Loan Processing Costs, Technological Change and Economic Development

By

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Abstract

The paper presents a model in which credit-constrained firms might delay the adoption of new and more productive technologies because of the very high external financing costs they face. Our point of departure is that the efficiency of the banking system can have a profound impact on real resource and investment allocation not only directly, by reducing the amount of resources channelled to the credit market, but also indirectly by affecting entrepreneurs' investment decisions. Along these lines of reasoning we develop a model of information asymmetries in the credit market in which high costs of processing bank loan applications might obstruct investments in high-tech projects and favour, instead, low-return, self-financed investments in mature sectors. The result is that these kinds of costs have a negative impact on the average capital productivity and on the rate of economic growth. In specific circumstances, the combination of these costs and the dynamics of capital accumulation can be such that the economy incurs in a "technology trap", in which even if readily available, new technologies will never be adopted because of high frictions and inefficiencies in the credit market, a situation that seems to be relevant to many developing countries.

Key words: credit market, information asymmetries, loan processing costs, financial development, economic growth.

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1. Introduction

In recent years, many studies have investigated the impact of credit market frictions on real resource allocation. The basic idea of these analyses is that the cost of accessing external financial resources can affect firms' investment decisions, and in turn, capital accumulation and growth. As widely discussed by a vast literature (Rotschild and Stiglitz, 1976; Townsend, 1979; Stiglitz and Weiss, 1981; and Williamson, 1986, 1987 among others), the presence of information asymmetries between borrowers and lenders, can significantly alter the optimal financial contract. Indeed, problems of moral hazard or adverse selection can increase the cost of external financial resources and, by this way, affect firms' investment opportunities. On these theoretical grounds, it is possible to explain the linkages between financial development and real economic growth by assuming that capital accumulation can influence one or more of the components entering the financial contract. Decreasing monitoring or screening costs, a change in signalling costs or a change in the level of information asymmetry are all possible channels through which financial variables can affect real resource allocation and growth (Bernanke and Gertler, 1989; Bencivenga and Smith, 1991, 1993; Bose and Cothren, 1996, 1997; Boyd and Smith, 1998; Blackburn, Bose and Capasso, 2003, among others).

Typically, in the presence of information asymmetries the financial contract will involve higher interest rates, lower level of funds transferred or additional features, otherwise absent, such as a probability of rationing or screening. It is clear that if only one of these components influences to a different extent the relative degree of profitability of alternative investment opportunities, firm's investment choice will depend on the form and features of the financial contract: investing in specific sectors or in specific types of project might involve lower financial costs. The consequence is that some projects may be more profitable than others even when they offer a lower expected real rate of return.

Empirical evidence points out, for example, that under informational asymmetries the costs of external finance arising from credit market distortions are superior for high-tech firms and for high-tech-high-growth projects. By analysing investment decisions of a large cross-section of Italian manufacturing firms, Guiso (1998) finds, very interestingly, that under credit constraints and information asymmetries, financial intermediaries are more likely to allocate a larger share of funds to traditional, low-risk-low-return projects rather than to high-risk-high-return projects. There can be different reasons behind this result. High-tech projects often involve innovative ideas as well as specialised know-how and private information which make these projects less likely to be understood by outsiders. Moreover, the need to defend the market rent generated by a new design or technology will certainly involve a lower incentive for firms to disclose precious information to financial intermediaries or others. This behaviour may exacerbate the degree of informational asymmetries and worsen credit market frictions. Finally, high-tech projects require, in general, a lot of R&D which, by its own nature, attracts more costly financial resources than other kinds of investment.[1]

[1] The reason is that R&D involves usually larger initial outlays, higher probabilities of default and it cannot be used as collateral.

The idea that high-tech projects might attract less and more costly financial resources is not new. Already some decades ago, Arrow (1962) argued that in presence of moral hazard problems innovative investment might be more difficult to be financed. More recently, along the same lines of thought, Stiglitz (1993) maintains that the level of credit rationing can be higher for firms which are more intensively engaged in innovative investments.

Given that, in the presence of credit market frictions, high-tech investments usually require higher financial cost, entrepreneurs might find not optimal to undertake this kind of projects when other alternatives are also available. Following this line of thought, in the present paper we develop a model in which credit-constrained firms might delay the adoption of new and more productive technologies because of the very high external financing costs they face; subsequently we analyse the resulting impact on capital dynamics and growth.

We model this idea by assuming that firms have two alternative investment projects. They can either undertake a low-investment-low-return project, in a traditional sector, which does not require external finance; or a high-investment-high-return project, a typical high-tech investment, which requires, instead, an initial high outlay. The latter project can only be self-financed partially and it forces entrepreneurs to access the credit market. In the presence of information asymmetries, however, the access to the credit market can be very costly.

Pivoting on this basic framework, we focus on some imperfections and frictions of the credit market which have not been sufficiently analysed by the recent literature on finance and growth. Our point of departure is the empirical evidence which seems to suggest that, among other features, the process of applying for a loan can be very costly by itself for entrepreneurs. These costs consist of the time spent queuing, producing papers and documentation and the loss of alternative opportunities. In the case of a high degree of credit rationing, i.e. when entrepreneurs face a high probability of not obtaining credit, these costs might deter entrepreneurs from applying for a loan to undertake those projects requiring high initial investment – the high-tech projects, for example –, even when these projects offer higher expected returns than other technologies which, instead, do not require external financing – see the case of more traditional projects. Indeed, given a significant level of credit rationing, these loan processing costs might be so high to lower the expected return on the high-tech project to the extent that the investment in the low-return traditional project is more profitable. Under these circumstances, entrepreneurs might optimally decide to remain out of the credit market. The empirical evidence supporting the idea that loan processing costs can be relevant in investment decisions is quite conclusive. In a recent empirical study, Cavalluzzo *et al.* (1999), by using data from the 1993 National Survey of Small Business Finances in US, have shown that in a three-year period, almost 50% of the firms they interviewed reported that they did not apply for a loan since they believed that they would not be able to obtain it. The above interesting finding implicitly supports the argument that applying for a loan is a costly process; most importantly, the large fraction of firms not accessing the credit market outlines the relevance of those costs in the decision making process.

The mechanism we have just described not only provides further insights in the interpretation of the impact of credit market distortions on real resources allocation and growth, but also, it can provide an alternative explanation to other stylised facts such as the non-linear dynamics in technology diffusion and the technological traps in which many developing countries seem to remain for long period of time.

A rather vast empirical literature clearly shows that technology diffusion is not a linear and predictable phenomenon (Mansfield, 1989; Griliches, 1992; Jaffee and Trajtenberg, 1996; Jaffee *et al.*, 1993; Karshenas and Stoneman, 1993; Pennings and Harianto, 1992

among others). The introduction of new technologies is not always followed by their direct and immediate adoption. Very often it takes long time for some firms to put in place new equipment or to implement new production processes. In particular, the time path of technology usage seems to follow an S-curve: an initial slow implementation, followed by a rapid diffusion and a final lower rate of adoption. Many theoretical works have attempted to explain in different ways such peculiar patterns (Metcalfe, 1988; Stoneman, 1987; Kashenas and Stoneman, 1995). Some of these works hinge on the assumption of exogenous frictions in technology diffusion (epidemic models); others focus on more firm-specific features in decision making (probit models)[2]. Along these lines of research, the model we develop in this paper attempts to provide further insights on this issue. A new available technology might not be initially implemented by those (skilled) entrepreneurs who can benefit most from it simply because these entrepreneurs have alternative investment opportunities that others do not have. Interestingly enough, the new technology might initially attract a higher share of unskilled and venturous entrepreneurs with no alternatives. As a result, the economy's growth path will show non-monotonic behaviour which strongly depends on firms' alternative investment opportunities and endowments.

The rest of the paper is structured as follows. In section 2 we describe the economy: technologies, agents' endowments and investment opportunities. In section 3 we outline the main features of the credit market. The design of the optimal financial contract and entrepreneurs' choices are determined and discussed in section 4 and 5. The description of the capital accumulation process is the subject of section 6. Some final comments are included in the concluding section 7.

2. The Economy

Time is discrete and indexed by 1, 2…∞. The economy is populated by an infinite sequence of identical two-period lived overlapping generations. Population is divided into a unit mass of countable entrepreneurs (or borrowers) and a fraction $n > 1$ of households (or workers). Young agents are endowed with one unit of labour that is supplied inelastically in the market in return for the current wage rate, w_t. All agents are risk neutral and care only about old age consumption. Young entrepreneurs are also endowed with two alternative technologies to produce capital: a high-investment-high-return technology (*h–h technology*) and a low-investment-low-return technology (*l–l technology*). The expected return on each technology depends on entrepreneurs' type. Entrepreneurs are divided at birth into skilled (fraction 0,5 of entrepreneurs population) and unskilled (the other half of entrepreneurs population). Entrepreneur's type is private information and unobservable by any other agent.

The h-h technology requires an initial investment of q units of output at time t to deliver $Q > q$ units of capital at time t+1 with probability p^s (p^u) when run by a skilled entrepreneur (unskilled entrepreneur). With probability $1 - p^s$ ($1 - p^u$) the project fails and it delivers 0 units of capital, where $p^s > p^u$. We further assume that $w_t < q$ implying that entrepreneurs can only partially finance the h-h project with their wage.

The l-l technology requires an initial investment of b units of output at time t to deliver, with certainty at time t+1, B^s units of capital to a skilled entrepreneur and B^u units of capital to an unskilled entrepreneur. This technology does not require external funding since the initial outlay is low enough for the entrepreneur to completely self-finance the project, $w_t > b$.

[2] For an excellent literature survey on this issue see Geroski (2000).

Once one technology is started the entrepreneur cannot switch to the other i.e. investment is irreversible. The h-h technology can be seen as the technology in use in high-tech sectors in which relatively high and costly initial investment, typically large investment in R&D, is counterbalanced by relatively high rate of return. The l-l technology, on the other hand, resembles the technology in use in low-tech sectors, or mature sectors (with low level of R&D), in which the required initial capital outlay is relatively low and so is, correspondingly, the rate of return.

All entrepreneurs will produce output in the second period of their life by employing capital, k_{t+1}, and labour, L_{t+1}, according to a standard Romer-type production function

$$y_{t+1} = \Theta K_{t+1}^{\alpha} k_{t+1}^{1-\alpha} L_{t+1}^{\alpha}, \tag{1}$$

where, K_{t+1} is the aggregate level of capital. We assume that the market for output is perfectly competitive and factors are paid their marginal productivity. As a consequence, by virtue of the production function, eq. (1), the competitive wage rate is $w_{t+1} = (1-\alpha)\Theta K_{t+1}^{\alpha} k_{t+1}^{1-\alpha} L_{t+1}^{\alpha-1}$ and the interest rate on capital is $\rho_{t+1} = \alpha\Theta K_{t+1}^{\alpha} k_{t+1}^{-\alpha} L_{t+1}^{\alpha}$. Recalling that only mature entrepreneurs produce output, the number of firms will be constant over time and equal to unity. The supply of labour, instead, comes each period from young workers, whose number is fixed to n, and from all young entrepreneurs, whose number is 1. In equilibrium, each firm will employ an equal amount of capital and labour. Hence, per firm capital is equal to the aggregate capital, $K_{t+1}=k_{t+1}$, while per firm labour supply is $L_{t+1}=1+n$. Using these expressions, the equilibrium wage rate and the equilibrium interest rate can be written in the following way

$$w_{t+1} = \alpha\Theta(1+n)^{\alpha-1} k_{t+1}, \tag{2}$$

$$\rho_{t+1} = (1-\alpha)\Theta(1+n)^{\alpha}. \tag{3}$$

Entrepreneurs wishing to run the h-h technology can obtain financial resources by applying for a bank loan. As in Diamond and Dybvig (1983), we assume that banks are institutions consisting of coalitions of agents born at t. Banks obtain financial resources by offering competitive deposits at a competitive rate to young households and employ these resources either by offering loans to entrepreneurs or by investing in a technology which can only be implemented on large scale and, therefore, inaccessible to single agents. This technology delivers ε units of capital at time t+1 per unit of output invested at time t. We assume that this technology is always dominated by both the h-h and l-l technology and, therefore, it is used by banks only residually for the employment of resources not lent to entrepreneurs. More formally we assume that

$$\frac{p^i Q}{q} > \frac{B^i}{b} > \varepsilon > 1. \tag{4}$$

Finally, the banking system is competitive and, hence, banks' profit is zero.

Applying for a bank loan is costly. An entrepreneur who enters a bank to ask for a loan will need to queue, to fill in forms, to provide all the necessary documentation, etc. These are obstacles for entrepreneurs and, certainly, represent a cost in terms of time, energy and missed opportunities. These costs reflect the efficiency of the banking system. The more efficient is the banking system the lower are the queuing time, the official procedures, the

amount of paperwork to be produced in order to obtain a loan etc. These costs might not directly affect the efficiency of the project to be financed, but they will certainly affect the utility of the entrepreneur asking for a loan. If these costs are very high, they might even deter the entrepreneur from applying for the loan.

In order to capture these costs, we assume that applying for a bank loan can affect entrepreneurs' ability to produce any additional income. Entrepreneurs have access to a storing technology. This technology allows a skilled entrepreneur to transform 1 unit of time t output into $\beta^s > 1$ units of time $t+1$ output. However, if the entrepreneur applies for a bank loan, the efficiency of the storing technology will decrease and the entrepreneur will only be able to store a fraction, $0 < \gamma < 1$, of what could normally store. In other words, applying for a loan will allow the entrepreneur to transform 1 unit of time t output into $\gamma\beta^s > 0$ units of time $t+1$ output. Unskilled entrepreneurs have a less efficient storing technology. They are able to transform 1 unit of time t output into β^u units of time $t+1$ output. In order to simplify matters further we set $\beta^u = 0$.

3. The Credit Market

The credit market works in the following way. At time t young entrepreneurs supply labour in the market, obtain the wage and decide whether to undertake the h-h technology or the l-l one. The latter can be completely self-financed and does not require credit (recall that $w_t > b$). Therefore, an entrepreneur requires external finance and applies for a bank loan only if she decides to run the h-h technology.

Entrepreneurs' type is private information and it cannot be observed either by banks or by any other agent in the economy. The presence of informational asymmetries generates agency costs in the credit market which agents try to minimise by designing optimal and incentive-compatible financial contracts.

Each entrepreneur willing to undertake the h-h project requires a total of q units of output to invest. Therefore, the minimum amount of funds an entrepreneur needs to borrow is $q - w_t$, given that each one can self-finance the project by a maximum of w_t units of output. Under the assumption that the capital production technology delivers the highest return per unit of output invested among all alternatives, each entrepreneur optimally invests the maximum amount of available funds (w_t) in the project and requires a loan of $q - w_t$ units of output.

The interest rate banks charge on this loan to a skilled entrepreneur is easily determined by the bank's zero profit constraint

$$R^s_{t+1} = \frac{(q - w_t)\varepsilon\rho_{t+1}}{p^s}, \tag{5}$$

which requires that the expected repayment on the loan, $p^s R^s_{t+1}$, equals the alternative cost of investment in the large scale technology, $(q - w_t)\varepsilon$, in output terms.

Similarly, the interest rate charged to an unskilled borrower is:

$$R^u_{t+1} = \frac{(q - w_t)\varepsilon\rho_{t+1}}{p^u}. \tag{6}$$

Given that $R^s_{t+1} > R^u_{t+1}$, unskilled entrepreneurs have the incentive to pretend to be skilled in order to pay a lower interest rate. As in standard adverse selection problems, banks can solve the informational problem by separating borrowers. In this framework, as it is commonly

assumed, separation can be achieved through credit rationing. Since borrowers have different costs of being denied credit – skilled borrowers have a lower cost ($\gamma\beta^s > \gamma\beta^u = 0$) – banks can make the contract designed for good borrowers unattractive to unskilled ones by introducing a probability of credit rationing.

Let us now turn to the analysis of credit supply. Financial resources in the market are supplied by young households who transfer to the bank the remuneration of their work, the wage rate, in exchange for a competitive deposit rate. The deposit rate is determined by the return on the large-scale investment technology. Indeed, given that the banks' profit constraint is binding, lending out delivers to a bank the same expected return on the large-scale technology (eq. (5) and (6)) and, hence, in absence of other transaction costs, this is also the competitive deposit rate banks can offer.

In order to simplify matters, we further assume that entrepreneurs do not find optimal, or do not have the chance, to deposit. This is, in general, a logical consequence of the assumption that the large-scale technology is always dominated by both the h-h and l-l technologies. However, this might not be true in some circumstances and, specifically, when entrepreneurs have some resources left over or when they cannot run the investment project since they have been credit rationed. By assuming that the credit market closes instantaneously and that the capital production activity starts soon after the credit market has closed, we rule out this occurrence.

4. The Optimal Financial Contract

In order to separate borrowers, banks design different financial contracts for each type of borrower in a way that each entrepreneur asking for a loan weakly prefers the contract designed for her own type over other contracts. If this is the case, the choice of the contract is revealing of borrower's identity. With this in mind, we now turn to contract design.

Among the essential components a financial contract must specify, we focus on the loan size and the interest rate. The loan size is easily determined by recalling that the expected return on the project dominates the large-scale technology, which is bank's alternative investment opportunity. Under this assumption, banks will transfer to entrepreneurs as much as entrepreneurs demand and entrepreneurs invest as much as they can in the project. Given that the maximum amount of self-finance is w_t and that investment in h-h technology requires q units of output, each entrepreneur (of whatever type) demands a loan of $q - w_t$ units of output.

The interest rate is straightforwardly determined by bank's zero profit constraint – eq. (5) and (6). As already stressed, since skilled entrepreneurs pay a lower interest rate, there is an incentive for the unskilled ones not to reveal their type and pretend to be skilled. What banks can do to drive unskilled entrepreneurs away from the contract designed for skilled entrepreneurs is to credit rationing the latter. Therefore, the financial contract must be modified by the introduction of a probability of credit rationing which is determined by the following maximisation problem:

$$\underset{\pi_t}{Max}\ \pi_t p^s (Q\rho_{t+1} - R^s_{t+1}) + (1-\pi_t)\gamma\beta^s w_t \tag{7}$$

s.t.

$$p^u (Q\rho_{t+1} - R^u_{t+1}) \geq \pi_t p^u (Q\rho_{t+1} - R^s_{t+1}) \tag{8}$$

$$\pi_t \geq 0\,, \tag{9}$$

where π_t is the probability of credit being granted. Banks maximise skilled entrepreneur's expected utility subject to the incentive compatibility constraint, eq. (8), and the non negativity constraint, eq. (9). With probability π_t the loan application is successful and the entrepreneur will run the h-h technology which delivers a net profit of $p^s(Q\rho_{t+1} - R^s_{t+1})$. With probability 1-$\pi_t$ the loan is not granted and the entrepreneur can only invest her wage in the storing technology which will deliver, because of the loss in efficiency, a profit of $\gamma\beta^s w_t$, eq. (7). For borrowers to be separated, the contract must be incentive compatible which implies that, given the probability of being credit rationed, an unskilled entrepreneur must be at least indifferent between revealing her own type or pretending to be a skilled entrepreneur, eq. (8).

Under the assumption that running the project delivers always a higher expected rate of return, $p^s(Q\rho_{t+1} - R^s_{t+1}) > \gamma\beta^s w_t$, the expected utility is strictly increasing in π_t.[3] A strictly increasing π_t implies that the incentive compatibility constraint is binding and by virtue of (5) and (6), the probability of not being credit rationed is:

$$\pi_t = \frac{p^s[p^u Q - (q - w_t)\varepsilon]}{p^u[p^s Q - (q - w_t)\varepsilon]}. \tag{10}$$

The latter clearly indicates that the probability of not being credit rationed is a function of the wage rate, $\pi_t(w_t)$. In the specific, it is tedious but easy to show that this is an increasing, $\partial\pi_t(w_t)/\partial w_t > 0$, and concave, $\partial^2\pi_t(w_t)/(\partial w_t)^2 < 0$, function of w_t[4]. Since the wage rate is an increasing linear function of capital, eq. (2), it is possible to conclude that the probability that a skilled borrower will obtain a loan is an increasing and concave function of capital. Therefore, as capital accumulates, π_t increases and the level of credit rationing goes down.

Given the probability of being credit rationed, the expected utility of a skilled entrepreneur applying for a loan to run the h-h project is given by

$$\hat{U}(w_t;\gamma) = \frac{p^s}{p^u}\frac{p^u Q - (q - w_t)\varepsilon}{p^s Q - (q - w_t)\varepsilon}[p^s Q\rho_{t+1} - (q - w_t)\varepsilon\rho_{t+1} - \gamma\beta^s w_t] + \gamma\beta^s w_t. \tag{11}$$

The latter is a non-linear function of the wage rate and capital: as capital accumulates, and the wage rate increases, the expected utility of skilled entrepreneurs applying for a bank loan will increase non-monotonically. It is also worth pointing out that, *ceteris paribus*, an increase in bank's loan processing costs, $1-\gamma$, will reduce the level of expected utility for a given wage rate.

As an alternative to applying for a bank loan and undertake the h-h project, skilled entrepreneurs can run the l-l technology. This project, as outlined, will require a minimum initial investment of b units of output which can be completely covered by entrepreneurs' wage, $w_t > b$. The technology will deliver B^s units of capital after one period. The output left

[3] It is easy to show that for this to occur it must be $\varepsilon\rho_{t+1} > \gamma\beta^s$. This condition indicates that the entrepreneur will borrow as little as possible if the cost of borrowing, $\varepsilon\rho_{t+1}$, is higher than the alternative return on the storing technology, $\gamma\beta^s$.

[4] A formal proof is given in Appendix A1.

over after the investment, $w_t - b$, can be stored and it will be transformed into $\beta^s(w_t - b)$ units of next period output. The utility a skilled entrepreneur expect to obtain from running the l-l technology is, therefore,

$$\tilde{U}(w_t) = B^s \rho_{t+1} + \beta^s (w_t - b). \tag{12}$$

5. Project Choice

A straightforward comparison between the expected utility under the two alternatives will determine whether it is *ex ante* optimal, for skilled entrepreneurs, to apply for a bank loan in order to run the high-return technology, or to self-finance the low-return one. It is clear that the payoff attached to each of the two alternatives, eq. (11) and eq. (12), is a function of the wage rate. However, it is not straightforward to determine how the difference between the two payoffs evolves when the wage rate increases. On the one hand, given the loss in efficiency, an increase in the wage rate, and therefore, in the volume of funds that can be stored, causes an increase in the relative cost of applying for a bank loan relative to self-financing the project; on the other hand, an increase in the wage rate increases the probability of not being credit rationed and decreases the alternative expected cost of storage. A sufficient condition for entrepreneurs to prefer applying for a bank loan over self-financing is $\hat{U}(w_t;\gamma) > \tilde{U}(w_t)$. Self-financing will prevail, instead, only if $\hat{U}(w_t;\gamma) < \tilde{U}(w_t)$. Entrepreneurs will be indifferent between the two alternatives if $\hat{U}(w_t;\gamma) = \tilde{U}(w_t)$.

Let us define

$$F = \hat{U}(w_t;\gamma) - \tilde{U}(w_t) = \\ \pi_t[p^s Q \rho_{t+1} - (q - w_t)\varepsilon\rho_{t+1} - \gamma\beta^s w_t] + \gamma\beta^s w_t - B^s \rho_{t+1} - \beta^s (w_t - b). \tag{13}$$

The latter is a non-monotonic function of the wage rate whose behaviour depends on the parameter values. We now turn to the analysis of such behaviour. It is possible to show (we provide a formal proof in Appendix A2) that assuming a return on the large-scale technology higher than the return on the storing technology, $\varepsilon\rho_{t+1} - \beta^s > 0$, it is sufficient to ensure that the difference in expected payoff, $F(w_t;\gamma)$, is a concave and monotonically increasing function of w_t, $F'(w_t;\gamma) > 0$ and $F''(w_t;\gamma) < 0 \ \forall \ w_t \in [b,q]$. This implies that the $F(w_t;\gamma)$, for feasible values of the wage, can intersect the horizontal axis at most once. A sufficient condition for this to happen is that:

$$\lim_{w_t \to b^+} F(w_t;\gamma) < 0 \iff \psi_1 \equiv \frac{\rho_{t+1}[p^u B^s - p^s(p^u Q - q\varepsilon + b\varepsilon)](p^s Q - q\varepsilon + b\varepsilon)}{\gamma b(p^s - p^u)(q-b)\varepsilon} > \beta^s \tag{14}$$

and

$$\lim_{w_t \to q^-} F(w_t;\gamma) > 0 \iff \psi_2 \equiv \frac{\rho_{t+1}(p^s Q - B^s)}{q-b} > \beta^s, \tag{15}$$

which, in more compact form, can be expressed in the following way

$$\beta^s \leq \min(\psi_1, \psi_2)\,. \tag{16}$$

If the latter is satisfied, then it exists a critical value for the wage rate, $w^c \in (b,q)$, such that $F(w^c;\gamma)=0$. Recalling that $F(w_t;\gamma)$ is monotonically increasing in [*b*, *q*], it is possible to infer that $\forall\ w_t < w^c$, the difference in expected payoff is negative, $F(w_t;\gamma)<0$, (i.e. $\hat{U}(w_t;\gamma)<\tilde{U}(w_t)$) and the expected payoff obtained by running the l-l self-financed project dominates the payoff obtained by applying for a loan to run the h-h technology. Whenever $w_t > w^c$, then $F(w_t;\gamma)>0$ (i.e. $\hat{U}(w_t;\gamma)>\tilde{U}(w_t)$) and entrepreneurs find optimal to undertake the h-h technology and apply for a bank loan.

As a consequence of the above restrictions on the behaviour of the $F(w_t;\gamma)$ function, and by assuming a low enough initial wage rate, $w_0 < w^c$, one can argue that the economy will start off with an equilibrium in which skilled entrepreneurs find optimal not to ask for a bank loan to finance the h-h project. They will self-finance the l-l project, instead. As capital accumulates and the wage rate increases, the $F(\bullet)$ increases and, when w_t reaches the critical value w^c, the economy switches to a new equilibrium in which it is optimal for skilled entrepreneurs to finance the h-h technology. This, however, does not occur if the economy reaches the steady state before the wage rate gets to the critical value. We will analyse in detail such possibilities and the resulting impact on the growth rate in the following section.

For now, it is worthwhile to note that the critical value of the wage rate, w^c, which defines the boundary for a financial regime switching, depends on the level of loan processing costs, γ. More specifically, it is straightforward to show that an increase in this cost – a decrease in γ – by shifting the $F(w_t;\gamma)$ downwards increases the value of w^c, and, therefore, delays the transition of the system to a new financial regime in which skilled entrepreneurs undertake the h-h technology instead of the l-l one. Indeed, an increase in the expected cost of applying for a loan acts as a disincentive for the entrepreneurs in entering a bank. Following this line of argument, it is possible to infer that a low enough γ might deter entrepreneurs from applying for credit for all values of w_t. We depict in Fig.1, two possible $F(w_t;\gamma)$ curves corresponding to two different loan application costs, γ_1 and γ_2.

Unskilled entrepreneurs do not have access to a storing technology, ($\beta^u = 0$), and therefore, they do not bear any cost in terms of loss in efficiency in the alternative storing technology. Moreover, unskilled entrepreneurs are never credit rationed. They are neither credit rationed in a separating equilibrium with information asymmetries, as already shown, nor they are when agents are fully informed (i.e. when skilled entrepreneurs do not access the credit market)[5]. In the wake of these considerations, we assume that unskilled entrepreneurs strictly prefer to apply for a bank loan for whatever wage rate level:

$$p^u Q - q + b > B^u\,. \tag{17}$$

A sufficient low level of B^u is enough to ensure that the latter is holding. As a consequence of eq. (17), at low level of the wage rate, when skilled entrepreneurs do not

[5] This is equivalent to argue that unskilled entrepreneurs always get their first best and, hence, their choice does not depend on the dominating financial contract.

access the credit market and prefer to undertake the l-l technology, only unskilled entrepreneurs run the risky projects[6].

6. Capital Accumulation

Since the wage rate is a linear positive function of capital, $w_t(k_t)$, as determined by eq. (2) , the prevailing financial regime is ultimately a function of the accumulated stock of capital. Along the lines of arguments already developed, we can retain that given an initial capital stock, k_0, such that $w(k_0) < w^c(k^c)$, the economy is characterised, for low levels of capital, $k_0 < k_t < k^c$, by a credit system in which skilled entrepreneurs prefer to self-finance their projects. For these values of capital, the high costs associated to bank loan application (high probability of credit rationing) causes the h-h technology to be unprofitable and skilled entrepreneurs find optimal to undertake the low-investment-low-return technology. In these circumstances, banks will only be approached by unskilled entrepreneurs. As a consequence, the average interest rate will be higher, as witnessed by empirical evidence, and the average capital productivity low.

As capital accumulates, it becomes more and more profitable for skilled entrepreneurs to undertake the h-h project. For values of capital which are high enough, $k_t \geq k^c$, the expected cost associated to a loan application is sufficiently low to cause the expected return on the investment in the h-h technology to be higher than the return on the l-l one. For these levels of capital, skilled entrepreneurs will find optimal to apply for a bank loan and undertake the high-investment-high- return technology. The change in technology usage will certainly increase the long term rate of growth, however, depending on the parameter values, the economy might initially experience a drop in the average capital productivity.

As already outlined, by affecting the level of credit rationing, π_t, and the volume of funds that can be transferred and stored, economic growth can affect the structure of the financial market and the features of the investment allocation. In turn, a change in the investment allocation will, inevitably, affect the process of capital accumulation and growth. Indeed, as we show below in detail, the economy moves along two different capital accumulation paths depending on the nature of entrepreneurs' choices concerning resource allocation.

At a low level of capital accumulation, $k_0 < k_t < k^c$, when skilled entrepreneurs prefer to self-finance their projects, the amount of capital produced in each period is given by the sum of the capital produced by unskilled entrepreneurs running the h-h technology, $0{,}5p^uQ$, the capital produced by skilled entrepreneurs running the l-l technology, $0{,}5B^s$, and the capital produced by banks by means of the large-scale technology, $[nw_t - (q - w_t)0{,}5]\varepsilon$. Hence, the capital accumulation path will exhibit the following dynamics

$$k_{t+1} = 0{,}5(B^s + p^uQ - q\varepsilon) + (n + 0{,}5)\varepsilon\alpha\Theta(1+n)^{\alpha-1}k_t, \qquad (18)$$

[6] This is only a simplifying assumption. Without altering the main results, we could have a group of unskilled entrepreneurs undertaking the h-h project and another group undertaking the l-l one (whatever is skilled entrepreneurs' choice), by assuming different returns on the l-l technology for each group. For instance, by assuming $B_1^u > B_2^u$ with $p^uQ - q + b > B_1^u$ and $p^uQ - q + b < B_2^u$, we would have group 1 always undertaking the h-h project and group 2, the l-l project.

where we have substituted for $w_t = \alpha\Theta(1+n)^{\alpha-1}k_t$. Moreover, we have assumed, by the law of large numbers, that the expected and the actual values of capital coincide i.e. $E[k_{t+1}] = k_{t+1}$.

As the economy reaches the critical level of capital, k^c, and skilled entrepreneurs apply for bank loans in order to undertake the h-h technology, the aggregate level of capital will be given by the sum of the capital produced by skilled entrepreneurs who are not credit rationed, $\pi_t 0,5 p^s Q$, the capital produced by unskilled borrowers, $0,5p^u Q$, and the capital produced by banks which invest in the large-scale technology what is left over from their lending activity, $[nw_t - \pi_t(q - w_t)0,5 - (q - w_t)0,5]\varepsilon$. Using (2) and (10), the capital accumulation path can be written in the following way:

$$k_{t+1} = \left[p^s Q + p^u Q - \frac{p^s + p^u}{p^u} q\varepsilon \right] 0,5 + \left(\frac{p^s + p^u}{p^u} 0,5 + n \right) \varepsilon\alpha\Theta(1+n)^{\alpha-1} k_t . \quad (19)$$

It is useful to note that both the capital accumulation paths in (18) and (19) are straight lines. A simple comparison between the two reveals that the slope of the latter is higher than the slope of the former. This implies that the rate of growth, in the case skilled borrowers apply for bank loans and run the h-h technology, is higher than the rate of growth prevailing in the regime in which skilled entrepreneurs run the l-l technology. The reason is that, as capital accumulates, the level of credit rationing decreases and more skilled entrepreneurs obtain a loan to finance the h-h project. The direct effect is an increase in the aggregate level of capital produced.

It is also possible to show that, under the condition that it exists a critical level of capital (and wage rate), $w(k^c)$, above which there is a regime switching, the intercept of line in (19) is lower than the intercept of the line in (18) (see Appendix A3). This implies that at the time of the regime switching, the economy might experience a temporary decrease in the growth rate. The drop will occur if in correspondence of the level of capital at which there is a regime switching, the capital accumulation path in (18) is higher than the capital accumulation path in (19), i.e. if the critical value of capital, k^c, is lower than the level of capital at which the two lines intersect, k^i. Notwithstanding the initial drop in the stock of capital, the new rate of growth will be higher. The economy will eventually move along a capital accumulation path higher than the original one. It is easy to understand that, whether this occurs or not it depends on the combination of the parameter values. We depict in Fig. 2 two possible cases. In the first case, Fig. 2a, the critical level of capital is lower than the value of capital at which the capital accumulation paths intersect: the economy experiences a temporary decrease in the stock of capital. In the second case, Fig. 2b, the critical level of capital is higher: the economy experiences a positive increase in capital stock, followed by a permanent increase in the rate of growth.

Whether or not the economy experiences a change in the financial regime, with skilled entrepreneurs switching to the h-h technology, it depends on the relative value of the critical level of capital. Let us define the steady state level of capital k^{ss}. If it happens that $k^c > k^{ss}$, then the steady state is reached before capital reaches the critical level and, as a result, the economy might be trapped in a situation in which only unskilled entrepreneurs undertake risky projects (see Fig. 3a). If we assume instead that $k^c < k^{ss}$, then the change in skilled entrepreneurs regime will occur before the economy reaches the steady state. In this case, the

economy will jump on the new capital accumulation path and will grow at a higher rate of growth (see Fig. 3b).

It is crucial to point out that, whether or not entrepreneurs prefer to undertake the high-return-high-investment technology or the low-return-low-investment one depends, *inter alia*, on the exogenous bank loan processing cost, γ. A decrease in this cost, for a given wage rate and capital level, will make more profitable for skilled entrepreneurs to apply for a loan in order to run the h-h technology. Graphically, an increase in γ results in a shift upwards of the $F(w_0; \gamma)$ curve and it reduces the critical level of capital and wage rate above which it is optimal to finance the h-h technology. One can, therefore, imply that an exogenous change in the level of efficiency of banks in screening credit requests might have a strong impact on capital accumulation and growth.

7. Concluding Remarks

The efficiency of the banking system can have a profound impact on real resource and investment allocation not only directly, by reducing the amount of resources channelled to the credit market, but also indirectly by affecting entrepreneurs' investment decisions. In a framework characterised by information asymmetries, financial intermediaries often react by credit rationing firms: the loan requests are often rejected or only partially satisfied. It is clear that if, in this framework, applying for a loan involves some sort of costs, entrepreneurs might *ex ante* find optimal to stay out of the credit market. This occurs when other investment opportunities, which do not require access to credit, are also available.

In line with the relevant empirical evidence, we maintain that high-tech investments are usually the kind of investment that requires large initial investment outlay and that those investments are more easily credit rationed. This is not true for investments in more mature traditional sectors which, instead, can be very often self-financed and do not involve very high agency costs. Along these lines of reasoning, we develop a model of information asymmetries in the credit market in which high costs of processing bank loan applications might obstruct investments in high-tech projects and favour, instead, low-return, self-financed investments in mature sectors. The result, as intuition indicates, is that these kinds of costs have a negative impact on the average capital productivity and on the rate of economic growth. In specific circumstances, the combination of these costs and the dynamics of capital accumulation can be such that the economy incurs in a "technology trap", in which even if readily available, new technologies will never be adopted (or they will be adopted only by very venturous high risk firms with no alternatives) because of high frictions and inefficiencies in the credit market, a situation that seems to be relevant to many developing countries.

The model, to a certain extent, also explains the irregular dynamics observed in reality in the rate of new technology usage. Alternative investment opportunities, firms' financial endowments and the structure of the credit market, as already outlined, have strong influence on firms' investment decision and on the types of projects undertaken. Readily available new technologies might not be adopted simply because they may be not profitable because of the very high financial costs they involve. As a consequence, it is possible to have economies in which firms do not implement new technologies or where those are adopted with substantial delay. One can go further by arguing that if competition is positively correlated to the level of inefficiency, then government policies directed to reduce the degree of monopoly in the

credit market and improve the efficiency of the financial sector will remove these costs and frictions and they will have a greater expansionary impact on the economic system.

Appendix

A1

By differentiating (10), we obtain

$$\frac{\partial \pi_t}{\partial w_t} = \frac{p^s}{p^u} \frac{\varepsilon Q(p^s - p^u)}{\left[p^s Q - (q - w_t)\varepsilon\right]^2}$$

which is strictly positive, given that $p^s > p^u$. On the other hand,

$$\frac{\partial^2 \pi_t}{(\partial w_t)^2} = -\frac{p^s}{p^u} \frac{2\varepsilon^2 Q(p^s - p^u)}{\left[p^s Q - (q - w_t)\varepsilon\right]^3} = -\frac{\partial \pi_t}{\partial w_t} \frac{2\varepsilon}{\left[p^s Q - (q - w_t)\varepsilon\right]} < 0$$

since $p^s Q > (q - w_t)\varepsilon$ by assumption (see eq. (4)).

A2

By differentiating $F(\bullet;\gamma)$, we obtain

$$\frac{\partial F}{\partial w_t} \equiv G(w_t) = \frac{\partial \pi_t}{\partial w_t}\left[p^s Q \rho_{t+1} - (q - w_t)\varepsilon\rho_{t+1} - \gamma\beta^s w_t\right] + \pi_t\left[\varepsilon\rho_{t+1} - \gamma\beta^s\right] + \gamma\beta^s - \beta^s$$

and

$$\frac{\partial^2 F}{(\partial w_t)^2} = -\frac{\partial \pi_t}{\partial w_t} \frac{2\varepsilon}{p^s Q - (q - w_t)\varepsilon}\left[p^s Q \rho_{t+1} - (q - w_t)\varepsilon\rho_{t+1} - \gamma\beta^s w_t\right] +$$

$$+2\frac{\partial \pi_t}{\partial w_t}\left[\varepsilon\rho_{t+1} - \gamma\beta^s\right] = G'(w_t)$$

Rearranging the latter we can write

$$\frac{\partial^2 F}{(\partial w_t)^2} = G'(w_t) < 0 \iff \varepsilon\rho_{t+1} - \gamma\beta^s - \frac{\varepsilon}{p^s Q - (q - w_t)\varepsilon}\left[p^s Q \rho_{t+1} - (q - w_t)\varepsilon\rho_{t+1} - \gamma\beta^s w_t\right] < 0$$

and in a more concise form,

$$\frac{\gamma\beta^s(q\varepsilon - p^s Q)}{p^s Q - (q - w_t)\varepsilon} < 0 \quad \forall w_t$$

The latter is always satisfied and, hence, we can write

$$\frac{\partial^2 F}{(\partial w_t)^2} = G'(w_t) < 0 \quad \forall w_t .$$

Given that $G'(w_t) < 0$, $G(w_t) > 0 \quad \forall w_t \in [b,q]$ *iff* $G(q) > 0$. Therefore, the necessary condition for $\frac{\partial F}{\partial w_t} = G(w_t) > 0$ is that

$$\varepsilon\rho_{t+1} - \beta^s + \frac{\varepsilon(p^s - p^u)}{p^s Q p^u}\left[p^s Q\rho_{t+1} - \gamma q\beta^s\right] > 0$$

And since $p^s Q\rho_{t+1} > \gamma q\beta^s$, a sufficient condition to have $\frac{\partial F}{\partial w_t} = G(w_t) > 0$ is

$$\varepsilon\rho_{t+1} - \beta^s > 0 .$$

A3

Proposition: The intercept of the line in (18) is greater than the intercept of (19) *iff*

$$p^u B^s > p^s Q p^u - p^s q\varepsilon .$$

Proof: By virtue of (14), $p^u B^s - p^s(Qp^u - q\varepsilon + b\varepsilon) > 0$ and, rearranging,

$$p^u B^s > p^s Q p^u - p^s(q-b)\varepsilon > p^s Q p^u - p^s q\varepsilon$$

QED

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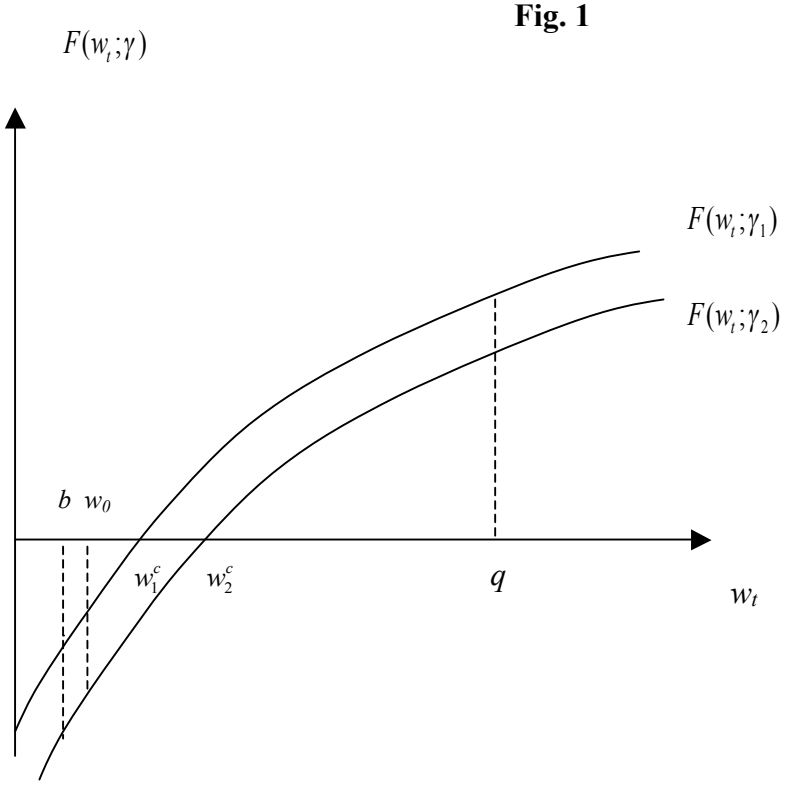
Fig. 1



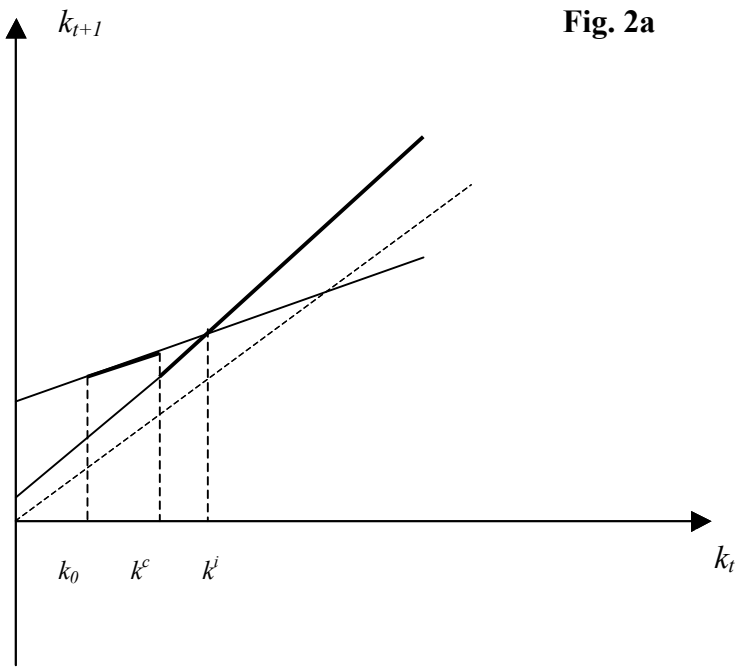


Fig. 2a

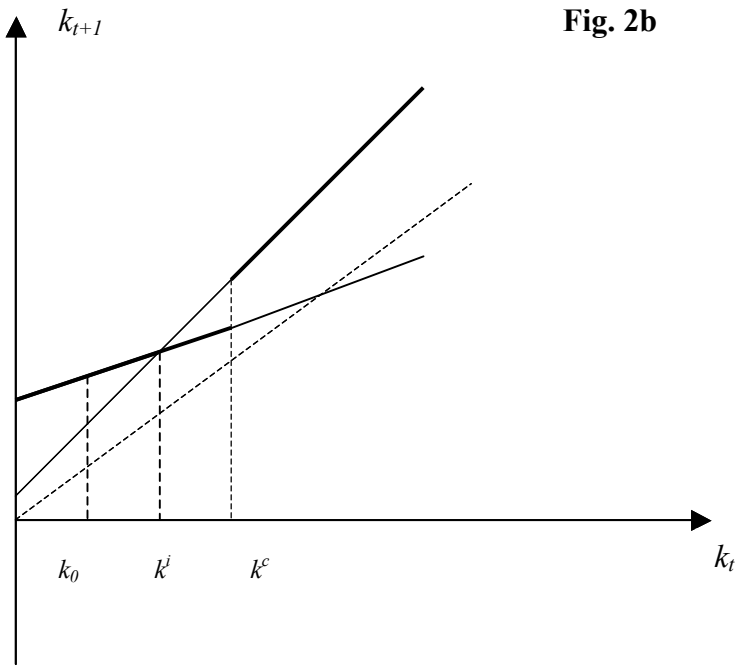


Fig. 2b

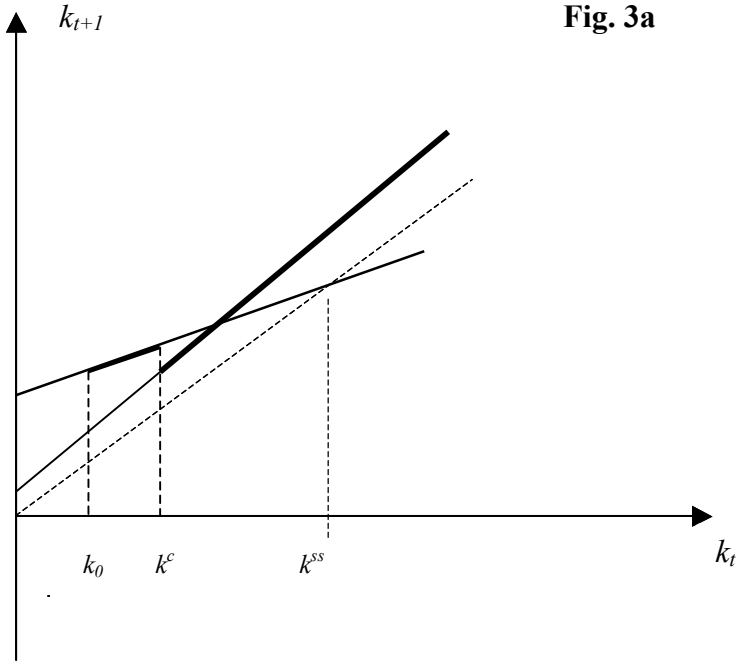


Fig. 3a

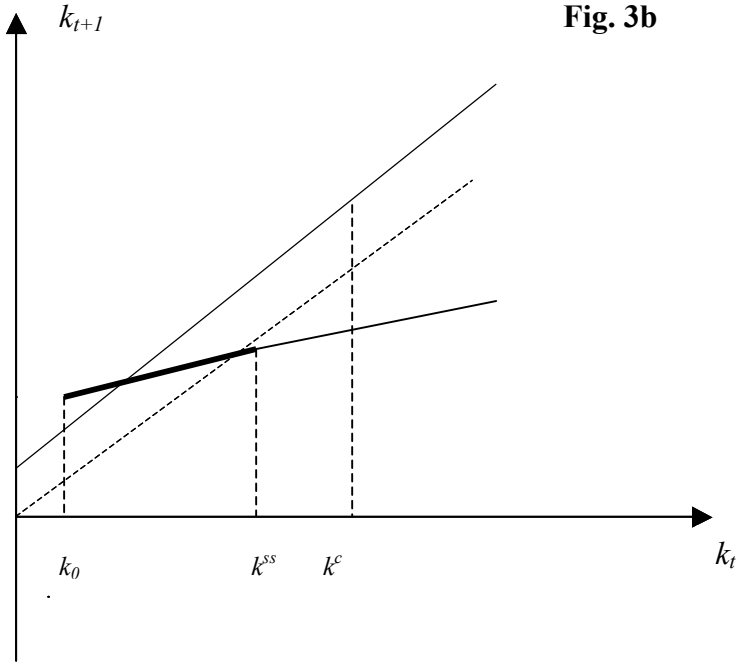


Fig. 3b