A note about credit rationing on research and development

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Abstract

This note develops an overlapping generations model with credit rationing on research and development, in which both are determined simultaneously and endogenously. The model provides a useful tool to examine different policies that may help alleviate the negative effect of financial constraints faced by firms. (JEL D82, D91, D92).

1 Introduction

The link between financial intermediation and economic growth has concentrated a great deal of academic attention during the last two decades. The empirical evidence, mostly in the form of cross-country studies, has shown a close positive relationship between the development of banking and the financial system on the one hand and economic growth on the other.[1]

The theory has been developed almost in parallel to the cross-section empirics. Research in this area has firstly identified the potential channels through which financial development could possibly promote economic

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[1]For example, King and Levine (1993a) find a positive and significant correlation between bank-credit development and faster economic growth. Similar results have been obtained in more recent empirical studies (e.g. Rousseau and Watchel, 1998; Rioja and Valev, 2004).

growth, either by enhancing the social productivity on investment (e.g. Greenwood and Jovanovic, 1990), or by increasing the fraction of savings channelled to productive investment (e.g. Bencivenga and Smith, 1991). Although these analytical contributions were more realistic in their approach to the problem than standard models of growth and development along the neoclassical tradition,[2] they treated the financial market in a relatively simple fashion.

The additional issue of the role played by agency costs due to asymmetric information in weakening economic development would have been taken up in a second group of papers. Central to this kind of literature is the interaction between informational asymmetries that give rise to credit rationing and real growth in an overlapping generations model of any kind.

In this sense, the seminal article of Bencivenga and Smith (1993) is significant.[3] They present a model where they analyze the effect of credit rationing through an endogenous growth model. In their framework, externalities of the type presented in Shell (1973) and Romer (1986) are incorporated in the model via the production technology. Information asymmetries are built in by assuming that there two distinct groups of agents (high vs low ability agents) and lenders cannot easily distinguish between the two groups. Faced with an adverse selection problem, lenders' optimal reaction may lead them to ration credit. This puts a limit on the attainable growth rate of the economy. As a consequence, policies designed to reduce credit rationing by guaranteeing some loans, promote growth, so that there is room for some policy intervention.

In this note, I intend to further elaborate in this direction. Building on the work of Bencivenga and Smith (1993) above mentioned, I propose a theoretical framework to examine the consequences of asymmetric information in financing R&D expenditures.

In fact, it is intuitively plausible that informational frictions are more severe with regard to firm expected to invest more (or exclusively) in R&D (hereafter R&D).[4] This is due to the unique characteristics of it: long term in nature, high risk in terms of probability of failure, quite unpredictable in outcome,[5] labour intensive and idiosyncratic. (Holmstrom, 1989) Thus,

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[2]Since, in these models, markets are perfectly competitive and agents symmetrically informed.

[3]Similarly, Ma and Smith (1996).

[4]The relatively few empirical studies on R&D financing, confirm this hypothesis. See, for example, Hall (1992) and, more recently, Ozkan (2002).

[5]A R&D project may not be a technological success, or it may not meet the needs of

sorting out good and bad projects is more difficult than in more traditional fields. Furthermore, entrepreneurs have poor incentives to disclose information to investors since this might reveal useful for competitors. (Carpenter and Petersen, 2002; Bhattacharya and Ritter, 1983)

The key point is to show the way credit rationing can affect this rate of growth, since it affects the level of R&D and therefore innovation. However, it is not just a problem of substituting R&D expenditure for physical capital. We need to treat explicitly the R&D and it's stochastic nature in a formal analysis. To my knowledge this is the first model to specifically address this issue.

The model below endogenizes credit rationing and real growth rates simultaneously. Abstracting from Bencivenga and Smith (1993), I will use a simple non-deterministic production function with just one input (labour) and where R&D plays a role in such a way that we can avoid diminishing returns. The function, however, exhibits diminishing returns to labour input. In this economy, the only investment that takes place is on R&D and these investments will be financed only by credit. The rationale for using R&D as the only type of investment (instead of physical capital) is because I consider that R&D more susceptible to credit rationing since it cannot be used as a collateral.[6]

The model considers also two types of agents: low and high ability individuals. The low ability individuals have less probability of being successful in the R&D activity. Lenders in this model, do not have complete information about potential borrowers. Hence asymmetric information is present in this model. This framework show that the probability of getting a loan for a low ability individual is higher than for a high ability individual. In this context whenever credit restrictions are present, the group that is more likely to succeed in R&D activity will face this financial constraint.

The model provides also a tool to examine different effects from changes in parameters.

The paper is organized as follows: section 2 develops the model. Section 3 performs some comparative static exercises. Section 4 concludes.

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the marketplace, or competitors may develop a better, cheaper product more quickly.

[6]Note that a number of theoretical papers (e.g. Basanko and Thakor, 1987; Bester, 1985) have argued that collateral can fit as a sorting device (for example between good risk and high risk borrowers). Since R&D is not a collateral, those theoretical arguments cannot apply.

2 The model

2.1 Households

Time is discrete and indexed by $t = 0, ..., \infty$. There is a countable infinite number of two-period-lived agents belonging to overlapping generations of non-altruistic families. The size for all generations is identical. In particular, at each time t, we have two simultaneous generations: the old generation and the young generation. Old generation has no labour endowment. Each young generation is divided at birth into two groups of market participants, lenders and borrowers. To fix ideas, I normalize the size of each generation to one, of which one-half are lenders and the other half are borrowers, and each agent has a unit of labour endowment, which I suppose to be supplied inelastically. I proceed with the formal description of the economy with reference to circumstances facing agents of generation t.

Young lenders at time t sell their labour to firms receiving the real wage w_t, of which they decide to consume some at time t or to loan to other agents (borrowers). The utility function of young lenders can be captured by:

$$U^l = c^l(1) + c^l(2) \tag{1}$$

where $c^l(t)$ is the consumption of lenders (l) at time $t = 1, 2$.

The utility function of young borrowers (b) is given by:

$$U^b = c^b(2) \tag{2}$$

where $c^b(2)$ is the consumption of borrowers at time $t = 2$.

I assume that lenders do not have consumption good endowment at the end of the period. Young borrowers also have unit of labour at time t. For which, they have two different possibilities. First, they can sell the labour to the firms and receive (wages) w_t. In this case they will store the consumption goods (w_t) until next period $t+1$, because young borrowers care more about old age consumption. If they store these consumption goods they will receive a return $\beta_i \leq 1^7$ units of the consumption good at time $t+1$.

Or they can allocate the labour unit to operate a R&D project. However, to exploit such an opportunity, a borrower must acquire consumption goods

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[7] The index i will be defined below.

q (as a form of "external finance") from a lender of the same generation, in addition to her own unit of labour.

The result of this project is a stochastic process. They can receive qQ[8] units of "innovation" at time $t+1$ with probability p_i or zero units of R&D (innovation) with probability $(1-p_i)$.

Young borrowers are divided into two different groups:

a) High ability to develop the R&D project which can be considered as "low risk" agents (type L). A fraction of $(1-\lambda) \in (0,1)$ are of type L.

b) Low ability to develop the R&D project which can be considered as "high risk" agents (type H). A fraction of $\lambda \in (0,1)$ borrowers are of type H.

The values p_i $(i = L,\ H)$, satisfy:

$$1 \geq p_L > p_H \geq 0 \tag{3}$$

and the β_i values satisfy:

$$\frac{\beta_L}{p_L} > \frac{\beta_H}{p_H} \tag{4}$$

Condition (4) implies that $\beta_L > \beta_H$, which means that high ability agents can obtain a higher return in case they sell their labour endowment and they store it until period $t-1$.

2.2   Firms

Young borrowers that operate successful R&D projects become firm owners to produce final goods, using labour as the only input to manufacturing. The productivity of labour will depend on the amount of R&D that they use. They can rent labour at the competitive price w_t and also they can rent R&D at the rental rate ρ_t.

The production function that firms use to produce final goods (consumption goods) is described by:

$$Y_t = \alpha L_t^\theta \tag{5}$$

where $0 < \theta < 1$. The production function that I use exhibits diminishing returns to labour . However, we have to notice that total output depends on

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[8]Being Q an exogenous technological parameter representing the process of converting consumption goods (labour) into R&D.

the amount of labour that is used and also on the value of α. I assume that this parameter can take two values: high (α_h) with probability P or low (α_l) with probability $(1-P)$, depending on the amount of R&D that the firm uses. This probability depends on R&D (let's call it "x") and it satisfies:

$$P = P(x),\ P'(x) > 0,\ P''(x) = 0 \tag{6}$$

We can think of it as a density function to describe $P(x)$ in the following way: R&D could be expressed as an index of percentage with respect to total output. In which case the maximum value of R&D or "x" is 1 (or 100%). Now we can rewrite the production function of final goods as follows:

$$E(Y_t) = P(x)\alpha_h L_t^{\theta} + [1 - P(x)]\,\alpha_l L_t^{\theta} \tag{7}$$

and the expected profit function will be given by:

$$E(profit) = P(x)\alpha_h L_t^{\theta} + [1 - P(x)]\,\alpha_l L_t^{\theta} - w_t L - \rho_t x \tag{8}$$

The first order conditions can be expressed as:

$$\{P(x)\alpha_h \theta + [1 - P(x)]\,\alpha_l \theta\}\, L^{-(1-\theta)} = w \tag{9}$$

$$P'(x)L^{\theta}\,[\alpha_h - \alpha_l] = \rho \tag{10}$$

We can think of the first order conditions as the equality between marginal products and marginal costs of inputs. Notice that the marginal product of each input depends on the probability of having a high α which depends on the amount of R&D that we use in the production function.

2.3   Credit Markets

Assume that each agent knows which type she belongs to (*ex ante* information),[9] but she has no information about the rest of the agents. This fact produces the well-known adverse selection problem in the credit markets. (Stiglitz and Weiss, 1981; Takayama, 1993)

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[9]In particular, borrower quality is *ex ante* undetectable by the lender.

The bevaviour of agents in credit markets is as follows. At time t young lenders announce loan contracts consisting of three variables: (R_t, q_t, π_t), where R_t is the gross real interest rate, q_t is the quantity of loan offered by lenders, and π_t is the probability to get a loan once a borrower has applied for a credit contract. Lenders take other announcements (credit contracts) as given.

At the beginning of period t, each potential borrower applies for a credit contract that previously a lender has announced. The potential borrower can only apply to one lender.[10] With probability π_t, a type t borrower is granted the loan. In this case, type i borrower will undertake the R&D project. Otherwise, she has to sell the labour endowment to firms and to store this consumption goods w_t, obtaining a return $\beta_i w_t$ in the next period. The lender allocates q_{it} units of consumption good after he has received his salary w_t in order to provide the loan to the borrower. Obviously the loan quantity and salaries must satisfy the constraint: $q_{it} \leq w_t$.

Considering that borrowers care just about consumption (recall that $U^b = c^b(2)$), in the second period we can express the expected utility of a type i borrower as:

$$p_i \pi_{it}(Q\rho_{t+1} - R_{it})q_{it} + (1 - \pi_{it})\beta_t w_t \tag{11}$$

Equation (11) tells us that the probability π_{it} the borrower is granted the loan. Then the borrower allocates the labour unit that she has and q_{it} units of consumption goods that she has borrowed. With probability p_i, the R&D project is successful and he obtains Qq_{it} units of R&D (innovation). These units of innovation earns a return of ρ_{t+1} and borrowers have to pay to lenders the quantity $R_{it}q_{it}$.[11]

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[10] The assumption of one-to-one matching between lenders and borrowers is not uncommon in the literature (e.g. Bencivenga and Smith, 1993; Bose and Cothren, 1996, 1997; Bose and Pereira, 2004) and is made in the present context largely to save on notation. If a lender were to be approached by more than one borrower (each of whom is identical ex ante), then the lender would offer the contract on the same terms and divide her loanable funds equally between borrowers. Given that there are equal numbers of lenders and borrowers, the equilibrium outcome in each case would be equivalent to a one-to-one matching. Alternatively, the assumption might be justified by appealing to the existence of search costs which prohibit the breakup of any initial lender–borrower pairing.

[11] We need to assume that output is observable by everyone. Then lenders know about the successful of R&D projects. If they do not pay back the loan they will be punished in the next period.

With probability $(1 - \pi_{it})$ the loan is denied and the type i borrower sells the unit labour receiving w_t which she stores until next period receiving a return of $\beta_i w_t$. If the project results are unsuccessful, than the R&D output is zero and nothing is received or repaid to the lender.

We assume that borrowers prefer to undertake the R&D project rather than to sell their labour endowment to firms. Therefore equation (11) is increasing in π_{it}. This implies that:

$$p_i(Q\rho_{t+1} - R_{it})q_{it} \geq \beta_t w_t \tag{12}$$

Expression (4) implies that high quality (low risk-type L) borrowers are different from low ability borrowers (high risk-type H). Thus $(R_{Ht}, q_{Ht}, \pi_{Ht}) \neq (R_{Lt}, q_{Lt}, \pi_{Lt})$. This implies that self-selection occurs among borrowers in such a way that contract-loans should satisfy the following conditions:

$$p_H\pi_{Ht}(Q\rho_{t+1} - R_{Ht})q_{Ht} + (1 - \pi_{it})\beta_H w_t \geq p_H\pi_{Lt}(Q\rho_{t+1} - R_{Lt})q_{Lt} + (1 - \pi_{Lt})\beta_H w_t \tag{13}$$

and

$$p_L\pi_{Lt}(Q\rho_{t+1} - R_{Lt})q_{Lt} + (1 - \pi_{it})\beta_L w_t \geq p_L\pi_{Ht}(Q\rho_{t+1} - R_{Ht})q_{Ht} + (1 - \pi_{Ht})\beta_L w_t \tag{14}$$

These conditions mean that high ability borrowers will not accept credit contracts under low ability borrower's conditions, and *viceversa*. Therefore self-selection occurs. In this case, assuming that lenders have no incentives to offer an alternate contract at any date,[12] taking other contracts as given,

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[12]This assumption is not without consequences. In fact, a major difference between models of financial intermediation and growth, largely revolve around the treatment of the timing of asymmetric information. A standard result in the literature (e.g. Bencivenga and Smith, 1993; King and Levine, 1993b; Bose and Cothren, 1996) is that asymmetric informations play a role in precontracting and intermediaries are endowed with the ability to induce separation of heterogeneous borrowers by self-selection. However, as suggested by more recent models, there could be postcontract incentives, especially if it is the borrower who makes the first move (by way of approaching a lender with a loan application), therefore revealing additional information that the principal can use. Furthermore, there can be postcontract incentive for agents to shirk or deceive (e.g. Morales 2003; Aghion *et al.* 2005) but, as noted by Trew (2006), these moral hazard issues often simply add another wedge between agents and firms, scaling down balanced growth rates.

as well as ρ_t, we will have a Nash equilibrium in credit markets.

Also, we can see condition (13) as the condition that ensures that whoever applies for $[R_{Ht}, q_{Ht}, \pi_{Ht}]$ loan is certainly high risk. The contract is designed to make them reveal their type.

Now let us see the position of lenders is. The expected profit function of a lender could be expressed as:

$$E(profit)_{lender} = p_t R_{it} q_{it} - q_{it} \qquad (15)$$

I assume that competition drives lenders' economic profit to zero. Given that p_i $(i = L, H)$ is the probability with which the R&D project is successful (and so the lender is repaid), the zero-profit condition of the lender pins down the lending rate as:

$$R_{it} = \frac{1}{p_i} \qquad (16)$$

We need to remember that $p_L > p_H$, so that $R_L < R_H$. From the previous conditions, we can see that for type H (high risk-low ability) borrower the credit contract is not subject to self-selection because she is willing to pay a higher interest rate than type L agent. In this case, lenders will compete for such type of borrowers. To see this point, we can apply the same argument for health insurance premiums. In this situation, we expect a higher risk for people who are willing to pay higher premiums. However, companies compete for these customers because of the fact that other people who choose a lower premium do not ensure them that these people have lower risk. Health insurance companies announce different type of contracts (high or low premium) and customers will apply for them (in the same way that we have described in the credit market). We have to notice that health insurance companies (as lenders) do not know all about the quality of customers. Therefore, they will try to compete for the customers that are willing to pay a higher premiums. In fact, there are more restrictions to get a low-premium health insurance than a high-premium health insurance. Following the previous argument, we can see that the probability of high risk borrowers to get the credit is one $(\pi_{Ht} = 1)$.

And the assumption (12) implies that $q_{Ht} = w_t$.

With respect to low-risk (high ability) borrowers, the equilibrium contract is given by $R_{Lt} = \frac{1}{p_L}$ and should satisfy the self selection condition given by (13). Then, substituting $q_{Ht} = w_t$ and $\pi_{Ht} = 1$ into expression (14) we have:

$$q_{Lt} = \frac{\left(p_H Q \rho_{t+1} - 1\right) w_t - (1 - \pi_{Lt})\beta_H w_t}{p_H \pi_{Lt}(Q\rho_{t+1} - (1/p_L))} \tag{17}$$

The previous value of q_{Lt} satisfies $q_{Lt} \leq w_t$ iff

$$\pi_t \geq \frac{p_H Q \rho_{t+1} - 1 - \beta_H}{p_H Q \rho_{t+1} - (p_H/p_L) - \beta_H} \tag{18}$$

In equilibrium and considering assumption (4) we have

$$q_{Lt} = w_t \tag{19}$$

and

$$\pi_{Lt} = \frac{p_H Q \rho_{t+1} - 1 - \beta_H}{p_H Q \rho_{t+1} - (p_H/p_L) - \beta_H} \leq 1 \tag{20}$$

Now, let's examine the equilibrium conditions. We have to recall that all agents act competitively in both the labour and the R&D markets.

Assuming that all borrowers (remember that 50% of all agents are lenders and 50% are borrowers) with positive quantities of R&D become firm's owners, we can figure out the firms per capita:

$$0.5\left[\lambda p_H - (1 - \lambda)\pi_{Lt}\right] \tag{21}$$

Half of all agents are borrowers and a fraction λ (high risk) receive credit with probability one, resulting in λp_H successful R&D projects. We need to add agents (low risk) of type (1-λ) in which case the number of successful R&D projects will be given by the second term of equation (21).

The per capita supply of labour will be given by:

$$0.5\left[1 - (1 - \lambda)(1 - \pi_{Lt})\right] \tag{22}$$

Therefore the quantity of labour per firm (assuming that in equilibrium all firms use the same quantity of labour) is:

$$L_t = \frac{1 - (1 - \lambda)(1 - \pi_{Lt})}{\lambda p_H - (1 - \lambda)p_L \pi_{Lt}} \tag{23}$$

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We can now substitute (23) into (10) and we have:

$$\rho_t = P'(x) \left[\alpha_h - \alpha_l\right] \left\{ \frac{1 - (1-\lambda)(1-\pi_{Lt})}{\lambda p_H - (1-\lambda)p_L \pi_{Lt}} \right\}^{\theta} \tag{24}$$

Therefore, equations (24) and (20) give us the equilibrium values of (ρ_t, π_{Lt}) and once we have these values we have the equilibrium values for L and also the expression for the rate of growth of R&D, since we know that $x_{t+1} = Q q_t = Q w_t$. Substituting expression (9) into the previous expression we get:

$$x_{t+1} = Q \left\{P(x_t)\alpha_h + [1 - P(x_t)] \alpha_l\right\} \theta L^{-(1-\theta)} \tag{25}$$

At the equilibrium, we can rewrite the expression (10) in the following way:

$$L_t = \left[\frac{\rho}{P'(x)\left[\alpha_h - \alpha_l\right]} \right]^{-\frac{1}{\theta}}$$

Using the previous expression, we can solve for x:

$$x_{t+1} = Q \left\{P(x)\alpha_h - [1 - P(x)] \alpha_l\right\} \theta \left[\frac{\rho}{P'(x)\left[\alpha_h - \alpha_l\right]} \right]^{-\frac{1}{(1-\theta)\theta}} \tag{25'}$$

Now we can substitute expression (23) into (25) Also we can consider a linear density function [that comes from assumption (7)] for $P(x)$ and in this case we can rewrite expression (25) as follows:

$$\frac{x_{t+1}}{x_t} = Q \left[\Upsilon(x)\alpha_h\theta - \Gamma(x)\alpha_l\theta\right] \left[\frac{1 - (1-\lambda)(1-\pi_{Lt})}{\lambda p_H - (1-\lambda)\pi_{Lt}} \right]^{-(1-\theta)} \tag{26}$$

where: $\Upsilon(x) = P(x)$ and $\Gamma(x) = 1 - P(x)$.

From the previous expression we can take the derivative with respect to the probability of getting the loan for low risk agents and we will obtain the

relationship between the rate of growth of R&D and credit rationing. We have to notice that the probability of getting the loan for low risk agents is also a function of some of the parameters that appear in the expression (26). Therefore the relationship between credit rationing and the rate of growth of R&D expenditures will be given by:

$$\frac{\partial \ln(x_{t+1}/x_t)}{\partial \pi_L} \frac{\partial \pi_L}{\partial (parameter)}$$

It can be proved that the first part is positive

$$\frac{\partial \ln(x_{t+1}/x_t)}{\partial \pi_L} = -Q(1-\theta)\theta \left[\frac{1+(1-\lambda)(1-\pi_L)}{\lambda p_H + (1-\lambda)\pi_L p_L} \right]^{-(2-\theta)} *$$

$$* \left[\left(\frac{(1-\lambda)[\lambda p_H + (1-\lambda)\pi_L p_L]}{[\lambda p_H + (1-\lambda)\pi_L p_L]^2} \right) - \left(\frac{(1-\lambda)p_L [1+(1-\lambda)(1-\pi_L)]}{[\lambda p_H + (1-\lambda)\pi_L p_L]^2} \right) \right] > 0$$

$$(27)$$

Hence, policy actions that can reduce credit rationing (increases on π_L) will increase the rate of growth of R&D and consequently the rate of economic growth. Notice that, at equilibria, the return on R&D will be constant and the same will happen for the probability of low risk agents to get the loan from lenders.

The slopes of equations (20) and (24) are given by:

$$\frac{\partial \rho}{\partial \pi_{L\,(20)}} = \frac{[p_H Q \rho - (p_H/p_L) - \beta_H]^2}{p_H Q [1 - (p_H/p_L)]} > 0 \qquad (28)$$
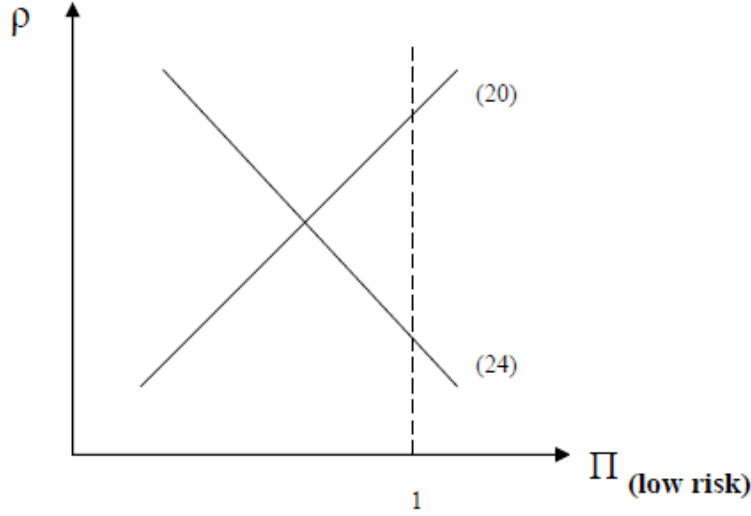
$$\frac{\partial \rho}{\partial \pi_{L\,(24)}} = \frac{-P'(x)(\alpha_h - \alpha l)(1-\lambda)[\lambda p_H + (1-\lambda)p_L \pi_{Lt}]}{[\lambda p_H + (1-\lambda)p_L \pi_{Lt}]^2}$$

$$\frac{-(1-\lambda)p_L P'(x)(\alpha_h - \alpha l)[1+(1-\lambda)]}{[\lambda p_H + (1-\lambda)p_L \pi_{Lt}]^2} < 0 \qquad (29)$$

Graphically:

Note that the maximum probability of getting a loan for low type risk agents is one, which is indicated by the vertical dotted line (figure 1).

The next section exhibits the results obtained by comparative statics.

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Figure 1

3   Comparative Statics

It is easy to verify that ρ^* and π_L^* are differentiable with respect to the parameters of the model: Q, p_H, p_L, β_H, λ, α_h, α_l and θ. Therefore we can analyze the effects of changes of some of these parameters for equilibrium rats of growth.

3.1   Effects of changing α_h

The consequences of increasing α_h, which increases final output for low ability agents, are depicted in picture 2. As we can see the locus defined by equation (20) is not affected, but the locus defined by equation (24) is affected by changes in α_h. The horizontal shift in that locus is given by:

$$\frac{\partial \pi_L}{\partial \alpha_h}_{(d\rho=0)} > 0$$

Therefore, increases in α_h implies increases in ρ and π_L. Moreover, we can see from (24) that $\frac{x_{t+1}}{x_t}$ will be increased. We have to notice that increasing

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Figure 2
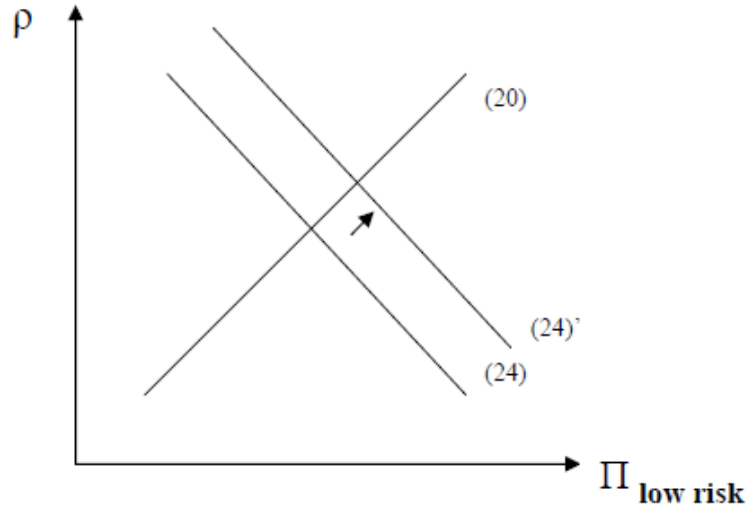
α_h reduces the gap that exists between low and high ability people which means that the probability to get the loan for high risk agents will increase or, in other words, credit rationing decreases. Also, ρ will increase. The increase in α_h can be justified by a technological improvement that affects the production conditions for low ability ar high risk people.

If we consider an increase of α_h, the gap between high and low ability agents will increase which implies that lenders will increase credit rationing.

3.2 Effects of changing Q

Increases in Q represent an improvement in the process of converting consumption goods and labour into R&D. The effect is simply depicted in figure 3. As we can see clearly the locus defined by expression (24) is not affected, while the locus defined by equation (20) shift horizontally to the right. The horizontal shift is given by:

$$\frac{\partial \pi_L}{\partial Q}_{(d\rho=0)} > 0$$

while

$$\frac{\partial \pi_L}{\partial p_L}_{(d\pi_L=0)} = 0$$

As it is apparent from equation (26), $\frac{x_{t+1}}{x_t}$ will be increased, which leads to increased rates of growth of R&D. As we can see in figure 3, increases in Q imply an increase in π_L which means a reduction of credit rationing. It also induces a reduction on ρ.

Although human capital is not explicitly present in the previous model we can think in improvements in human capital which will lead to a more efficient way to convert consumption goods and labour into R&D. In other words we can justify increases in Q because of improvements in human capital.

Figure 3
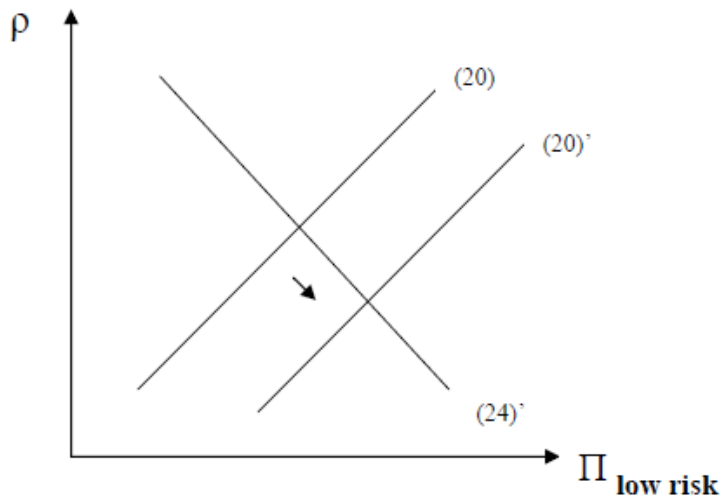
3.3 Effects of changing p_L

An increase in p_L leads to a shift in the locus given by equations (20) and (24). The shift will be given by:

$$\frac{\partial \pi_L}{\partial p_L}_{(d\rho=0)} \leq 0$$

$$\frac{\partial \rho}{\partial p_L}_{(d\pi_L=0)} \leq 0$$

Increase in p_L represent an improvement in type L investment projects. In other words the probability of being successful in the production of R&D for high ability people. Here, we have to notice that if p_L increases, R_L decreases, which implies that the adverse selection problem will lead to rise the credit rationing.

Besides the previous effect, we have to consider that the increase in p_L, can induce an increase in ρ and that will induce a decrease in the rate of growth on R&D.

4 Concluding remarks

Many economists agree that credit rationing reduces the level of economic activity. The key point in the present theoretical exercise is to show that credit rationing affects the rate of growth since it affects the level of R&D and this type of investment is financed just by borrowings. I feel it is important to emphasize the R&D activity, since it has some special characteristics. The main characteristic is the fact that it cannot be used as a collateral to ensure a loan. Thus, when credit rationing increases, we can expect that the activity that is more affected is the R&D activity.

In addition, the model lends itself to the use of comparative statics and the consequences of different policies are analyzed. In this sense, the model suggests that changes the improve the ability of the high-risk group of borrowers will induce a decrease in credit rationing and therefore it will lead to an increase in the rate of economic growth. In other words, measures that tend to reduce the gap between the ability of individuals will help to reduce credit rationing.

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