EDUCATIONAL POLICY AND SKILL HETEROGENEITY WITH CREDIT MARKET IMPERFECTIONS

by

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ABSTRACT

An overlapping-generations model where agents choose whether to become educated when young is presented. Education enhances productivity, but needs to be financed by borrowing. Because of the possibility of default, lenders may ration credit. We characterize the steady-state equilibrium with and without credit constraints and show that credit rationing tends to be associated with lower education and a lower real interest rate. We then examine the role of public policy in remedying the inefficiency which occurs in the presence of credit rationing and derive results on optimal public education spending and on allocative and distributional issues.

Keywords: Education, Credit Rationing, Public Policy.

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1. INTRODUCTION

There is much evidence that investment in human capital is of considerable importance in explaining long-run developments in countries' productive capacities and economic growth.[1] Education, undoubtedly a source of much human capital accumulation, is often provided by the state or subject to extensive state intervention. Why is this? A primary reason is that purely private provision of education would involve market failures. What market failures are there in the case of education? We focus on those due to credit market imperfections although we realize this may not be the only reason why purely private provision might be suboptimal. This is because little has been done in an intertemporal general-equilibrium framework to analyze the allocative and distributional consequences of such imperfections and to explore the ways in which public policy may provide a remedy.[2]

Credit market imperfections are pervasive in the case of education loans due at least partly to the moral hazard problem facing borrowers given that human capital is inalienable and does not act as collateral for loans. Empirical evidence on the existence of credit constraints in the context of human capital accumulation abounds. For example, Lazear (1980) and Jacoby and Skoufias (1997) find strong links between financial market imperfections and human capital accumulation in the context of U.S. college and rural Indian child education, respectively.

In this paper, we present a model which considers the general-equilibrium ramifications of educational choice in a framework which incorporates these aforementioned market failures. We concentrate on the implications of credit market imperfections for the schooling decision, assuming no imperfection in the credit market for purchasing physical capital goods. We extend previous work on education and credit constraints, to be outlined below, in several significant aspects. Our framework is rich enough to allow us to obtain further insights into the macroeconomic relationships between education and income inequalities, as well as to examine more thoroughly the allocative and distributive roles of education-related public policy.

We introduce credit market imperfections as follows: suppose an individual borrows, ostensibly to finance education. The lender cannot guarantee that the borrower will actually spend the money on education - instead, the borrower may "take the money and run" - which is a classic *moral hazard* problem.[3] The lender will only lend if he believes the borrower will not have an incentive to default and this generates an incentive compatibility constraint. An implication is that there are circumstances under which credit rationing may occur - there is a ceiling to the amount the lender will lend; the borrower would be willing to borrow more, invest in education and repay the loan (and prefer this to having the loan denied), but cannot commit to doing this, so the lender is not willing to lend more.[4] We also show that our main conclusions are robust under an alternative setup where the borrower is allowed to invest in education and then abscond without repaying the loan.

We embed this framework in an overlapping-generations model where agents live for two periods. Agents, endowed with one unit of labor over their lifetime, differ only in their "distaste for education" (or, equivalently, "ability to learn"). Those with the lowest distaste (highest ability) will typically borrow when young to be educated. They become skilled in the second period and earn a high wage, which enables them to consume and repay the loan. Those who are uneducated instead work as unskilled workers, saving their earnings to the second period when they consume. Unskilled workers have a constant, low marginal product of labor and hence receive a constant, low real wage. Skilled labor is complementary with capital, in the sense that an increase in the employment of skilled workers raises the marginal product of capital. There is a single, homogeneous good which is used either for consumption or investment in physical or human capital. Into this framework, we introduce the possibility of credit rationing and consider various policy options available to the government, such as an educational subsidy or public provision of education, to remedy the problems caused by credit market imperfections.

Our paper contributes to the literature on educational choice and endogenous credit rationing pioneered by Zeira (1991), Tsiddon (1992) and Galor and Zeira (1993).[5] In contrast to Galor and Zeira who assume an exogenous safe real interest rate, we allow for endogenous determination of the real interest rate which has additional allocative and distributive consequences. Our paper also differs from these previous studies in the context of individual heterogeneity. Both Zeira and Tsiddon assume that all agents are *ex ante* the same and take the same decision (whether to become educated or not); *ex post* they may differ because of luck in the outcome of education - so they differ in the number of efficiency units of labor they embody, but skilled and unskilled workers are still perfect substitutes. In Galor and Zeira, agents differ in their initial wealth, which mainly serves for the purpose of analyzing properties of income distribution. We instead consider that agents are heterogeneous in taste/ability *ex ante* and in skills and wages *ex post* as an equilibrium outcome, and that skilled and unskilled workers are *not* perfect substitutes. Under this structure, skilled workers borrow when young and unskilled workers are lenders. Thus, not only is educational choice determined in equilibrium, but the division of the population into borrowers and lenders is *endogenous*. The latter feature contrasts with virtually all the previous studies except for the trickle-down growth theory developed by Aghion and Bolton (1997) which is nevertheless very different from ours.[6]

Endogenous determination of borrowers and lenders, endogenous credit constraints and an endogenous real interest rate are crucial to our analysis, and matter significantly in explaining the macroeconomic consequences of credit rationing for education, capital accumulation, and income distribution.[7] For example, credit rationing means an increased fraction of the population are unskilled workers and lenders. As a consequence, there is a substitution of physical capital for skilled workers, the real interest rate decreases, and the skilled wage rate increases. There are hence general equilibrium effects on income distribution: the income inequality between the skilled and unskilled is widened - skilled workers, who are borrowers, benefit, whereas the unskilled, who are lenders, suffers from the decline in interest income. We also provide a fairly thorough discussion of public policy designed to remedy the problem caused by the credit market imperfection in education loans. These above considerations have important implications for the evaluation of the allocative and distributive roles of education-related public policy, which will be elaborated upon in Sections V below. We are unaware of any remotely comparable discussion in the existing literature.

The main findings of this paper are as follows. By characterizing the steady-state equilibrium with and without credit constraints, we show that credit rationing is associated with lower education, a lower real interest rate, and widened income inequality between the skilled and the unskilled. In the presence of credit market imperfections, a proper Pigovian subsidy to education financed solely by a tax on the young unskilled can restore the first-best unconstrained equilibrium and may result in Pareto improvements, whereas a subsidy financed at least partly by a tax on the old educated cannot do so. Under an equally weighted utilitarian social welfare function, the socially optimal public provision of education financed by a tax on the educated is associated with an education level and private capital accumulation higher than that in the unconstrained equilibrium; if financed by a tax on the unskilled it is associated with a level of education the same as that in the unconstrained case, though education is rationed with the educated better-off and the uneducated worse-off than in the unconstrained equilibrium. Under a social welfare function giving more weight on the utility of the poor than the rich, the socially optimal public provision of education may result in mandatory education, educating some individuals who are otherwise unwilling to undertake schooling.

The plan of the rest of the paper is as follows. Section 2 presents the basic model and Section 3 analyzes the steady state in the absence of credit constraints. Credit market imperfections, and their implications, are studied in Section 4. Public policies designed to remedy the market failure are examined in Section 5; we consider two such policies, a subsidy to education and public provision of education. Some concluding remarks appear in Section 6.

2. THE MODEL

Time is discrete. The economy is populated with two-period overlapping generations, in which agents make just one decision - whether to become educated when young.[8] Individuals are identical, except that they differ in their disutility of acquiring education. The measure of those born in any particular time is normalised to unity. Agents have no initial wealth but supply a unit of labor inelastically in one of the periods of their life (in the second period if they acquire education; otherwise in the first period).[9] All agents derive utility from second-period consumption of a single good; apart from this, only the disutility of acquiring education (of those who do acquire education) affects utility. There is neither endogenous leisure nor altruism. For simplicity, the utility function is assumed linear.[10]

The disutility costs incurred in acquiring education, denoted α, are assumed to be uniformly distributed in the population, with a maximum value of ϵ and a minimum value of $-\epsilon$, i.e., $\alpha \sim U(-\epsilon,\epsilon)$. We can interpret α in various ways; for example, it could represent the nonpecuniary cost of acquiring education, or (the inverse of) ability. In addition to this cost, education costs an amount θ per person in units of goods. In the absence of initial wealth or bequest, this cost of education must be financed by borrowing (for the moment, we assume an agent who wishes to borrow has no difficulty doing so, an assumption which will be relaxed in Section 4 below when credit is allowed to be rationed). Agents choose education if the benefit - being able to earn a high-skilled wage in the second period - outweighs the cost - loss of earnings in the first period plus the costs of becoming educated.

For an agent born at time t-1, the (real) interest rate on the education loan is r_{t-1}. Education enables the agent to become a high-skilled worker in the next period (t) and to receive a gross wage $w_{H,t}$, which is used for loan repayment and for consumption.[11] If an agent born at t - 1 decides not to become educated in the first period, he works at the low-skilled wage $w_{L,t-1}$, saves the proceeds and becomes a lender, receiving interest (at the rate of r_{t-1}) plus the original value of his capital in the next period to spend on consumption. Note that in choosing whether to become educated an agent is also deciding whether to become a borrower or a lender in the first period, and this endogenous division of agents into borrowers and lenders will have important implications for the macroeconomic consequences of credit rationing. The sequence of actions in this basic framework is depicted in Figure 1.

Given linear utility in second-period consumption and the disutility costs of education, the criterion for an agent born at time t-1 to choose education is hence:

$$w_{H,t} - (1 + r_{t-1})\theta - \alpha_{t-1} \geq (1 + r_{t-1})w_{L,t-1}, \tag{1}$$

where we assume that if an agent is exactly indifferent, he chooses education (obviously inconsequential as such agents are of measure zero). The left-hand side of this expression gives the benefit from being educated - high-skilled wage less repayment of the loan less subjective cost of education; the right-hand side gives the benefit to remaining uneducated - evaluated in terms of second-period consumption. If there is to be a mixture of educated and uneducated workers, there must be a critical value of α_{t-1} (denoted α_{t-1}^*) between $-\epsilon$ and ϵ at which an agent is indifferent between acquiring education and remaining unskilled. That is, α_{t-1}^* is defined by the following equation:

$$w_{H,t} - (1 + r_{t-1})\theta - \alpha_{t-1}^* = (1 + r_{t-1})w_{L,t-1}. \tag{2}$$

Agents of type $\alpha_{t-1} \in [-\epsilon, \alpha_{t-1}^*]$ become educated, whereas those with $\alpha_{t-1} \in (\alpha_{t-1}^*, \epsilon]$ remain uneducated. We assume that $\theta > \epsilon$, so that education is costly for everyone (i.e., no one does it for fun - the reason to become educated is to raise one's lifetime income).

The single good in the economy is produced either by unskilled workers or by skilled workers combining with capital, so that we can regard the economy as comprised of two sectors: $Y_t = Y_{L,t} + Y_{H,t}$, where Y_t is total output at time t, and $Y_{i,t}$ (i = L, H) is the output of "sector" i at time t. Let $\ell_{i,t}$ represent aggregate employment in sector i in period t. In the benchmark model, we assume that unskilled labor has a constant, low marginal product v > 0 and does not combine with capital to produce output: $Y_{L,t} = v\ell_{L,t}$. Further, skilled labor combines with capital in a Cobb-Douglas production technology with constant returns to scale: $Y_{H,t} = \ell_{H,t}^{\beta} K_t^{1-\beta} = \ell_{H,t} k_t^{1-\beta}$, where K_t is the amount of capital available at the beginning of period t and $k_t \equiv K_t/\ell_{H,t}$ is the capital-skilled labor ratio (which we will henceforth describe as the capital-labor ratio). That is, we impose capital-skilled labor complementarity, a plausible assumption with considerable empirical support (e.g., see Griliches (1969) and Bergström and Panas (1992)).[12] Accordingly, the output at date t is given by:

$$Y_t = v\ell_{L,t} + \ell_{H,t}\, k_t^{1-\beta} . \tag{3}$$

Competitive factor markets are assumed and factor prices are hence determined by the usual marginal productivity conditions:

$$w_{L,t} = v \tag{4a}$$

$$w_{H,t} = \beta k_t^{1-\beta} \tag{4b}$$

$$r_t = (1 - \beta)k_t^{-\beta} - \delta, \tag{4c}$$

where δ is depreciation of capital. Let x_{t-1} denote the proportion of the generation born at time t-1 who become educated. It follows that in labor market equilibrium, we have:

$$x_{t-1} = \ell_{H,t} ; \quad 1 - x_{t-1} = \ell_{L,t-1} . \tag{5}$$

It is straightforward to show that, with a uniform distribution of disutilities of education across the population, $x_{t-1} = (\alpha_{t-1}^{*} + \epsilon)/(2\epsilon)$, from which we obtain:

$$\alpha_{t-1}^{*} = - \epsilon + 2\epsilon x_{t-1} , \tag{6}$$

which provides a linear relationship between the proportion of the labor force which becomes educated and the critical value of disutility cost of education.

Finally, to complete the specification of the model, we turn to the goods market. The capital evolution equation can be written as:

$$K_{t+1} - (1 - \delta)K_t = Y_t - C_{H,t} - C_{L,t} - \theta x_t, \tag{7}$$

where $C_{i,t}$ (i = H,L) denotes the aggregate consumption of group i at time t:

$$C_{H,t} = [w_{H,t} - (1 + r_{t-1})\theta]x_{t-1}, \tag{8a}$$

$$C_{L,t} = w_{L,t-1}(1 + r_{t-1})(1 - x_{t-1}). \tag{8b}$$

The left-hand side of equation (7) gives the net increment to the capital stock over period t plus depreciation (i.e., total spending on investment goods). The right-hand side gives total output, less consumption by the two groups, less spending on education for those born in period t.

3. STEADY-STATE EQUILIBRIUM

We now define (unconstrained) non-degenerate steady-state equilibrium in our two-period overlapping-generations economy with endogenous educational choice.

Definition 1: *A non-degenerate steady-state equilibrium (NSSE) is a tuple of positive quantities* $\{C_L, C_H, \ell_L, \ell_H, k, Y, x\}$, *a tuple of positive prices* $\{w_L, w_H, r\}$ *and a critical value* $\alpha^* \in (-\epsilon, \epsilon)$, *all of which are constant over time, such that*

(i) *schooling is optimal: type* $\alpha \in [-\epsilon, \alpha^*]$ *chooses to be educated and type* $\alpha \in (\alpha^*, \epsilon]$ *remains uneducated, where* α^* *satisfies (2);*

(ii) *consumption of skilled and unskilled workers is determined by (8a) and (8b), respectively;*

(iii) *production technology is as in (3);*

(iv) *factor demands are given by (4a) - (4c);*

(v) *allocation of labor across sectors and labor market equilibrium are given by (5) and (6);*

(vi) *goods market equilibrium is achieved as in (7).*

As all variables take on their steady-state values, we drop time subscripts.

Our solution procedure is to reduce the steady-state relationships of the model to two equations in two unknowns, x (the fraction of population which becomes educated) and k (the capital-labor ratio). One, which we describe as the "schooling locus" (denoted by SS), relates the value of x which results from everyone making his or her optimal schooling decision to the capital-labor ratio k (and consequent factor prices). The second, referred to as the "goods market equilibrium locus" (denoted by EE), gives the combinations of values of x and k such that the goods market is in equilibrium. Using the SS and EE loci, the steady-state equilibrium values of x and k are determined. Substituting these into (4a)-(6), we obtain the steady-state equilibrium values of factor prices (w_L, w_H and r), labor demand in each sector (ℓ_L and ℓ_H) and the critical value of the disutility cost of education (α^*). Then, utilizing (3), (8a) and (8b), we obtain steady-state equilibrium output (Y) and consumption (C_L and C_H). Obviously, by definition, the steady-state equilibrium capital stock is K = xk. Thus, our main task is to characterize (k, x) using the SS and EE loci; the remaining endogenous variables of the system can be determined accordingly in a recursive manner.

To derive the SS locus, we substitute (4a)-(4c) and (6) into (2) and impose steady state to obtain:

$$\beta k^{1-\beta} = \epsilon(2x - 1) + [1 + (1 - \beta)k^{-\beta} - \delta](\theta + v), \tag{9}$$

which may be rewritten in a more intuitive form involving factor prices:

$$w_H(k) = \epsilon(2x - 1) + (1 + r(k))(\theta + v). \tag{10}$$

The locus has a positive slope of $\beta(r + \delta)[(\theta + v)/k + 1]/(2\epsilon)$ in (k, x)-space and a horizontal intercept of $k_{min} > 0$ (see Figure 2). Intuitively, an increase in k makes education more desirable for two reasons: it raises the skilled wage and reduces the real interest rate ($dw_H/dk > 0$ and $dr/dk < 0$), so that from (10) an increase in x is required for the increase in k to be compatible with individual rationality in educational choice. When k approaches zero, the skilled wage rate also tends to zero but the unskilled wage rate remains at $v > 0$. Given $\theta > \epsilon$, acquiring education is costly for all agents, implying that the skilled wage needs to be above the unskilled wage before education is strictly positive. At k_{min}, the skilled wage is such that the agent with the lowest marginal disutility cost of education is indifferent whether to acquire education or not.

To obtain the EE locus, we combine equations (3), (4a)-(4c), (6) and (7)-(8b), impose the steady-state condition and manipulate, yielding: $\delta xk = (1 - \beta)xk^{1-\beta} + [(1 - \beta)k^{-\beta} - \delta][(\theta + v)x - v]$, which, providing $r > 0$, can be simplified to:

$$x(k + \theta) = v(1 - x). \tag{11}$$

Equation (11) states that the savings of the unskilled (the right-hand side) comprise capital accumulated and education loans (the left-hand side). The locus has a negative slope of $-(\theta + v + k)/x$ in (k, x) space and a vertical intercept of $x_{max} = v/(\theta + v) < 1$, with the horizontal axis as the asymptote when k approaches infinity (see Figure 2). Intuitively, an increase in x means less savings are generated, while more is lent for educational purposes. This means that capital accumulation must fall in order to maintain goods market equilibrium.

The system is illustrated in Figure 2 where point E indicates the (unconstrained) steady-state equilibrium. To ensure the existence of an NSSE solution for (k, x), we assume:

Condition U: (Existence of the Unconstrained equilibrium) $\theta > v$.

When $\theta > v$, the SS locus must lie above the EE locus at $k = k_{max} \equiv [(1-\beta)/\delta]^{1/\beta}$, which corresponds to the case of $r = 0$.[13] However, when $k = k_{min}$ ($< k_{max}$), the EE locus lies above the SS locus. The SS locus is upward sloping, the EE locus is downward sloping, and both curves are continuous, so the curves must intersect once. It follows that under Condition U, there exists a unique NSSE solution for (k, x), in which $k \in (k_{min}, k_{max})$ and $x \in (0, v/(\theta+v))$. Then, from (3)-(6), (8a) and (8b), the NSSE solution for the other endogenous variables is uniquely determined. Summarizing:

Theorem 1: (Existence of NSSE) *Under Condition U, there is a unique non-degenerate steady-state equilibrium in which a nontrivial fraction of high-α agents become unskilled workers and a nontrivial fraction of low-α agents undertake education and become skilled workers.*

4. CREDIT RATIONING

The analysis in the previous section has assumed there to be no problem in borrowing to finance education. In reality, credit markets are notoriously imperfect and borrowing for many purposes is often difficult and sometimes impossible, giving rise to what we call credit constraints or credit rationing. The existence of such constraints in many contexts is well-documented: evidence is provided by, for example, Evans and Jovanovic (1989) on lending to entrepreneurs, Japelli and Pagano (1994) on household credit markets, Gertler and Gilchrist (1994) for credit constraints on small firms and, of greatest relevance for the current study, Lazear (1980) and Jacoby and Skoufias (1997) on financial loans and human capital accumulation.

To generate the possibility of credit rationing, we focus on the presence of the moral hazard problem.[14] The basic idea is to capture the moral hazard story illustrated by Banerjee and Newman (1993): "[an agent may] attempt to avoid his obligations by fleeing from his village, albeit at the cost of lost collateral" (p. 280). More specifically, the borrower may have the option of "taking the money and running" (or "absconding"), which means that he will not repay the loan.[15]

We consider two ways to model this moral hazard problem. The first is where the lender can ensure that a borrower who obtains a skilled job repays the loan (by, for example, an automatic payroll deduction), but cannot ensure that the borrower actually spends the money on education rather than absconding with the loan. A second approach (following Sappington, 1983 and Hart and Moore, 1994) is to assume that the lender can ensure that the money lent is spent on education, but cannot force the borrower to repay the loan (although penalties will be imposed on him if he defaults). The borrower hence has two choices: whether to borrow and invest in education and, if he has done so, whether to repay the loan. We consider the first assumption more plausible and use it in the bulk of the paper. However, for the sake of completeness, and to explore the robustness of our results, we also derive the implications under the second approach. In both models, we assume school enrollment to be fully observable so that a borrower who intends to abscond would never work as an unskilled worker in the first period of his lifetime.

A. THE BASIC MODEL

In the basic model, the lender cannot ensure that the borrower will actually invest the money rather than take the money and run. The lender will therefore lend only if he knows that the borrower has an incentive to use the money to invest in education rather than abscond, and for this reason may ration the amount he is willing to lend the borrower. Thus, the incentive compatibility constraint states that a borrower will not abscond if and only if the benefit from education net of loan repayment costs exceeds the benefit from absconding, which is the amount of money lent, evaluated in the second period, less costs of default in units of consumption goods (denoted π): $w_H - (1 + r)\theta - \alpha \geq (1 + r)\theta - \pi$, where we assume, again inconsequentially, that an agent who is exactly indifferent whether to abscond or not, chooses not to do so.[16] The costs of default represent the expected values of penalties, by which defaulters may suffer, or the net resources used for defaulters in absconding.[17]

We assume that lenders can observe the disutility of education (α) of each potential borrower, where the observability of α can be thought of as based upon information such as exam results and letters of recommendation, etc.[18] Thus, there is a critical value of α, denoted $\alpha^*(x^c)$, at which a borrower is indifferent between using the loan to educate himself and absconding, where x^c is the corresponding fraction of the educated labor force under credit rationing, satisfying:

$$w_H - (1 + r)\theta - \alpha^*(x^c) = (1 + r)\theta - \pi. \qquad (12)$$

Therefore, individuals with $\alpha \leq \alpha^*(x^c)$ want to, and are able to, borrow to finance education. Those with $\alpha > \alpha^*(x^c)$ are unable to borrow, as were they to do so, they would not repay the loan. Lenders realize this and hence do not lend to these individuals. This is so even though there would be mutual gains if the money were lent and spent on education, which can be seen by noting that the criterion for education to be individually worth undertaking (inequality (1)) can be satisfied for an individual with an α greater than $\alpha^*(x^c)$. Note that in this model, default will not be observed in equilibrium, although its possible occurrence is of crucial importance in generating some of our results.

It might be asked whether the financial contracts we postulate are optimal. We can argue that indeed they are, provided financial intermediaries are competitive (which we implicitly assume). Consider the alternative that conditions repayments on observable features of the borrowers, that is, α. It is obvious that a monopoly lender would do this (those with lower α's being required to repay more). However, with competition, this would not be possible – if a lender offered a financial contract to a borrower with an effective interest rate greater than r, he would be undercut by another lender.

The above considerations provide a simple way to endogenize the credit constraints, contrasting with the exogenous borrowing constraints setup in the conventional literature such as Hare and Ulph (1981), Azariadis and Smith (1993) and De Gregorio (1996). In our model, we say that (endogenous) credit rationing exists if there is a set of agents of positive measure with $\alpha > \alpha^*(x^c)$ for whom schooling is desirable (i.e., (1) is satisfied). Using the steady-state version of (6), we can rearrange (12) to obtain:

$$x^c = (1/2\epsilon)[\epsilon + w_H - 2(1 + r)\theta + \pi]. \tag{13}$$

Accordingly, the definition of steady-state equilibrium becomes:

Definition 2: *A non-degenerate steady-state equilibrium with credit rationing (NSSECR) is a tuple of positive quantities $\{C_L, C_H, \ell_L, \ell_H, k, Y, x\}$, a tuple of positive prices $\{w_L, w_H, r\}$ and a critical value $\alpha^*(x^c) \in (-\epsilon, \epsilon)$, all of which are constant over time, such that (ii)-(vi) in Definition 1 are met and*

(i)′ there is credit rationing: type $\alpha \in [-\epsilon, \alpha^*(x^c)]$ receive education loans and are educated, type $\alpha \in (\alpha^*(x^c), \epsilon]$ are denied loans and remain uneducated, where x^c solves (13); moreover, there is a set of agents of positive measure with $\alpha > \alpha^*(x^c)$ for whom (1) is satisfied.

It is useful to compare the constrained education level x^c with the unconstrained one in the absence of credit rationing (which we denote by x^u) in terms of factor prices and parameters. The latter can be obtained from (10):

$$x^u = (1/2\epsilon)[\epsilon + w_H - (1 + r)(\theta + v)]. \tag{14}$$

Equating (13) and (14), we see that x^u and x^c coincide at the level of r given by $r = -1 + \pi/(\theta - v)$ (recall that under Condition U, $\theta - v > 0$). Credit rationing occurs if $x^u > x^c$ at the level of $r > 0$, that is, if the following condition is met:

Condition C: (Credit Rationing) $(1 + r)(\theta - v) > \pi > \theta - v$.

The first inequality implies $x^u > x^c$ and the second ensures that in a non-degenerate steady-state equilibrium with credit rationing, the real interest rate is positive ($r > 0$). Note that we include in Condition C the endogenous variable r. One could solve for the NSSECR values of (k, x) using (4b), (11) and (13), thus yielding the corresponding value of r and eliminate r from the statement of Condition C, but this would make the condition far less transparent. Moreover, as it can be seen later, the second inequality is sufficient but not necessary for an NSSECR to exist. We can now establish:

Theorem 2: (Existence of NSSECR) *Under Conditions E and C, there is a unique non-degenerate steady-state equilibrium with credit rationing in which a nontrivial fraction of high-α agents choose to work as unskilled, a nontrivial fraction of intermediate-α agents desire schooling but are credit constrained by the lenders, and a nontrivial fraction of low-α agents obtain loans, undertake education and become skilled.*

To verify the existence and uniqueness of the NSSECR, we again rely on the recursive property of the system. If the unconstrained steady-state equilibrium level of x (determined by the intersection of the EE and

SS loci, as analyzed in Section 3) is below x^c, then credit rationing does not occur. If it is above the critical level, loans will not be made to finance this unconstrained level of education and the economy features equilibrium credit rationing. Substitution for w_H and r from (4b) and (4c) into (13) yields:

$$\beta k^{1-\beta} = \epsilon\,(2x - 1) + 2[1 + (1 - \beta)k^{-\beta} - \delta]\theta - \pi, \tag{15}$$

which is referred to as the CR (credit rationing) locus in (k, x) space. Its slope is easily calculated as $\beta(r + \delta)(2\theta/k + 1)/2\epsilon$, which is positive and greater than the slope of the SS locus described by (9) given Condition U (i.e., $\theta > v$). Intuitively, an increase in k relaxes the incentive compatibility constraint as it raises the high-skilled wage (hence increasing the return to education) and reduces the interest rate (hence decreasing the amount that needs to be repaid and also the benefits from absconding). As a consequence, lenders are willing to lend to individuals with lower α's, so x rises. This explains why the CR locus is upward sloping.

Figure 3 depicts the three loci, where the SS and CR loci intersect at A and incentive compatibility is satisfied for all (k, x) lying below the CR locus (so the segment of the SS locus above point A remains effective). The second inequality of Condition C implies point A is associated with a value of $k < k_{max}$ and thus the constrained (or credit-rationed) equilibrium (point C), if it exists, must be accompanied by a positive real interest rate. For the constrained equilibrium to exist, the unconstrained equilibrium (point E) must violate the incentive compatibility constraint. Put differently, point A must be to the right of point E and $x^u > x^c$, which is ensured by the first inequality of Condition C. By the monotone property of CR and EE, the uniqueness of the NSSECR is trivial. Comparing points E and C and using (4b) and (4c), we conclude:

Proposition 1: (Constrained vs. Unconstrained Equilibrium) *The constrained equilibrium is Pareto inefficient whereas the unconstrained equilibrium is Pareto efficient. In the steady state, the presence of credit rationing is associated with a lower level of education, a higher capital-labor ratio, a lower real interest rate, and a greater skilled wage rate, than is its absence.*

Proof: All proofs are in the Appendix.

The Pareto inefficiency of the constrained equilibrium is not surprising, as credit constraints limit some agents' opportunities to undertake education despite its desirability. The result that credit rationing means a lower real interest rate corroborates the finding of Azariadis and Smith (1993), although the underlying mechanism is rather different. In their pure exchange model, adverse-selection induced credit rationing means savings in the economy rise, which drives down the real interest rate. In our production economy, moral-hazard induced credit rationing means education falls and some agents switch from being borrowers to lenders. It is for this reason that savings rise and, with capital-skilled labor complementarity, the marginal product of capital and the real interest rate fall.[19] Obviously, this result differs dramatically from the investment loan models, such as Aghion and Bolton (1997) and Chen, Chiang and Wang (1997), in which credit rationing constrains investment and decreases capital accumulation, leading to a higher marginal product of capital and a higher real rate of interest. An important empirical implication of this theoretical finding is that the effect of credit rationing on the real rate of interest depends crucially on whether the rationing applies to loans to finance investment in human or physical capital.

Proposition 1 also implies that credit rationing has distributional effects. Those who are excluded from education because of credit rationing suffer, and all the unskilled lose because of the lower real interest rate. Those who can still borrow to purchase education gain in two ways from the presence of credit rationing: the high-skilled wage rises and the real interest rate (and hence cost of education) fall. So credit rationing not only has efficiency costs by distorting educational choice, but also widens the gap between the skilled and the unskilled. It is interesting to note that, in models with an exogenous real interest rate, the distributive effect of credit rationing via the latter channel is absent.

Proposition 2: (Inequality) *The presence of credit rationing widens income inequality between the skilled and the unskilled.*

To characterize the constrained equilibrium, we totally differentiate (15) and (11) to obtain:

$$\begin{bmatrix} -2\epsilon & a_{12} \\ a_{21} & -x \end{bmatrix} \begin{bmatrix} dx \\ dk \end{bmatrix} = \begin{bmatrix} 2x-1 & 0 & 2(1+r) & -1 \\ 0 & (x-1) & x & 0 \end{bmatrix} \begin{bmatrix} d\epsilon \\ dv \\ d\theta \\ d\pi \end{bmatrix}, \tag{16}$$

where $a_{12} = \beta(r + \delta)(2\theta/k + 1)$ and $a_{21} = -(\theta + v + k)$. Straightforward comparative static analysis yields:

Proposition 3: (Characterization of the NSSECR) *The non-degenerate steady-state equilibrium with credit rationing possesses the following properties:*

(i) *a mean-preserving spread of the distribution of the disutility cost of education (i.e., a larger ϵ) encourages education and discourages capital accumulation when the fraction of the population educated is less than half;*

(ii) *an increase in the productivity (wage) of the unskilled (v) raises both the capital-labor ratio and the level of education;*

(iii) *an increase in the pecuniary education cost (θ) reduces the proportion of the population educated and has an ambiguous effect on the capital-labor ratio;*

(iv) *an increase in the absconding cost (π) increases the proportion of the population educated and decreases the capital-labor ratio.*

As far as a change in ϵ is concerned, the EE locus remains unaffected while the CR and SS loci both shift. Thus, in either unconstrained or constrained equilibrium, x and k change in opposite same directions (along the same EE locus). Their responses depend crucially on the relative size of the educated. For example, an increase in ϵ (i.e., a mean-preserving spread of the distribution of α's) raises x and reduces k as long as x is less than ½, which, as can be seen from (11), is true under the assumption of $\theta > v$ (Condition U). Diagrammatically, the effects of the increase in ϵ are represented by a shift in the SS locus; the shift is leftwards for $x < ½$. The explanation is that, when the majority of the population is low-skilled ($x < ½$), an increase in ϵ reduces the marginal disutility cost of education of the person on the margin between becoming educated and not becoming educated. The incentive to acquire education hence rises and more people become educated; with fewer unskilled workers, savings fall and more resources are used for education, so k must fall.

A change in the productivity (and wage) of the unskilled (v) does not affect the CR locus, but affects the SS and EE loci. This means in a constrained equilibrium, the opportunity cost effect (from a local perturbation in the neighborhood of the original constrained equilibrium) on education is absent. An increase in v not only results in a higher opportunity cost of becoming educated but generates more savings. Yet, under credit rationing, the opportunity cost effect is absent and the savings enhancement effect becomes the sole channel. As a consequence, there is more capital accumulation and the level of education increases.

The effects of an increase in the pecuniary cost of education (θ) on x is negative whereas its effect on k could go in either direction. Diagrammatically, the SS locus shifts rightwards and the EE locus inwards (since education is more expensive, less savings are available for capital accumulation). Intuitively, an increase in θ causes more agents to be credit constrained, thereby lowering the proportion of the population becoming educated. While the resultant increase in savings allows for more capital accumulation, the reduction in skilled labor lowers the marginal product of capital (due to capital-skill labor complementarity) and hence the demand for capital. Thus, the net effect on the capital-labor ratio is ambiguous.

Finally, an increase in the absconding cost (π) merely relaxes the severity of credit constraints, inducing a leftwards shift in the CR locus without affecting the SS and EE loci. As a result, more agents undertake education and the associated reduction in savings leads to a lower capital-labor ratio.

B. AN ALTERNATIVE APPROACH TO MODELING MORAL HAZARD

Under the alternative setup, the lender can ensure that the money lent is actually invested, but cannot appropriate the return. In this case, the borrower may invest in education and become a skilled worker without repayment. The incentive compatibility constraint is therefore modified to: $w_H - (1 + r)\theta - \alpha \geq w_H - \alpha - \pi$ (again, an agent who is exactly indifferent about absconding is assumed to choose not to do so), or, simply, $\pi \geq (1 + r)\theta$. Substituting (4c) into the constraint with equality yields a modified CR locus:

$$[1 + (1 - \beta)k^{-\beta} - \delta]\, \theta = \pi. \tag{15)$'$ (}$$

which determines a critical value of the capital-labor ratio, $k_{IC} = [(1-\beta)/(\pi/\theta - 1 + \delta)]^{1/\beta}$. When $k \geq k_{IC}$ the real rate of interest is at such a low level that the loan repayment becomes less than the absconding cost, thus ensuring incentive compatibility. The reader may find this incentive compatibility constraint is analogous to the limited liability constraint (PAii) in Sappington (1983, p. 6).

We now illustrate the constrained and unconstrained equilibria in Figure 4. A major difference from the basic model (analyzed by Figure 3) is that the CR locus is vertical in (k, x) space. By similar arguments as in the basic model, we give a condition for credit rationing to obtain:

Condition C′: (Credit Rationing) $\beta[(1-\beta)/(\pi/\theta - 1 + \delta)]^{(1-\beta)/\beta} > \pi/\theta > 1$.

Theorem 2′: (Existence of NSSECR) *Under Conditions E and C′, there is a unique non-degenerate steady-state equilibrium with credit rationing.*

The first inequality of Condition C′ guarantees that the incentive compatibility constraint is binding (so point C is to the right of point E). The second inequality of Condition C′ implies the constrained equilibrium (point C) is accompanied by a positive real interest rate.

By comparing the constrained and unconstrained equilibria, one can easily see that credit rationing results in a lower level of education, a higher capital-labor ratio, a lower real interest rate, and a greater skilled wage rate in the steady state, as in the benchmark model. However, the comparative statics differ in two respects: (i) a mean-preserving spread of the distribution of α's will no longer have any influence on the steady-state level of education or capital-labor ratio; and, (ii) the effects of the opportunity and pecuniary costs of education on the capital-labor ratio will change (while k becomes independent of v, an increase in θ raises the capital-labor ratio unambiguously). However, the steady-state response of education to changes in the pecuniary cost of education and the effect of a change in the cost of absconding remain qualitatively unchanged.

Finally, are there any reasons for preferring one specification of the moral hazard problem facing lenders over the other? First, we note that if default costs are the same (i.e., whether one defaults as a worker or a non-worker), borrowers will always prefer to work and default rather than take the money and run. This can easily be seen by comparing the two incentive compatibility constraints and noting that lenders will only lend to borrowers for whom the net benefits of education (i.e., skilled wage less loan repayment less subjective cost) are nonnegative. However, it is highly plausible that the costs of default are higher for workers. There are two reasons for this; one is that a worker will probably need to disclose information about himself to become employed and reveal information while employed; also, being employed makes it more difficult to hide from one's creditors (for example, it may be possible to find out one's place of work). For this reason, the likelihood of being punished for default should be much higher for the employed. Secondly, the penalties that can be imposed on an employed worker will likely be higher (as he will have more assets that can be seized). If the expected cost of default always exceeds $(1 + r)\theta$ (for possible values of r) then the incentive compatibility constraint never binds for employed workers and we can use our preferred assumption that default means absconding with an education loan without being educated.

5. PUBLIC POLICY

We now turn to the question concerning what public policy can do to remedy the problem caused by credit market imperfection, namely that some individuals for whom the private (and social) return to education exceeds the relevant interest rate cannot obtain financing. We assume that the government cannot do anything which directly impinges upon the source of the problem, namely that there is no way in which borrowers can commit to repaying loans. We consider two policy issues: (i) whether a Pigovian subsidy to education can restore the Pareto-efficient unconstrained equilibrium and (ii) optimal public provision of education. In addressing these issues, the question arises as to how the government spending is financed. We allow for two possibilities: the first is a tax on the old educated, the second is a tax on the young unskilled. The former is a tax on the beneficiaries of education and hence (arguably) justified on equity grounds; conversely, the latter does not affect the goods market equilibrium condition (see the discussion later) and hence might be argued to be nondistortionary.

A. EFFECTIVENESS OF A PIGOVIAN SUBSIDY TO EDUCATION

We consider a Pigovian subsidy s to everyone who buys education. Thus, the price of education faced by a potential purchaser falls to θ - s. We use τ_H to denote the wage tax rate on the old educated (paid in the second period of their lives) and τ_L to represent the wage tax rate on the young skilled (paid in the first period of their lives).[20] Taking into account tax effects, (8a) and (8b) are modified to obtain steady-state consumption of the skilled and the unskilled, respectively: $C_H = [w_H(1 - \tau_H) - (1 + r)(\theta - s)]x$; $C_L = v(1 - \tau_L)(1 + r)(1 - x)$. Utilizing these expressions, the EE locus now becomes:

$$r[x(k + \theta) - v(1 - x)] + xw_H\tau_H = (1 + r)[sx - v(1 - x)\tau_L]. \qquad (17)$$

This may be compared with equation (11), which results when $\tau_L = \tau_H = s = 0$.

Since our focus is on permanent government expenditure/subsidy and flat taxes, debt financing is not sustainable. The (steady-state) government budget constraint can thus be written as:

$$sx = x\tau_H w_H + (1 - x)\tau_L v, \qquad (18)$$

which can be substituted into (17) to obtain the corresponding EE locus:

$$x(k + \theta - rw_H\tau_H) = v(1 - x). \quad (19)$$

So a subsidy shifts the EE locus only if it is financed, at least partly, by a tax on the educated (τ_H). If it is financed by a tax on the uneducated (τ_L), this does not change the resources available for financing education - the savings of the uneducated are reduced by exactly the amount of the tax, so the reduction in private finance is offset by the government's finance. This is not so when the subsidy is financed by taxing the educated: provided $r > 0$, such a tax changes the resources available for financing education and capital accumulation, as shown by the last term on the left-hand side of (19). Notably, this intertemporal effect is absent in static public finance models.

Turning now to the CR locus, it now becomes:

$$(1 - \tau_H)w_H = 2(1 + r)(\theta - s) - \pi - \epsilon(1 - 2x). \quad (20)$$

Consider first the case where $\tau_H = 0$. By comparing (20) with (10), it is seen that for the CR locus in the presence of a subsidy to coincide with the original SS locus, the subsidy needs to be set at the level: $s = (\theta - v) - \pi/(1 + r)$, which is positive under Condition C. So with such a subsidy, the original unconstrained equilibrium is restored. When $\tau_H > 0$, a simple Pigovian subsidy ensuring the CR and original SS loci to coincide induces a shift in the EE locus. Thus, the unconstrained equilibrium is not restored.

Moreover, denoting r' as the pre-subsidy, credit constrained real rate of interest, we consider,

Condition P: (Pareto Improvement) $v(r - r') > (1 - \delta)(\theta - v)$ and $x < ½$.

These conditions are sufficient to ensure that an education subsidy at the level $s = (\theta - v) - \pi/(1 + r)$, financed by a tax on the unskilled leads to unambiguous Pareto improvements over the constrained equilibrium in the absence of policy intervention. Although the unskilled are worse off because of the tax, they are better off as a consequence of the resultant increase in the real interest rate, and, under Condition P, the second effect outweighs the first. In this case, those who remain skilled or unskilled and who switch from unskilled to skilled are all better off and hence such an education subsidy policy is Pareto-improving. This also reconfirms the Pareto inefficiency property of the constrained equilibrium. Summarizing,

Proposition 4: (Education Subsidy) *In the presence of credit market imperfections, a Pigovian subsidy to education at* $s=(\theta-v)-\pi/(1+r)$ *financed solely by a tax on the young unskilled can restore the unconstrained equilibrium, whereas a subsidy financed at least partly by a tax on the old educated cannot do so. Under Condition P, the former subsidy leads to a Pareto improvement over the constrained equilibrium.*

B. OPTIMAL PUBLIC PROVISION OF EDUCATION

We now consider that the government provides education free of cost to users, again financing it with a tax on either the old educated or young unskilled. We assume that those with the lowest subjective costs of education are educated (i.e., any given amount of education is allocated efficiently) and that there are no cost differences between the public and private provision of education.[21] The government effectively picks a point on the EE locus, taking into account how the locus is affected by its financing method. So the CR and SS loci are no longer relevant in pinning down the level of education, although the SS locus is crucial in determining whether education is "rationed" or "mandatory". If the level of x determined by the government is lower than that determined by the intersection of the EE and SS loci, then education is "rationed" - that is, some individuals for whom the net private benefits of education are positive are not educated. On the other hand, if the value of x that the government chooses is greater than that given by the intersection of the two loci, we describe education as "mandatory" - that is, some individuals for whom the private net benefits of education are negative nevertheless are educated. We assume that mandatory education can be costlessly enforced.

Consider that the government seeks to maximize an appropriately defined social welfare function, subject to the relevant constraints, which are the goods market equilibrium condition (equation (17) with θ

replacing s) and the government budget constraint (equation (18) with θ replacing s). The government's instruments are x and one of the tax rates (depending on the government's financing scheme). It is useful to define the private net benefit of education (Γ):

$$\Gamma \equiv (1 - \tau_H)w_H - (1 + r)(1 - \tau_L)v - \epsilon(2x - 1). \quad (21)$$

For comparison purposes, we give the private net benefit of education for the case where education is privately provided in the absence of credit rationing:

$$\Gamma^U \equiv w_H - (1 + r)(\theta + v) - \epsilon(2x - 1). \quad (22)$$

Intuitively, Γ represents the net benefit of education of the person with the highest disutility of education (α) who is educated. If it is positive, education is rationed; a negative value of Γ means education is mandatory.

By substituting the government budget constraint (18) into (17) (with θ replacing s), we obtain the modified EE locus as: $(1 - \tau_L)v(1 - x) = kx$. There are two cases to distinguish. The first, EE^H, is where education is financed entirely by taxation of the skilled ($\tau_L = 0$):

$$xk = v(1 - x), \quad \text{with } \tau_H = \theta/w_H(x). \quad (23)$$

The second, EE^L, is where education spending is financed by taxation of the uneducated ($\tau_H = 0$):

$$x(k + \theta) = v(1 - x), \quad \text{with } \tau_L = \theta x/(1 - x)v, \quad (24)$$

which is identical to the original locus, i.e., EE^L coincides with EE. Further examination of (23) shows that EE^H lies to the right of the original EE locus, with a vertical intercept of 1 (see Figure 5). The explanation is that with education financed by the taxes paid by the skilled, all the savings of the unskilled now go into physical capital accumulation; however, with the unskilled taxed for such a purpose, no additional resources are generated for human and physical capital accumulation. Thus, the macroeconomic consequences of government spending on education may depend critically on how it is financed.

We next specify the government objective. A natural approach is to use the equally weighted utilitarian social welfare function (recall that the individual utility function is linear):

$$\Omega \equiv C_H(x) + C_L(x) - \epsilon x(x - 1). \tag{25}$$

The first two terms are total consumption of the skilled and unskilled, respectively. The last term subtracts the "total disutility of education" of those who become educated.[22] Therefore, in the social optimum, the government chooses x to maximize (25), subject to the appropriate constraint (i.e., either (23) or (24) depending on the financing method). An increase in x affects social welfare, first of all, because it transfers people from the unskilled to the skilled sector, raising social welfare if the marginal person transferred is better off (which is true provided that the private net benefit Γ is positive). However, there are also general-equilibrium effects on social welfare stemming from the induced changes in before-tax factor prices (which are shown in the Appendix to exactly cancel under the constant-returns-to-scale production technology). There is an additional "government revenue" effect via the corresponding changes in the tax rates needed to balance the budget.

We can derive results on socially optimal public provision of education:

Proposition 5: (Socially Optimal Public Provision of Education) *Under an equally weighted utilitarian social welfare function, the socially optimal public provision of education possesses the following properties:*

(i) *when it is financed by a tax on the educated, the private net benefit is zero at the margin, and the resultant education level and private capital accumulation are higher compared to the unconstrained equilibrium;*

(ii) *when it is financed by a tax on the unskilled, the resultant level of education is the same as that in the unconstrained case; however, education is rationed with the educated better-off and the uneducated worse-off than in the unconstrained equilibrium.*

Since taxing the unskilled does not affect the EE locus, it is possible for the unconstrained equilibrium allocation to be achieved in this case, and it is interesting that in this case social optimality means that exactly the same level of education is chosen. However, although taxing the unskilled does not affect the EE locus, it does obviously affect the attractiveness of education for the unskilled (who, compared with the unconstrained case are worse off by the extent of the taxes they pay to finance education; those who become educated are better off since they now do not pay for their education at all). It follows that for public education financed by taxation of the unskilled, optimality requires rationing of education - that is, the marginal person educated derives positive net private benefit from education and there are some people for whom the private benefit of education would be positive who are not educated. The reason for the discrepancy between individual and social optimality is that the state takes into account the fact that someone who transfers from the unskilled to the skilled sector thereby avoids paying taxes, and therefore restricts access to education for that reason. Put differently, there is a private benefit to becoming educated (avoiding taxation) which is not a social benefit, hence requiring education to be restricted for optimality. This "tax avoidance" effect does not exist in the case when the beneficiaries of education are taxed. In this case, there is a coincidence of private and public incentives -social welfare will increase as long as the marginal person educated is individually better off.

A diagrammatic illustration may be helpful (see Figure 5). Let SS^H and SS^L represent the private SS loci in the case of taxation of the skilled and the unskilled, respectively. These loci are derived by setting τ_L equal to zero and τ_H equal to zero, in turn, in equation (21) and can be directly compared with the original SS locus (which is equivalent to (22)). Obviously, SS^L lies above SS^H: for any given k, and hence w_H and r, the return to becoming educated is higher if the low-skilled, rather than the high-skilled, finance it through taxation, and therefore the equilibrium level of x is higher. We can also see that SS^H is above the original SS locus, because the private net benefit with taxation of the skilled exceeds that in the absence of credit constraints for a given value of k. A indicates the unconstrained equilibrium, which is also the social optimum in the case of

$\tau_H = 0$. The social optimum in the case of $\tau_L = 0$ is given by point A. It is clear that the socially optimal public provision of education financed by a tax on the educated (point A) results in a higher level of x than the unconstrained equilibrium (point E). Moreover, the fact that point E lies below the SS^L locus indicates that when public spending is financed by taxing the unskilled, education must be rationed. On the other hand, since point A lies on the SS^H locus, public education financed by taxing the skilled is neither rationed nor mandatory – we described such education as "voluntary."

So far, we have carried out the analysis with an objective function which does not embody inequality aversion. How would a social welfare function which put more weight on the utility of the poor than the rich change matters? An analysis of this case turns out to be quite complex and hence not provided here. However, we point out that one implication is that such a social welfare function could imply the desirability of mandatory education. Suppose we consider the social optimum with taxation of the high skilled which, as shown above, means voluntary education. Now let us introduce some inequality aversion into the social welfare function. This means giving more weight to the welfare of the unskilled rather than to that of the skilled. But the only way the state can attain this modified social welfare maximum is to raise x, which raises the marginal product of capital and the real interest rate, and hence increases the well-being of the uneducated. Thus, the modified optimum lies above the SS^H locus, which involves mandatory education.

6. CONCLUSION

This paper has presented an overlapping-generations model with educational choice where lenders cannot ensure that money lent is actually invested in human capital accumulation. This gives rise to the possibility of credit rationing, which means that certain potentially mutually beneficial transactions do not take place. We consider some comparative statics effects in both the credit-rationed and the non-credit-rationed economy, and explore the difference credit rationing makes. In general, it seems that credit rationing reduces the amount of human capital accumulation and raises physical capital accumulation.

We explore the effects of public policy designed to remedy the problem. One important consideration is how the government finances its spending on education. It turns out that a given amount of government spending on education reduces capital accumulation more if it is financed by taxing the unskilled than by taxing the skilled. The optimal level of government spending on education is greater if it is financed by taxing the educated than by taxing the uneducated; the latter optimum, but not the former, entails rationing of education. If the government objective function exhibits inequality aversion, then the optimum with education financed by taxing the skilled may involve mandatory education. It seems that on both efficiency and equity grounds a strong case can be made for education to be financed by taxation of the educated – this is of relevance to the discussion that is taking place in a number of countries about the financing of education (particularly higher education). A tax on the educated to finance higher education may be described as a "graduate tax," something that has been proposed in a number of countries and implemented in Australia.

Of possible extensions to our analysis, we would mention two. First, one may extend our model to allow for endogenous growth in a way similar to Glomm and Ravikumar (1992) and then study issues concerning growth versus inequality in our framework. In particular, what is the consequence of *ex ante* distribution (of the disutility cost of education) on economic growth? How does the *ex post* distribution of income evolve as the economy grows? Under what condition can the Kuznets hypothesis be supported? Another possible extension relates to the fact that we have considered two extreme alternatives - either entirely private or entirely public education. In reality, private and public education coexist, and it would be interesting to develop a model which allows for this possibility. We have noted that with public provision of education (free to the user) there will often be excess demand for education and hence rationing (although there are circumstances under which mandatory education might be desirable). Private schools may hence be set up to educate some of those rationed out of the state sector. However, there is a "lemons" problem if the state could choose those with the lowest private cost of education. It also seems that no one would be educated at a private school if it were possible to secure a place at a public school, which is obviously counterfactual. To generate the possibility of the co-existence of private and public education, one might allow private education to be more efficient and relax the assumption that there is a unique outcome to education. Peer group effects together with unequally generated wealth might produce an interesting model with the rich being educated at expensive private schools with positive peer group effects raising the incentive to be educated privately (as well as being a source of externalities). An analysis of appropriate public policy in such a model can generate rich economic implications.[23]

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APPENDIX

Proof of Proposition 1: First, recall that the CR locus cuts the SS locus from below. By utilizing Figure 2 to compare the unconstrained (point E) and constrained (point C) equilibria, the results of lower x and higher k (and hence higher w_H and lower r) follow immediately. In the absence of market imperfections or distortions, it is clear that the unconstrained equilibrium is Pareto efficient. To show the Pareto inefficiency of the constrained equilibrium, we use a revealed preference argument. In the presence of credit rationing, there is a fraction of agents of positive measure who desire education but are forced to be uneducated – they are unambiguously worse-off. It is therefore clear that credit constrains limit individuals' choice without enhancing the production possibility set. Thus, the constrained equilibrium is Pareto inefficient, though it is not Pareto comparable to the unconstrained equilibrium (because those remaining skilled are better-off whereas those remaining unskilled are worse-off under credit rationing). ■

Proof of Proposition 3: We define the determinant of the pre-multiplying matrix as $\Delta \equiv 2x\epsilon - a_{12}a_{21} \equiv 2x\epsilon + (k + \theta + v)(k+2\theta)(r + \delta)\beta/k > 0$. Applying Cramer's rule to (16) yields:

$$dx/d\epsilon = (1 - 2x)x/\Delta \quad > 0 \quad (\text{for } x < ½)$$
$$dk/d\epsilon = - (1 - 2x)(k + \theta + v)/\Delta \quad < 0 \quad (\text{for } x < ½)$$
$$dx/dv = (1 - x)\beta(r + \delta)(2\theta + k)/k\Delta \quad > 0$$
$$dk/dv = 2\epsilon(1 - x)/\Delta \quad > 0$$
$$dx/d\theta = -x[\beta(r + \delta)(2\theta + k)/k + 2(1 + r)]/\Delta \quad < 0$$
$$dk/d\theta = 2[(k + \theta + v)(1 + r) - \epsilon x]/\Delta$$
$$dx/d\pi = x/\Delta \quad > 0$$
$$dk/d\pi = - (k + \theta + v)/\Delta \quad < 0.$$
■

Proof of Theorem 2′: From (9) and (11), the unconstrained equilibrium capital-labor ratio k^U solves:

$$\begin{aligned}\Phi(k) &\equiv \{\beta k^{1-\beta} - (\theta + v)[1 + (1 - \beta)k^{-\beta} - \delta]\}(\theta + v + k) + \epsilon(\theta - v + k)\\ &= \{\beta k^{1-\beta} - (\theta + v)[1 + (1 - \beta)k^{-\beta} - \delta] + \epsilon\}(\theta + v + k) -2 \epsilon v\\ &= 0,\end{aligned}$$

where Φ is locally increasing in k because (9) implies $\beta k^{1-\beta} - (\theta + v)[1 + (1 - \beta)k^{-\beta} - \delta] + \epsilon = 2 \epsilon x > 0$ at $k=k^U$.

In order for an NSSECR to exist, we must thus have $k^U < k_{IC} < k_{max}$, where $k_{IC} = [(1-\beta)/(\pi/\theta - 1 + \delta)]^{1/\beta}$ and $k_{max} \equiv [(1-\beta)/\delta]^{1/\beta}$. Obviously, the second inequality is equivalent to $\pi > \theta$. We next turn to establishing a sufficient condition to ensure the first inequality. Utilizing the locally monotone increasing property of Φ, we have $k^U < k_{IC}$ if $\Phi(k_{IC}) > 0$. Since $1 + (1 - \beta)(k_{IC})^{-\beta} - \delta = \pi/\theta$, $\theta > v$ and $k > 0$, it is sufficient for $\Phi(k_{IC}) > 0$ if $\beta(k_{IC})^{1-\beta} > \pi/\theta$. Finally, the uniqueness property is trivial as the EE locus is downward sloping while the CR locus is vertical. ■

Proof of Proposition 4: The first part of the Proposition concerning the possibility of either type of education subsidies to restore the unconstrained equilibrium has been proved in the text. We therefore focus on the second part: a subsidy of education by taxing the unskilled may generate Pareto improvement under Condition P. To perform Pareto ranking, we distinguish three types of agents: (i) (type-H) originally skilled under credit rationing and still skilled with subsidy; (ii) (type-M) originally unskilled under credit rationing and skilled with subsidy; and, (iii) (type-L) originally unskilled under credit rationing and still unskilled with subsidy. By the revealed preference argument, all type-M agents are obviously better-off with the education subsidy. In the constrained equilibrium with an education subsidy at the level $s = (\theta - v) - \pi/(1 + r)$, both x and k are restored to the unconstrained values, as do w_H and r, thus implying,

$$c_H = w_H(1 - \tau_H) - (1 + r)(\theta - s); \quad c_L = v(1 - \tau_L)(1 + r).$$

In the constrained equilibrium without education subsidy, we have:

$$c_H' = w_H' - (1 + r')\theta; \quad c_L' = v(1 + r').$$

where primes are use to denote pre-subsidy variables under credit rationing. Define D_i as the net utility change of a type-i agent from a constrained equilibrium without subsidy to that restoring the unconstrained level of (x,k) with a subsidy s. Using the SS locus (10) and the CR locus (20) to substitute out w_H and w_H', respectively, and applying the expression for s and the government budget constraint (18), we obtain:

$$D_H = c_H - c_H' = 2\epsilon(x - x') + \theta(r - r') - (1 - \delta)(\theta - v);$$

$$D_L = c_L - c_L' = v(r - r') - (1 - \delta)\,[\theta - v - \pi/(1 + r)]\,[x/(1-x)]$$

From Proposition 1, we learn that $x - x' > 0$ and $r - r' > 0$. Also, recall that $\delta < 1$ and $\theta > v$. Thus, under Condition P (i.e., $v(r - r') > (1 - \delta)(\theta - v)$ and $x < ½$), both $D_H > 0$ and $D_L > 0$. That is, an education subsidy at the level s leads to a Pareto improvement. ■

Proof of Proposition 5: We denote the net private benefit of education in the case of taxing the unskilled ($\tau_H = 0$) by Γ^L, and by Γ^H for the case of taxing the skilled ($\tau_L = 0$). From (21), one obtains:

$$\Gamma^L \equiv w_H - (1 + r)(1 - \tau_L)v - \epsilon(2x - 1); \;\; \Gamma^H \equiv (1 - \tau_H)w_H - (1 + r)v - \epsilon(2x - 1).$$

Taking into account the government budget constraint (with either $\tau_L = 0$ or $\tau_H = 0$), we get:

$$\Gamma^U = \Gamma^H - r\theta = \Gamma^L - \theta(1+r)/(1-x).$$

Consider the case where $\tau_L = 0$. Let k(x) denote the level of k as a function of x given by equation (23), and write the high-skilled wage and real interest rate as $w_H(k)$ and r(k), respectively. Then the first-order condition for maximizing the social welfare function, as specified in (25), with respect to x is:

$$\Gamma^H + [x\, dw_H(k)/dk + v(1 - x)\, dr(k)/dk]\, dk(x)/dx \quad = \quad 0.$$

Using (23), the term in the square bracket on the left-hand side of the above equation can be rewritten as: $[dw_H(k)/dk + k\, dr(k)/dk]x$, which is zero under our CRS production technology. Thus, the condition for social optimality is that $\Gamma^H = 0$, or, equivalently, $\Gamma^U + r\theta = 0$. By $\Gamma^H = 0$, socially optimal provision of education is neither mandatory nor rationed; the optimal level of x (and k), however, is associated with $\Gamma^U < 0$, implying more investment in education (and capital accumulation) than in the unconstrained equilibrium.

We turn now to the case where $\tau_H = 0$. The first-order condition for social welfare maximization now becomes:

$$\Gamma^L + [x\, dw_H(k)/dk + v(1 - x)(1-\tau_L)\, dr(k)/dk]dk(x)/dx - (d\tau_L/dx)(1 + r)v(1 - x) \quad = \quad 0.$$

By similar arguments, (24) and the CRS production technology imply that the second term on the left-hand side is zero. Since $\tau_L = \theta x/[(1-x)v]$, the last term on the left-hand side reduces to $\theta(1+r)/(1-x)$. The condition becomes: $\Gamma^L - \theta(1 + r)/(1 - x) = 0$, or, $\Gamma^U = 0$. Therefore, social optimality requires rationing of education (since $\Gamma^L > 0$) and the optimal level of x (and k) exactly coincides with the unconstrained equilibrium (with $\Gamma^U = 0$). ■

Figure 1: Sequence of Actions in the Basic Framework

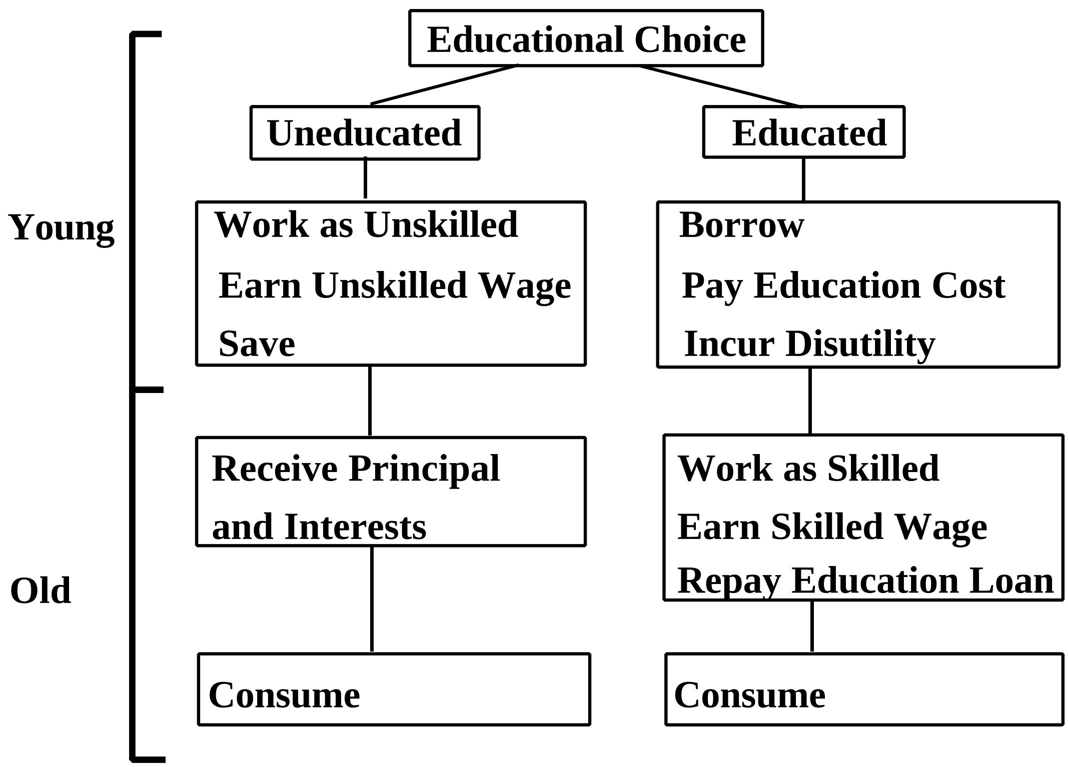


Figure 2: Nondegenerate Steady-State Equilibrium Without Credit Rationing

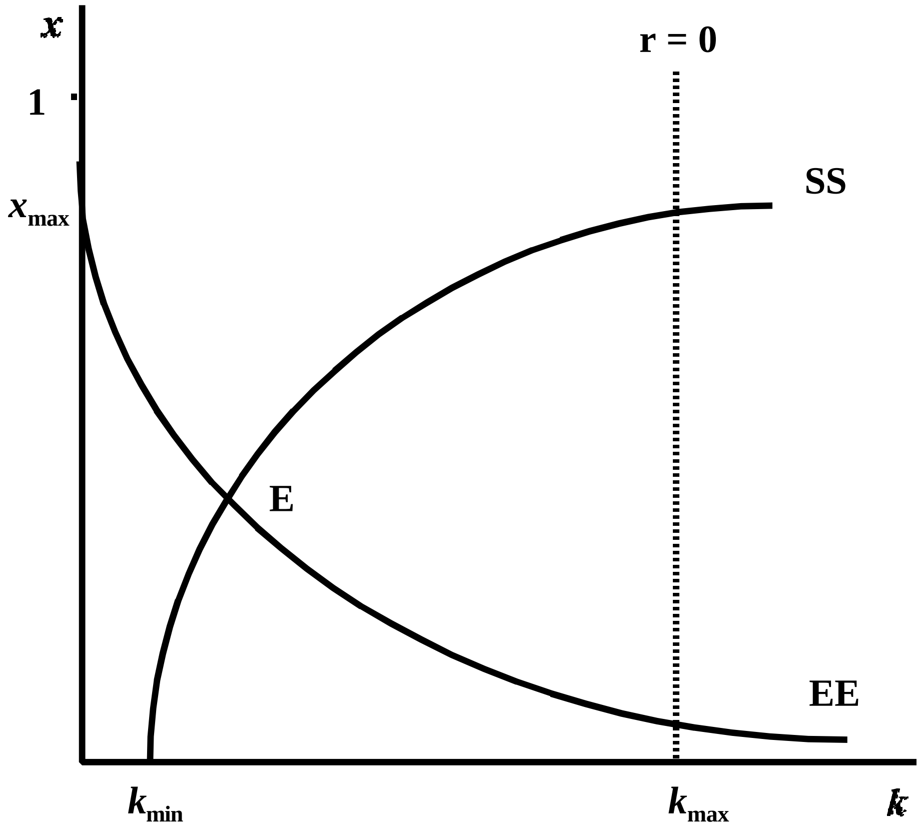


Figure 3: Nondegenerate Steady-State Equilibrium With Credit Rationing

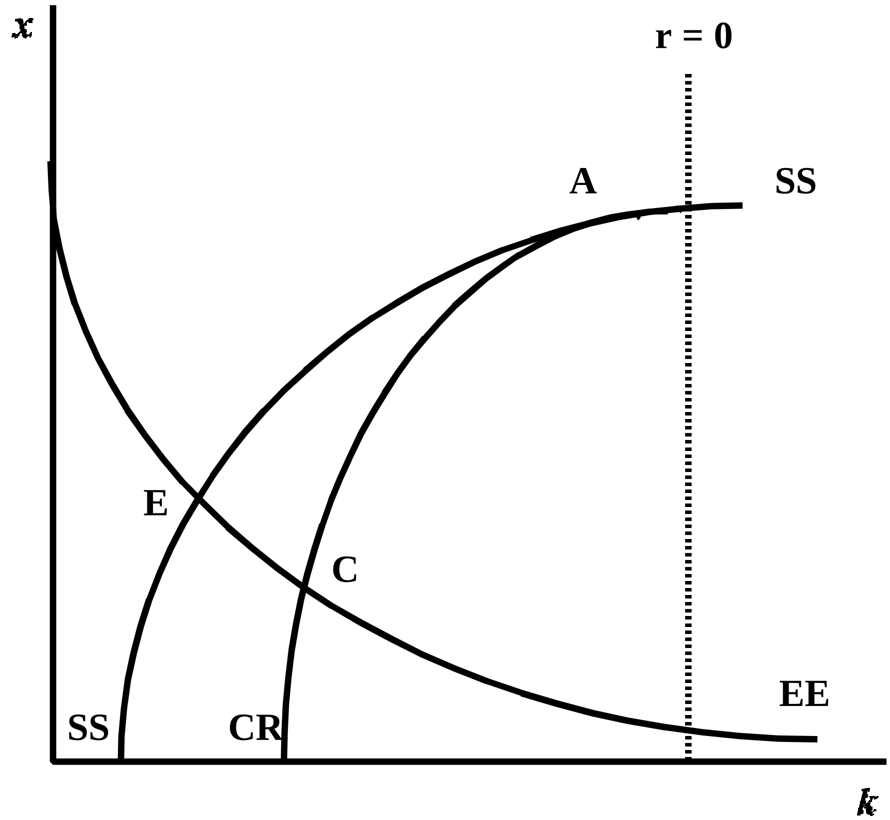


Figure 4: Nondegenerate Steady-State Equilibrium With Credit Rationing Under the Alternative Setup

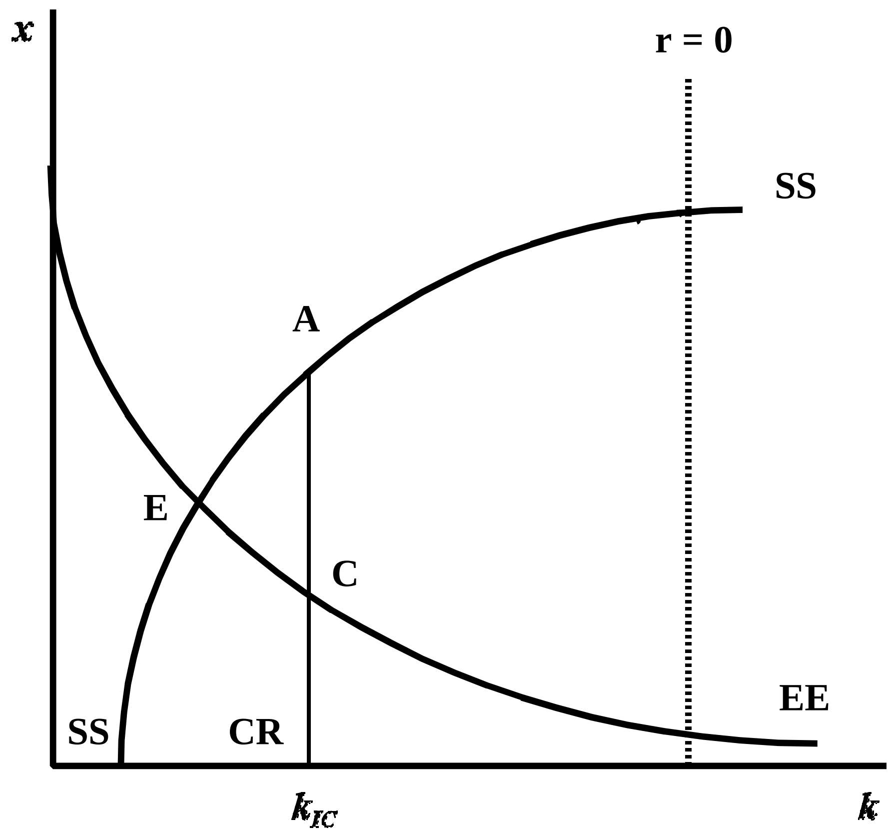
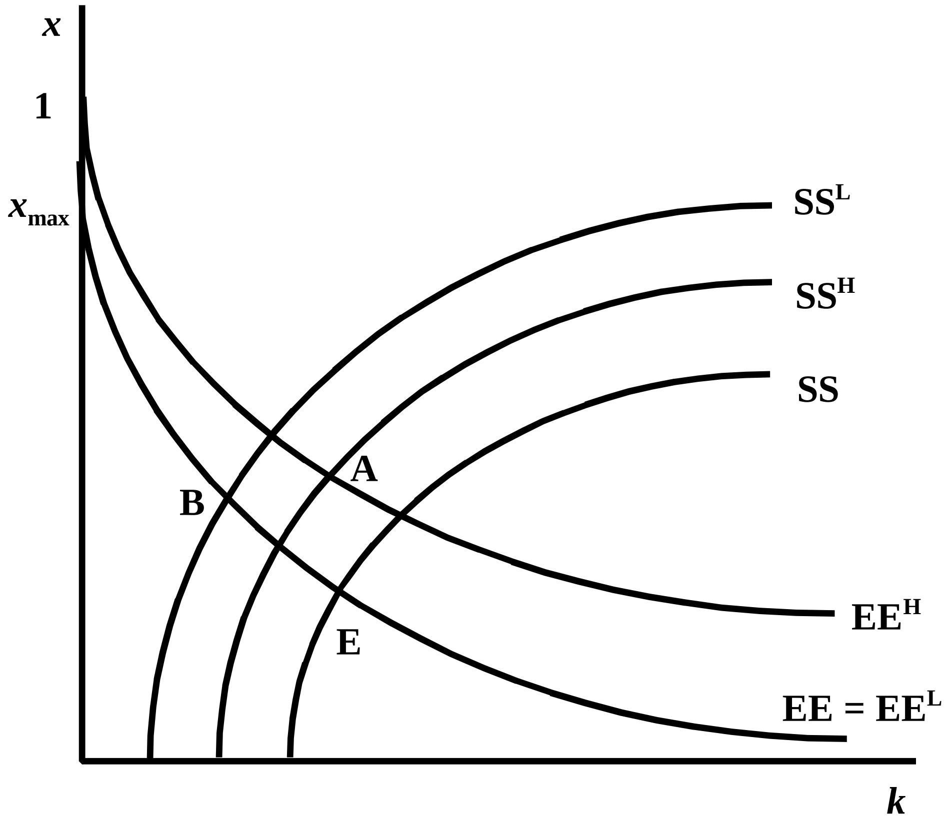


Figure 5: Optimal Public Education Policy



ENDNOTES

1. See, for example, Barro (1991), Mankiw, Romer and Weil (1992), and Benhabib and Spiegel (1994), suggesting in cross-country regressions that educational achievement accounts for 5 - 28% of output growth; in a case study of Taiwan, Tallman and Wang (1994) find the contribution of human capital up to 45%.

2. We discuss in more detail the differences between our paper and the rest of the literature later in the Introduction.

3. Moral hazard is defined by Keynes thus: “voluntary default or other means of escape, possibly lawful, from the fulfilment of the obligation” (Keynes, 1936, p. 144).

4. It might be asked whether the term “credit rationing” is appropriate since we do not have observationally equivalent borrowers, some of whom are granted loans whereas others are turned down – those who are rejected for loans are denied credit because they are worse risks than those who are successful. The fact that individuals' characteristics are observable means that borrowers are not observationally equivalent. Whether the credit market imperfection in our model should be described as credit rationing is something we regard as merely semantic, although it is compatible with the use of the term in some of the literature; readers who object may substitute “credit market imperfection(s)” for “credit rationing”.

5. Other related (but to a lesser degree) papers are Hare and Ulph (1981), Glomm and Ravikumar (1992), Azariadis and Smith (1993), Barham, Boadway, Marchand and Pestieau (1995), Laing, Palivos and Wang (1995), De Gregorio (1996) and Eicher (1996). Glomm and Ravikumar, Laing et al. and Eicher, among many others, model education in a dynamic general-equilibrium framework *without* considering credit market imperfections. Azariadis and Smith present a model of credit rationing in a *pure exchange* economy. Both Hare and Ulph and Barham et al. study educational choice and imperfect capital markets, assuming *exogenous* credit constraints and interest rates. De Gregorio incorporates *exogenous* borrowing constraints in a growth model with human capital accumulation. Finally, none of these papers permits an endogenous choice between borrowing and lending, which plays an essential role in generating the main results in our paper.

6. Aghion and Bolton (1997) allow for endogenous choice between becoming a borrower or a lender in a framework where individuals differ in initial wealth and physical investment loans are subject to credit constraints. Under a very different setup, they consider primarily the trickle-down effect of physical capital accumulation when credit constraints underpin persistent income inequalities.

7. Since credit rationing is endogenous, our discussion of “the consequences of credit rationing” might be objected to. We have a parameter which measures the costs of default, and when we discuss “the consequences of credit rationing,” what we really mean are “the consequences of reducing the costs of default

parameter”. We crave the reader's indulgence for such a terminological inexactitude.

8. It is for analytical convenience that we adopt the two-period lifetime model and assume that when agents are young only those not receiving education work (such an assumption is also made in Eicher (1996), for example). We have explored other possibilities, including an overlapping generations model with three-period lives, but found that while such a structure complicates the model, it does not change the basic results.

9. We could allow the uneducated to work in both periods without altering the results qualitatively.

10. The assumption that agents only value their second-period consumption implies that agents who choose to work in the first period necessarily save their entire first-period income (“forced savings”?). However, since occupational choice is endogenous, saving decisions are also endogenous. The assumption (that agents do not value first-period consumption) serves to simplify the analysis, without loss of generality. Similarly, the assumption of linear utility simplifies the optimal schooling criterion as well as the social welfare function (see Sections 2 and 5 below).

11. Individual (but not aggregate) uncertainty about the outcome of education can be handled with no essential changes in the framework, provided all agents are still able to repay their loans. If the outcome of the uncertainty is such that some individuals would be unable to repay their loans in full, there would be a number of changes (for example, lenders would require a higher interest rate on loans) which would complicate the analysis without changing anything essential, so we prefer to retain the certainty assumption about the outcome of education.

12. We shall sometimes contrast the results of this benchmark model with an alternative model which uses the opposite assumption, namely that the marginal product of skilled labor is constant and it is unskilled labor which combines with capital in a Cobb-Douglas technology. While we do not consider this alternative model particularly realistic, it allows us to check how robust the results of the benchmark model are. The more general case, where capital combines with both skilled and unskilled labor in a CES function is much more complex. Nevertheless, we have analyzed the case where skilled and unskilled labor are perfectly substitutable (with one unit of skilled labor substitutable for more than one unit of unskilled labor) and the appropriate labor aggregate combines with capital to produce output. It turns out that the results are virtually identical with those of the benchmark model. (Results for these versions of our model are available on request.)

13. The assumption of $\theta > v$ is sufficient but not necessary. It is imposed to simplify the analysis. One of its implications is that in equilibrium, the fraction of the educated population must be less than half (otherwise, there will be insufficient funds to support education expenditure); this further simplifies the comparative static results. Also, it is worth noting that in order for credit rationing to emerge (see Section 4 below), this

assumption is required; it can be weakened if we allow the unskilled and defaulters (who borrow but do not invest in education) to earn wages in the second period of their lives.

14. There are, of course, adverse selection arguments for credit rationing, as well, which we do not adopt here, because of their greater analytical complexity.

15. The account developed here is based on Fender (1995). Related moral hazard explanations of credit rationing are found in Banerjee and Newman (1993) and Kehoe and Levine (1993), as well as in Zeira (1991), Tsiddon (1992) and Galor and Zeira (1993).

16. In the absence of costs of financial intermediation, it is not necessary to distinguish the loan rate (which appears on the left-hand side of the inequality) from the deposit rate (which enters into the right-hand side). For those interested in this issue, see Chen, Chiang and Wang (1997).

17. Such costs therefore capture the spirit of Kehoe and Levine (1993) in which "creditors can seize the assets of debtors who default on their debts" (p. 869).

18. If lenders cannot observe α, then we would expect them to lend to everyone who requests a loan, but to charge a risk-related interest rate which ensures that they, on average, just break even. If there is no interest rate at which this happens, then there is no lending - a rather extreme case of credit rationing.

19. In the alternative model when capital and unskilled labor are complementary, the marginal product of capital effect tends to raise the rate of real interest. However, the negative effect of credit rationing on the real interest rate remains as long as its effect on the unskilled wage dominates its effect on the marginal product of capital. Notably, in the static, partial-equilibrium loanable funds model of Stiglitz and Weiss (1981), credit rationing is also associated with a lower real interest rate, due to an entirely different reason – a lower rate of interest reduces borrowers' incentive to undertake riskier projects.

20. Tim Besley has raised the point that if lenders can observe individuals' α's, the government should be able to do so as well, and should be able to condition taxes on values of α, and hence in our assumption about taxes, we are restricting the instruments at the government's disposal. One defence of our approach would be to suppose that, instead of being public information, an individual's value of α is private information, but she may costlessly and truthfully reveal it if it is in her own interest to do so, which would be the case when applying for a loan. However, the government would probably want to tax an agent with a lower α more (it would be taxing "surplus"), so it would not be in an agent's interest to reveal her own value of α to the government. More pragmatically, we might argue that lenders typically base lending decisions on a wider range of individuals' characteristics than do governments in their taxing decisions.

21. It is also assumed that when the government provides education, there is no private provision of education. This is reasonable if the amount of education provided by the state is greater than the amount that would be provided in the credit-rationed equilibrium (since no one will lend to those excluded by the state, as these will be sure to default), which is the case we analyze in the paper.

22. This is calculated as follows: the average disutility of education is $(-\epsilon + \alpha^*)/2$; multiplying this by x and using the steady-state version of (6) gives the last term on the right-hand side of (25).

23. Stiglitz (1974) presents a relevant analysis of educational choice between public and private school systems.