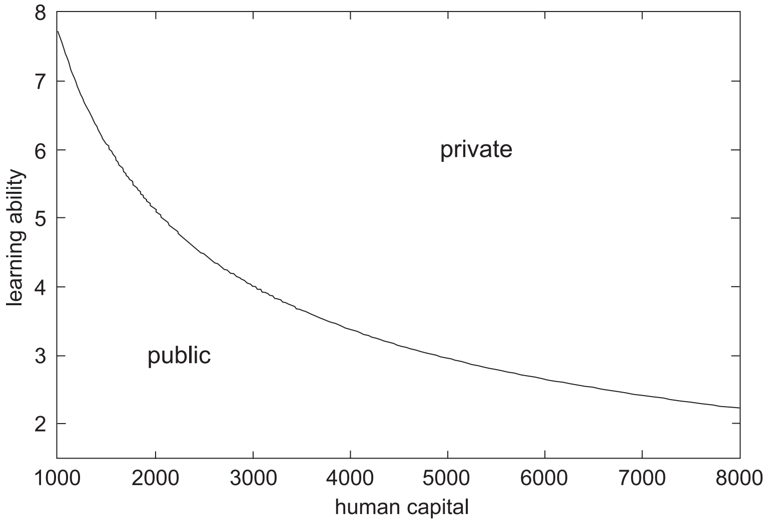

Fig. 1. Regions of choice between public and private schools.

When public and private regimes coexist, agents need to make their school choice based on lifetime utility. Proposition 3 demonstrates which type of agents will choose public/private schools.

Proposition 3. Given τ and H_t, parental human capital for those young agents who are indifferent between attending public or private schools will be a decreasing function of innate ability. Moreover, given innate ability, the lowest parental human capital for private school attendees will be higher than the highest parental human capital for public school attendees.

Proof. See Appendix B. □

Based on the parameter values calibrated in the next section, Fig. 1 shows which type of agents will choose public or private schools. As can be seen from the figure, rich or able young agents will choose private schools because their desired educational investment is higher, whilst poor agents, or those with lower abilities, will choose public schools.

Given that only those whose desired educational spending is higher than public education spending will choose to attend private schools,[16] the quality of a private school (measured by its expenditure on tuition) will always be higher than the quality of a public school.

Fig. 2 presents the histogram of educational expenditure under a mixed educational system, under the assumption that there are 10,000 agents living within the economy. Of these agents, 88.9% will choose to attend public schools, which demonstrates, as noted earlier, that expenditure on tuition is higher in private schools than the comparable

[16] According to Eq. (8), young agents with high parental human capital, or high innate abilities, or both, will desire greater investment in education.

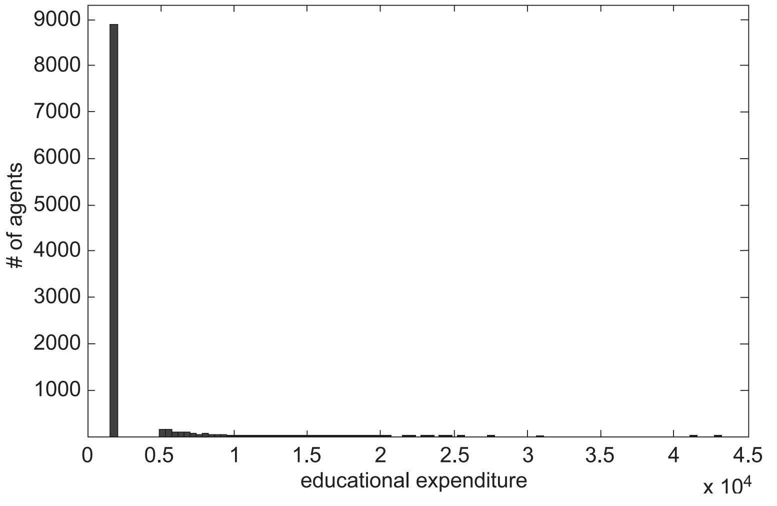

Fig. 2. Histogram of educational expenditure under a mixed educational system.

spending in public schools. Agents choosing to attend private schools will therefore accumulate their human capital in accordance with Eq. (10), whereas those attending public schools will accumulate their human capital in accordance with Eq. (11).

3. Simulations

Having constructed the model, our intention is to study its implications for growth and inequality. One way of determining this is by simulating equilibrium, which will allow us to quantify the impacts of educational policies on growth and income inequality through the accumulation of human capital. Prior to undertaking the simulation, we calibrate the parameter values using 1980 data on the US.[17]

We first calibrate the values of the human capital accumulation function parameters. Parameters γ and δ are the respective income elasticities for education expenditure and parental income. The results of the empirical study by Johnson and Stafford (1973) showed that income elasticity for education expenditure was 0.198, whilst the figure used by Fernandez and Rogerson (1997), based on the estimates of Card and Krueger (1992), was 0.2. Since the figures provided by these studies are virtually identical, we also set γ as being equal to 0.2.

Leibowitz (1974) demonstrated the decreasing impact of parental earnings over the life cycle, and found that they had a significant effect on children's earnings when the respondents had a mean age of 39. The corresponding elasticity of children's earnings with

[17] Although the US is not a small open economy, we chose to calibrate the model to US data based on convenience, the availability of data and the availability of prior empirical works. Our sensitivity examinations show that the simulation results are robust to parameter values.

respect to parental earnings is 0.655; hence, we set δ as being equal to 0.6 and the income elasticity of aggregate human capital $(1-\gamma-\delta)$ is therefore 0.2.

For ease of analysis, we consider a small open economy and assume that a period consists of 30 years; the discount factor is $\beta=(0.99)^{30}$. As discussed earlier, the real wage rate per unit of human capital is constant if the real global interest rate is constant over time. We assume that the real interest rate is 3.5% per year; thus, $R=(1.035)^{30}=2.8068$. We use the Cobb–Douglas production function and assume that the capital share in the final good sector is equal to 1/3. TFP for 1980 is 9.062,[18] and the factor price equation of the real interest rate implies that the equilibrium physical capital to human capital ratio (k^*) is 1.1164. According to Eq. (3), the real wage rate per unit of human capital is therefore 6.2672.

The two distributions which must be calibrated are the log-normal distributions of innate ability and initial human capital. We calibrate μ_{h1} and σ_{h1} under the baseline model for 1980 to match the median of US household income (\$17,710) and the Gini coefficient (35.2%).[19] Due to the structure of the model, household income is wh_t, which determines the median of human capital as being equal to \$2,825.80. Since we assume that the initial human capital stock is log-normally distributed, the median of human capital is $\exp(\mu_{h1})$. Accordingly, μ_{h1} is set at 7.9466, and σ_{h1} is set at 0.644.

We use the model, under a public education regime, to calibrate the distribution of innate ability for the baseline model. The average annual growth rate of per capita output for the US, from 1960 to 1998, is approximately 2%. Choosing a mean of innate ability equal to 2.1546 demonstrates that, along the balanced growth path in a public education regime, the growth rate of income is approximately equal to $(1.02)^{30}$. We calibrate the variance of $\log(z)$ so that under the baseline model, the Gini coefficient is roughly constant over the 10 periods.

Laitner and Ohlsson (2001) used US data from the Panel Study of Income Dynamics (PSID) to show that, conditional on positive inheritance being received by the respondents, the mean inherited amount was equal to 6.49% of the respondents' lifetime earnings.[20] With the annual growth rate being equal to 2%, η is assigned a value of 11.76%.[21] Note that using these calibrated parameter values, the annual growth rate along the balanced growth path, under a private education regime with a zero tax rate, is 2.45%, which is higher than the annual growth rate along the balanced growth path under a public education regime.

The ratio of public spending on education to gross domestic product (GDP) in 1980 was 6.7%.[22] Accordingly, we set the tax rate (τ) equal to 6.7%, which induces an 88.9% enrollment rate in public schools under a mixed educational system.[23] We use as

[18] See: Williamson (2002), Table 8.2.

[19] The median of US household income, at \$17,710, is obtained from the US Census Bureau, whilst the Gini coefficient of 35.2% is taken from Deininger and Squire (1996).

[20] Although Laitner and Ohlsson (2001) used the PSID survey for 1984, whilst our calibration is based on US data for 1980, using their empirical results causes no real problems providing there are no major changes in household bequest behavior.

[21] Because $\eta wH_t/wH_{t+1}=\eta(H_t/H_{t+1}=0.0649$, we can solve $\eta=11.76\%$.

[22] Source: UNESCO, United Nations.

[23] Since the public school enrollment rate in the US is around 88% in 1980, it is clear that our simulation results are very close to the US data.

Table 3
Comparison of public and private education regimes

Variables	Public education regime		Private education regime	
	Z_t homogeneous	Z_t heterogeneous	Z_t homogeneous	Z_t heterogeneous
Average growth rate 1–2 (%)[a]	1.829	1.850	2.318	2.488
Gini coefficient 1 (%)[b]	21.534	35.339	26.746	43.325
Average growth rate 1–10 (%)[c]	1.970	1.840	2.418	2.346
Gini coefficient 1–10 (%)[d]	8.877	35.229	13.507	47.727

[a] Average annual growth rate between the first and second periods.
[b] Gini coefficient at the end of the first period.
[c] Average annual growth rate over 10 periods.
[d] Average Gini coefficient over 10 periods.

our baseline model a mixed educational system with perfect credit markets and no vouchers.

4. Results

We begin by studying the pattern of growth and inequality under public and private education regimes. Table 3 presents the statistics on growth and income inequality (measured by the Gini coefficient) in the first period, along with the average over 10

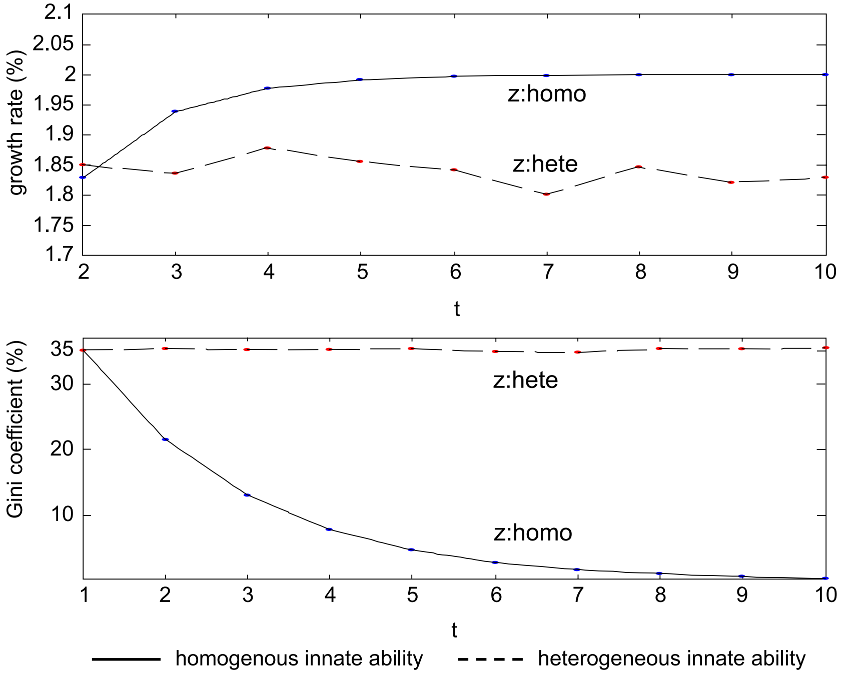

Fig. 3. Homogeneous and heterogeneous innate abilities under public education.

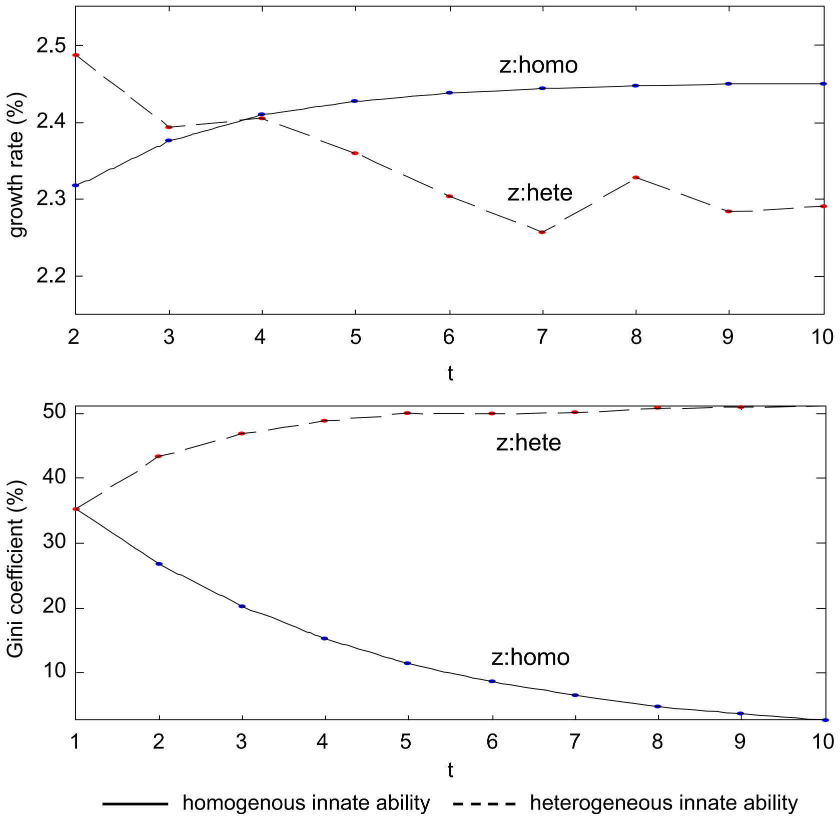

Fig. 4. Homogeneous and heterogeneous innate abilities under private education.

periods. During each period, the annual growth rate can be interpreted as the average growth rate over 30 years, with the Gini coefficient measuring income inequality at the end of the 13th year.

Fig. 3 shows transitions in the annual growth rate and the Gini coefficient over the 10 periods with homogeneous and heterogeneous innate abilities under a public education regime.

Fig. 4 shows transitions in the annual growth rate and the Gini coefficient over the 10 periods with homogeneous and heterogeneous innate abilities under a private education regime.

With homogeneous innate ability, in both education regimes the growth rates converge to the growth rate along the balanced paths [24] and the Gini coefficients converge to zero; the reason for this is that with homogeneous innate ability, income inequality decreases over time since the growth of human capital is a decreasing function of human capital, i.e., agents with high (low) human capital will accumulate their human capital much more

[24] That is, the growth rate converges to 2% under a public education regime, and to 2.45% under a private education regime.

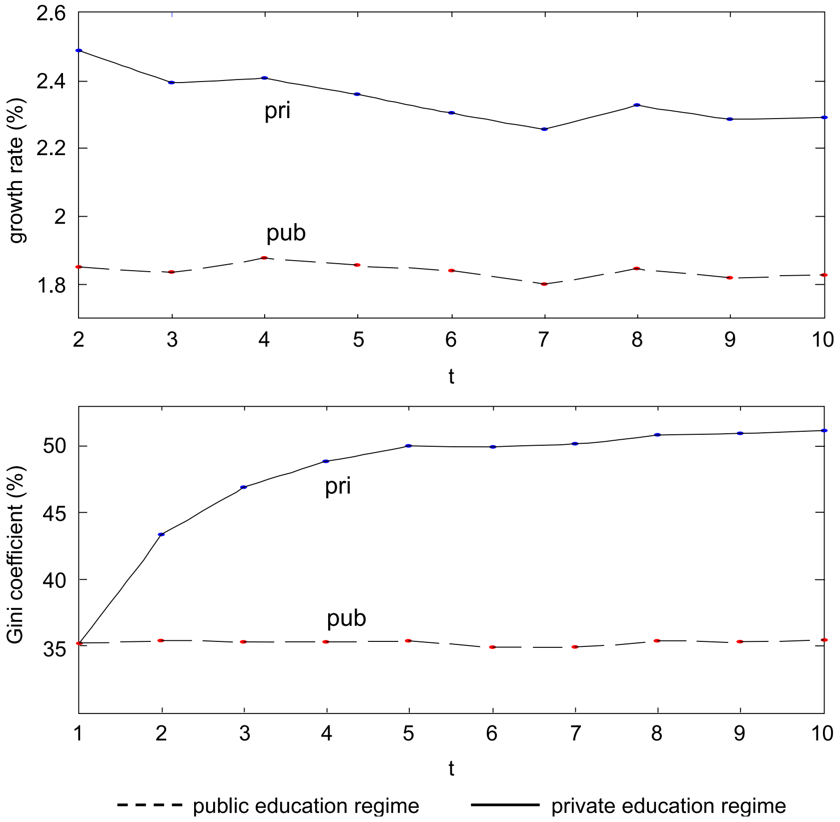

Fig. 5. Transitions in growth and Gini coefficients under public or private education.

slowly (quickly). Over the 10 periods, under both education regimes the average growth rate is higher and the average Gini coefficient is lower when innate ability is homogeneous, than when it is heterogeneous.

Fig. 5 compares the growth rate and income inequality under public education and private education with heterogeneous innate ability. Based on our calibration, the growth rate under a private education regime is higher than that under a public education regime over the 10 periods. Under a public education regime, although poor agents can benefit from such education, some agents who would prefer to invest more in education are now forced to accept public education. However, Eq. (14) shows that the growth rate under a public education regime is crucially dependent on the tax rate. If the tax rate is sufficiently high, the growth rate under a public education regime will be higher than that under a private education regime. Under a public education regime, income inequality is lower because everyone is forced to invest the same amount in education.[25]

[25] From Eq. (10), we can derive $\sigma^2_{h_{t+1}}$,pri equals $1/1-\gamma(\sigma_z^2+\delta^2\sigma_{h_t}^2)$ under a private education regime. From Eq. (14), we can derive $\sigma^2_{h_{t+1}}$,pub equals $\sigma_z^2+\delta^2\sigma_{h_t}^2$ under a public education regime. It is easy to check that $\sigma^2_{h_{t+1}}$,pri>$\sigma^2_{h_{t+1}}$,pub because $\gamma\in(0,1)$.

Table 4
The impacts of tax rates under a mixed educational system

Variables	Mixed educational system		
	τ=6.7%	τ=8%	τ=10%
Ratio of educational expenditure to GDP (%)	10.739	11.141	12.151
Ratio of savings to GDP (%)	−29.596	−28.802	−27.935
Enrollment in public Schools (%)	88.900	92.250	95.390
Utility[a]	15.855	15.867	15.881
Average growth rate (%)[b]	2.284	2.295	2.334
Gini coefficient (%)[c]	40.978	39.859	38.494

[a] Lifetime utility of agents born in the first period.
[b] Average annual growth rate between the first and second periods.
[c] Gini coefficient at the end of the first period.

Tables 4–7 present the simulation results at the end of the first period; Tables 4, 6 and 7 provide details of the impacts of policies, whilst Table 5 presents the effects of initial income inequality. Since we are comparing different policies and initial income inequalities, the rankings of all statistics in the tables over the 10 periods are the same as the rankings in the first period; therefore, we present only the simulation results for the first period in these tables.

Table 4 shows the impacts of tax rates under a mixed educational system, with the second column (τ=6.7%) representing our baseline model.

The statistics presented here are the ratio of educational investment to GDP, the ratio of young agents' savings to GDP, public school enrollment rate, the lifetime utility (welfare) for young agents, growth rate and Gini coefficient. As τ increases, there will be a corresponding increase in the rate of enrollment in public schools and the ratio of educational investment to GDP, due to an increase in public school spending per student.[26] This will in turn lead to a continuing increase in the growth rate, as well as the lifetime utility of young agents, whilst there will also be a corresponding reduction in the Gini coefficient because more individuals attend public schools and therefore have the same amount of investment in education.

Table 5 shows the effects of three different measures of initial income inequality: Gini=30%; Gini=35.18% (the baseline model); and Gini=40%; the table also shows that income inequality will be transmitted from one generation to another. A higher level of initial income inequality will result in higher income inequality at the end of the period. An increase in income inequality reduces the growth rate and public school enrollment rate, whilst also increasing the ratio of educational investment to GDP.

4.1. Voucher programs

In addition to providing public education, the government can also subsidize private education by providing tuition reimbursements (vouchers) to those households choosing to

[26] James (1993) observed a higher proportion of private enrollments in developing countries than in developed countries, because the limited spending on public education in the developing countries had the effect of pushing people to attend private schools.

Table 5
The impacts of the inequality of initial income distribution

Variables	Mixed educational system		
	Gini=30%[a]	Gini=35.18%[a]	Gini=40%[a]
Ratio of educational expenditure to GDP (%)	10.568	10.739	10.927
Ratio of savings to GDP (%)	−29.739	−29.596	−29.433
Enrollment in public schools (%)	89.030	88.900	88.720
Utility[b]	15.818	15.855	15.896
Average growth rate (%)[c]	2.306	2.284	2.258
Gini coefficient (%)[d]	39.015	40.978	43.045

[a] Gini coefficient at the start of the first period.
[b] Lifetime utility of agents born in the first period.
[c] Average annual growth rate between the first and second periods.
[d] Coefficient at the end of the first period.

attend private schools. We assume that vouchers can be used only for education; hence, the minimum that those individuals choosing to attend private schools will invest in education will be the value of the vouchers they receive. West (1997) found that most voucher programs around the world represented only a fraction of the total expenditure in public schools; hence, we assume that the tuition vouchers are a fraction (v) of the total expenditure on public education. We refer to v as the scale of vouchers, and examine the scale of vouchers at levels equal to 0.0%, 30%, 60%, and 90%; where 0.0% of the scale indicates the model of a mixed educational system with no vouchers.

The simulation results for the case with voucher programs in the first period are provided in Table 6. 'In receipt of vouchers' represents the number of young agents receiving vouchers as a proportion of the total young population, with the first column representing our baseline model.[27] As the scale of vouchers increases, the public school enrollment rate falls. The Gini coefficient and the ratio of educational investment to GDP will increase, and since the government maintains a balanced budget, an increase in the scale of vouchers will mean a reduction in public school spending per student. For those agents switching from public schools to private schools, there may well be an increase in the accumulation of human capital; however, those staying in public schools will accumulate less human capital. Hence, an increase in v could either raise or lower both the growth rate and utility.

Our simulation results show that there will be an increase in the growth rate along with an increase in v; however, its impact on the utility of young agents is unclear. Therefore, the implementation of voucher programs may not necessarily lead to the enhancement of welfare for young individuals.

Tables 4 and 6 demonstrate that under a mixed educational system with different policies for τ and v, both the growth rate and Gini coefficient lie between those under public and private education regimes. These tables also show that fiscal policies will affect

[27] Since we assume that anyone attending a private school can receive vouchers, the statistics for 'in receipt of vouchers' also represents the rate of enrollment in private schools. Hence, 'in receipt of vouchers (%)'=1−'enrollment in public schools (%)'.

Table 6
Simulation results with voucher programs

Variables	Mixed educational system			
	v=0	v=20%	v=60%	v=90%
Ratio of educational expenditure to GDP (%)	10.739	11.067	11.843	12.614
Enrollment in public schools (%)	88.900	86.490	78.100	60.980
In receipt of vouchers (%)[a]	–	13.510	21.900	39.020
Utility[b]	15.855	15.856	15.858	15.857
Average growth rate (%)[c]	2.284	2.313	2.379	2.440
Gini coefficient (%)[d]	40.978	41.296	41.908	42.125

[a] Refers to the those receiving vouchers as a proportion of the total young population.
[b] Lifetime utility of agents born in the first period.
[c] Average annual growth rate between the first and second periods.
[d] Gini coefficient at the end of the first period.

the choice of schools by young agents, and that the structure of the educational system will in turn affect economic growth and inequality.

5. Imperfect credit markets

The introduction of imperfect credit markets into our model allows us to study the impacts of financial development on growth and inequality. In order to simplify our analysis, we assume that there are no vouchers, and that imperfect credit market conditions will arise if future potential income (human capital) is not regarded as reliable collateral. When credit markets are imperfect, there are two types of young agents, those who are credit-constrained and those who are not. For 'unconstrained' young agents, school choice decisions, expenditure on education, savings and consumption will all be the same as those under perfect market conditions; however, other young agents may be subject to borrowing constraints. If such 'constrained' young agents choose to attend public schools, the borrowing constraints will only affect their savings and consumption decisions; however, those choosing to attend private school who find themselves credit-constrained, will also find their investment in education being affected by borrowing constraints, and as a result, they may make insufficient investment in education.

We therefore need to analyze the educational decisions for those credit-constrained individuals choosing to attend private schools, and in this study, we consider two types of credit constraints, exogenous credit constraints (which refer to zero borrowing) and endogenous credit constraints (which refer to the upper limit of borrowing being a fraction of future income).

5.1. Exogenous credit constraints

With no penalty for defaulting, the optimal position for borrowers is not to pay back their loans, thus, savings for young agents are restricted to being non-negative ($s_t \geq 0$) because no one will be willing to lend; we therefore refer to zero borrowing as the

Table 7
Financial regulations

Variables	Public Education			Private Education			Public and Private Education				
	Exogenous BC	Endogenous BC	Perfect market	Exogenous BC	Endogenous BC	Perfect market	Exogenous BC	Endogenous BC			Perfect market
								ϕ' =8.89%	ϕ' =10.69%	ϕ' =16.03%	
Enrollment in public schools (%)	–	–	–	–	–	–	100.000	97.190	93.230	89.550	88.900
Credit-constrained agents (%)[a]	99.800	96.070	0.000	99.830	98.780	–	99.800	97.070	76.490	20.070	–
Ratio of education expenditure to GDP (%)	6.700	6.700	6.700	1.515	6.368	13.142	6.700	7.437	8.676	10.164	10.739
Ratio of savings to GDP (%)	0.005	−15.328	−23.945	0.003	−16.009	−38.360	0.005	−15.956	−23.334	−27.965	−29.596
Utility[b]	15.133	15.739	15.809	14.803	15.496	15.721	15.133	15.748	15.825	15.852	15.855
Average growth rate (%)[c]	1.851	1.851	1.851	0.904	1.985	2.488	1.851	1.978	2.118	2.244	2.284
Gini coefficient (%)[d]	35.339	35.339	35.339	39.607	42.268	43.325	35.339	37.302	39.088	40.493	40.978

[a] Proportion of credit-constrained young agents to the total young population.
[b] Lifetime utility of agents born in the first period.
[c] Average annual growth rate between the first and second periods.
[d] Coefficient at the end of the first period.

exogenous credit constraint.[28] Using Eqs. (8) and (9), we can determine which type of agents attending private schools will be credit-constrained. For a given z_t, savings are non-negative if:

$$h_t \geq \left[\left(\frac{1+\beta\gamma}{\beta\eta} \right)^{1-\gamma} \frac{(1-\tau-\eta)(w\gamma)^{\gamma}}{R} z_t \right]^{\frac{1}{1-\gamma-\delta}} H_t \tag{15}$$

Eq. (15) indicates that in order to achieve a certain learning ability, poor agents will wish to borrow. Hence, the exogenous credit constraint will be binding on poor young agents, i.e., those with low inherited parental human capital stock.

Given h_t, savings are non-negative under a perfect market if:

$$z_t \leq \frac{R}{(1-\tau-\eta)(w\gamma)^{\gamma}} \left(\frac{\beta\eta}{1+\beta\gamma} \right)^{1-\gamma} \left(\frac{h_t}{H_t} \right)^{1-\gamma-\delta} \tag{16}$$

Eq. (16) indicates that for a certain level of parental human capital, agents with high innate ability will wish to borrow, and that the constraint is binding on able young agents. Young agents may therefore face problems with credit limits if they have low parental human capital or high learning abilities, or both.

The savings of young credit-constrained individuals are zero. If they choose to attend private schools, their investment in education will be:

$$q_{rt} = \frac{\beta\gamma}{1+\beta\gamma} \eta w h_t \tag{17}$$

Eq. (17) shows that the expenditure on education of a constrained agent is a fraction of the agent's endowment. Such investment is independent of innate ability, real interest rates and average human capital; thus, the law of motion of human capital for constrained agents is:

$$h_{t+1} = z_t \left(\frac{\beta\gamma\eta w}{1+\beta\gamma} \right)^{\gamma} h_t^{\gamma+\delta} H_t^{1-\gamma-\delta} \tag{18}$$

5.2. Endogenous credit constraints

The assumption of exogenous credit constraints in the previous section appears, however, to be an unreasonable assumption, since borrowing constraints may differ across individuals. Jappelli and Pagano (1994), for example, studied household savings in an OLG model in which liquidity constraints were a fraction of discounted lifetime income. However, they did not introduce human capital into their model, and as a result, their finding that the relationship between credit constraints and growth was positive was quite different from much of the literature which generally indicates that capital market imperfections will deter growth.

[28] We can also assume that young individuals can borrow up to a certain fixed level; however, the results will be similar to those obtained when the level is set at zero.

In order to make credit constraints arise endogenously, we follow the assumptions of Lochner and Monge (2003), which studied the effects of endogenous credit constraints on the accumulation of human capital.[29] We assume that if adults default, they will lose a fraction [$\phi \in (0, 1-\tau-\eta)$] of their income. There are, however, two main differences between their work and ours. First of all, we study the impacts of the educational system and allow for the coexistence of public and private schools, whereas they considered only a private education regime. Secondly, the relationship between growth and inequality was not a concern of their paper, whereas it is the main focus of this paper.

If borrowers choose to pay back their loan, their value function will be:

$$\Omega_{\text{adult}}(h_{t+1}, s_t) = \log c_{t+1} = \log((1-\tau-\eta)wh_{t+1} + Rs_t) \tag{19}$$

However, if they choose to default, their value function becomes:

$$\Omega^d_{\text{adult}}(h_{t+1}, s_t) = \log c_{t+1} = \log((1-\tau-\eta-\phi)wh_{t+1}) \tag{20}$$

The size of the credit limit is determined by allowing borrowers to be indifferent between repaying and defaulting. Creditors set the upper boundary of debt at a level where the value function of repaying the debt is at least as great as the value function of defaulting, so that no default will take place. By setting $\Omega_{\text{adult}}(h_{t+1}, s_t) \geq \Omega^d_{\text{adult}}(h_{t+1}, s_t)$, the credit limit will be:

$$-s_t \leq \phi' wh_{t+1} \tag{21}$$

where $\phi' = \phi/R$.

Eq. (21) gives the maximum debt that a young individual can carry over to the next period, which is a fraction of discounted future income. When ϕ increases, the cost of defaulting also increases and people are less willing to default; hence, lenders are willing to lend more. The first-order condition of optimal investment in education for a credit-constrained young agent attending a private school is:

$$\frac{1}{c_t}\left(\gamma\phi' w\frac{h_{t+1}}{q_{rt}} - 1\right) + \frac{\beta\gamma}{q_{rt}} = 0 \tag{22}$$

There is no analytical solution for q_{rt}; however, we can simulate the model and quantify the impacts of credit markets on educational choice, growth and inequality. Jappelli and Pagano (1994) reported that in 1980, consumer credit was 16.1% of the net national product in the US; hence, we give ϕ a value of 24.95% to match this data, and thus, allow agents to borrow up to 16.1% of their future income.[30]

Table 7 provides the simulation results for public and private education regimes under exogenous borrowing constraints (ϕ' =0), endogenous borrowing constraints (ϕ' =8.89) and perfect credit markets[31] (ϕ' =35.62%), with the statistics for 'credit-constrained agents

[29] Lochner and Monge (2003) used two punishments for defaulting; they constructed a three-period OLG model and an alternative punishment for defaulting wherein adults who defaulted could obtain only the lower rate of return of their savings.

[30] With an annual growth rate of around 2% and $\phi' wH_{t+1}/wH_t = (\phi/R)(H_{t+1}/H_t) = 0.161$, we can solve ϕ' =8.89% and ϕ=24.95%.

[31] Perfect credit markets implies ϕ=1; hence, $\phi' = 1/R$=35.62%.

(%)' measuring the proportion of credit-constrained young agents to the total young population.

Under a private education regime, given exogenous borrowing constraints, 99.83% of agents will be credit-constrained, whereas, under endogenous borrowing constraints, 98.78% of agents will be credit-constrained. Financial liberalization from exogenous credit constraints to perfect credit markets, through a stage of endogenous credit constraints, will increase the ratio of educational investment to GDP, the growth rate and income inequality. The growth rate will increase by 175.22%, the Gini coefficient will increase by 9.39%, and utility will also rise.

Under a public education regime, growth and inequality will not be affected by financial development because educational investment does not change, and, according to Eq. (14), the accumulation of human capital under a public education regime is independent of financial development.

Under a mixed educational system, all young agents will choose public schools when exogenous borrowing constraints exist; however, if the economy undergoes financial transition from exogenous to endogenous borrowing constraints, some young agents will switch to private schools. Therefore, in addition to calibrating the borrowing limits of ϕ' =8.89% into the data, we also consider the cases with ϕ' =10.69% and ϕ' =16.03% limits, with an increase in ϕ' indicating the loosening of borrowing constraints.

The last column of Table 7 represents the baseline model when credit markets are perfect. With financial liberalization, there will be an increase in private school enrollment and in the ratio of educational investment to GDP. This will in turn lead to an increase in the growth rate, income inequality and utility.

6. Empirical evidence

This paper offers an alternative approach to the consideration of the educational system. For developed countries with low income inequality, a mixed educational system with a higher private school enrollment rate may be a better choice than an educational system characterized by a lower private school enrollment rate, because financial markets will already have been liberalized and a high tax rate will be politically impractical.[32] Table 8 provides the average growth rates and the Gini coefficients from 1985 to 1994 for 26 developed countries.[33]

We use 90% of the public secondary school enrollment rate as our criterion. If a country had a public secondary school enrollment rate higher than 90% in 1985, we include that country in the group of countries with a larger public sector; if a country had a public

[32] This is because in democratic countries, tax rates are determined by voting; however, we do not include the voting system within this study; see Perotti (1993) and Cardak (2002) for consideration of this issue.

[33] According to Deininger and Squire (1996), there is no significant difference between Gini coefficients defined on the basis of net or gross income, and between household-based or individual-based estimates; however, the difference is significant between income- and expenditure-based estimates. Following their empirical results, we add 6.6 to the expenditure-based coefficients.

Table 8
Average growth rate and Gini coefficients for developed countries, 1985–1994

High income countries (OECD)	Growth rate (%)	Gini (%)	High income countries (non-OECD)	Growth rate (%)	Gini (%)
Australia*	3.0879	39.31	Bahamas*	1.282	43.708
Belgium*	2.0805	26.59	Bahrain*	3.3812	NA
Canada	2.4508	30.3	Cyprus	5.6262	NA
Denmark*	1.8724	33.175	Kuwait*	9.3959	NA
France*	2.1596	34.91	Malta*	5.1954	NA
Ireland*	4.5167	34.6	New Caledonia*	NA	NA
Italy	2.0334	33.52	Qatar*	NA	NA
Japan*	3.34	36.17	Reunion	NA	NA
Luxembourg	5.8916	27.13	Saudi Arabia	2.6312	NA
Netherlands*	2.7222	29.36	United Arab Emirates*	1.6742	NA
New Zealand	1.4863	36.92			
Norway	2.8325	32.6			
Spain*	2.9066	32.06			
Switzerland	1.6718	NA			
UK	2.374	29.77			
US	2.4976	37.72			

An asterisk beside the name of a country indicates that it has a private school enrollment rate in excess of 10%, and is therefore defined as a country with a larger private sector.
Those countries without an asterisk have private school enrollment rates of less than 10%, and are therefore defined as countries with a larger public sector.
Sources: Growth rates are obtained from World Development Data, World Bank; Gini coefficients are obtained from Deininger and Squire (1996), World Bank.

secondary school enrollment rate of less than 90% in 1985, we include that country in the group of countries with a larger private sector.[34]

The average growth rate for those countries with a larger public sector was 2.95% (10 countries), whilst the average growth rate for those with a larger private sector was 3.36% (13 countries). Income inequality was also higher for those countries characterized by a larger private sector than for those characterized by a larger public sector. The average Gini coefficient for those countries with a larger public sector was 32.57% (7 countries), whilst the average Gini coefficient for those with a larger private sector was 34.43% (9 countries).

Our model predicts that for a developing country, a large public sector is preferred to a large private sector, given the inherent lack of development of the financial markets. Table 9 provides the average growth rates and the Gini coefficients from 1985 to 1994 for 47 developing countries. The average growth rate for those countries with a larger public sector was 3.86% (14 countries), whilst the average growth rate for those with a larger private sector was 3.47% (32 countries).

In similar fashion to the case of the developed countries, income inequality was higher for those countries characterized by a larger private sector than for those characterized by a

[34] We use 90% of the public school enrollment rate as our criterion in order to create a more equal size distribution for each group.

Table 9
Average growth rate and Gini coefficients for developing countries, 1985–1994

Middle income countries	Growth rate (%)	Gini (%)	Low income countries	Growth rate (%)	Gini (%)
Argentina*	2.6143	NA	Bangladesh*	4.0435	NA
Botswana*	7.6893	60.81	Burkina Faso*	3.4146	NA
Brazil*	2.7660	58.02	Burundi*	2.6478	NA
Cameroon*	−1.5482	NA	Haiti*	−2.9963	NA
Chile*	6.8313	57.19	Mali	3.0196	60.60
Colombia*	4.3823	51.26	Niger*	1.5482	42.70
Costa Rica	4.4759	44.04	Senegal*	2.2758	60.72
Cote d'Ivoire*	1.2789	45.78	Tanzania*	NA	44.70
Fiji*	2.4000	NA	Zambia	0.5475	54.06
Gabon*	0.2620	NA			
Greece	1.8553	41.79			
Indonesia*	6.9810	38.86			
Jamaica	2.4821	47.60			
Korea*	8.6708	34.09			
Mauritius*	6.4350	44.77			
Mexico*	2.5745	54.16			
Morocco	4.1615	45.8			
Nicaragua*	−1.6101	56.92			
Oman	5.5020	NA			
Panama*	2.8986	56.47			
Paraguay*	3.4911	NA			
Peru*	1.9252	50.42			
Philippines*	2.2771	45.60			
Portugal	3.0951	36.20			
Singapore*	7.4790	40			
St. Kitts and Nevis	5.8362	NA			
St. Lucia	6.6341	NA			
St. Vincent and the Grenadines*	5.0520	NA			
Sri Lanka	3.8703	41.7			
Swaziland*	6.6172	NA			
Syrian Arab Republic	4.5520	NA			
Thailand*	9.0347	48.78			
Tonga*	2.3180	NA			
Tunisia	3.7757	48.22			
Turkey	4.2235	44.09			
Uruguay*	4.0008	NA			
Venezuela*	2.7225	47.70			
Zimbabwe*	2.6830	63.43			

An asterisk beside the name of a country indicates that it has a private school enrollment rate in excess of 10%, and is therefore defined as a country with a larger private sector.
Those countries without an asterisk have private school enrollment rates of less than 10%, and are therefore defined as countries with a larger public sector.

larger public sector. The average Gini coefficient for those countries with a larger public sector was 46.41% (10 countries), whilst the average Gini coefficient for those with a larger private sector was 50.12% (20 countries). If we focus on the data for low income countries, we find that most of these countries do not have high enrollment rates in public secondary schools. Table 9 also shows that developing countries with larger private sectors have high income inequality, as well as growth rates which are not particularly high, as predicted by our model.[35]

In light of these results, we believe that governments should think carefully about the long-run consequences of their educational policies. Although the differences in the growth rates and the Gini coefficients between the two groups are not very significant, these findings do provide some support for the predictions of our model.

7. Conclusions

This study develops a dynamic model within which households are allowed to make choices between public and private schools. Household decisions on education will determine the structure of the educational system, and our simulation results indicate that the structure of the educational system is important in explaining the relationship between growth and inequality.

We also analyze the impacts of alternative fiscal policies which the government can use to affect the structure of the educational system. An increase in the tax rate will increase public school spending per student and the rate of public school enrollment. Following such a policy will result in increasing the growth rate and utility, and will also lead to a reduction in income inequality. Alternatively, a government can provide public support for private education through the adoption of voucher programs. However, whilst increasing the scale of vouchers will undoubtedly lead to an increase in both the growth rate and inequality, it will not necessarily lead to any improvement in welfare for young agents.

In order to study the influence of financial development on economic growth, we go on to introduce imperfect credit market conditions into the model later in the paper, and find that the existence of imperfect credit markets precludes some agents from choosing private schools, whilst financial liberalization without any other interventions will increase both the growth rate and inequality. If any government intends to use financial reforms as a means of helping the poor, it would also need to apply an additional policy aimed at increasing the size of the public sector (e.g., increasing public school spending per student or reducing the amounts of vouchers). Our results therefore provide a cautionary note to those developing countries currently engaging in financial reforms.

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[35] A causality problem needs to be mentioned here. Our study demonstrates that the low public school enrollment rate in a low-income country will cause low growth rate and high income inequality, but it might be due to low income and unfeasibility of high tax rate. We thank one referee for pointing this out.

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Appendix A

Proof of Proposition 1. Note that τ=0 because there are no public schools or vouchers. From Eq. (10), we can derive:

$$\frac{h_{t+1}}{H_{t+1}} = \frac{\left[z_t\left(\frac{(1-\eta)w\gamma}{R}\right)^{\gamma} h_t^{\delta} H_t^{-\delta}\right]^{\frac{1}{1-\gamma}}}{H_{t+1}/H_t}. \tag{A1}$$

Thus,

$$b_{t+1} = \frac{\left[z_t\left(\frac{(1-\eta)w\gamma}{R}\right)^{\gamma} b_t^{\delta}\right]^{\frac{1}{1-\gamma}}}{g_{t+1}}. \tag{A2}$$

Along the balanced growth path, b_t=1 and $z_t=\bar{z}$ for all t. From Eq. (A2), this implies that the balanced growth rate under a private education regime is:

$$g_{t+1} = g^* = \left[\bar{z}\left(\frac{(1-\eta)w\gamma}{R}\right)^{\gamma}\right]^{\frac{1}{1-\gamma}}. \qquad \square$$

Proof of Proposition 2. Using Eq. (14), the human capital accumulation function can be written as:

$$h_{t+1} = z_t(\tau w)^{\gamma} h_t^{\delta} H_t^{1-\delta}.$$

Thus,

$$b_{t+1} = \frac{h_{t+1}}{H_{t+1}} = \frac{z_t(\tau w)^{\gamma} h_t^{\delta} H_t^{-\delta}}{H_{t+1}/H_t} = \frac{z_t(\tau w)^{\gamma} b_t^{\delta}}{g_{t+1}}. \tag{A3}$$

Along the balanced growth path, b_t=1 and $z_t=\bar{z}$ for all t. From Eq. (A3), this implies that:

$$g_{t+1} = g^* = \bar{z}(\tau w)^{\gamma} \qquad \square$$

Appendix B

Proof of Proposition 3. The first-order condition for agents choosing private or public schools is:

$$c_{t+1}^{i} = \beta R c_t^{i}, \quad i = \text{pri, pub} \tag{A4}$$

where pri represents private schools and pub represents public schools. The lifetime utility can then be written as:

$$u^i = \beta \log(\beta R) + (1+\beta)\log c_t^i, \quad i = \text{pri}, \text{pub} \tag{A5}$$

For agents who are indifferent between attending private or public schools, $u^{\text{pri}}=u^{\text{pub}}$. From Eq. (A5), this implies that $c_t^{\text{pri}}=c_t^{\text{pub}}$. From Eqs. (6), (8) and (9), we can derive:

$$c_t^{\text{pri}} = \frac{1}{\gamma(1+\beta)}\left\{\gamma\eta w h_t + (1-\gamma)\left[\frac{w\gamma(1-\eta-\tau)}{R} z_t h_t^\delta H_t^{1-\gamma-\delta}\right]^{\frac{1}{1-\gamma}}\right\} \tag{A6}$$

From Eqs. (11), (12) and (13), we can derive:

$$c_t^{\text{pub}} = \frac{1}{R(1+\beta)}\left\{R\eta w h_t + (1-\eta-\tau) w z_t \left(\frac{\tau w}{p_t}\right)^\gamma h_t^\delta H_t^{1-\delta}\right\} \tag{A7}$$

Hence,

$$c_t^{\text{pri}} = c_t^{\text{pub}} \text{ if } h_t = \left(\frac{1}{1-\gamma}\right)^{\frac{1-\gamma}{\delta\gamma}} \left[\frac{\tau R}{(1-\eta-\tau)\gamma w^\gamma z_t}\right]^{\frac{1}{\delta}} p_t^{-\frac{(1-\gamma)}{\delta}} H_t^\delta \tag{A8}$$

Eq. (A8) shows that h_t is a decreasing function of z_t.

Moreover, let $\tilde{h}(z_t) = \left(\frac{1}{1-\gamma}\right)^{\frac{1-\gamma}{\delta\gamma}} \left[\frac{\tau R}{(1-\eta-\tau)\gamma w^\gamma z_t}\right]^{\frac{1}{\delta}} p_t^{-\frac{(1-\gamma)}{\delta}} H_t^\delta$ represent the threshold of attending private schools for a certain level of z_t. Given $z_t=z$, $c_t^{\text{pri}}>c_t^{\text{pub}}$ if $h_t>\tilde{h}(z)$ and vice versa. Hence, the lowest parental human capital for private school attendees will be higher than the highest parental human capital for public school attendees. □

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