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Financial Markets and R&D Investments

A Discrete-Time Model to Interpret Public Policies

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Abstract

This paper introduces a discrete-time intertemporal investment model in which the flow of profits affects the risk premium on the cost of finance, and, as a consequence, the rate of discount of future profits. While public investments, according to a consolidated literature, constitute the main bulk of innovation policies, this model is used to comment and interpret the potential use of another, secondary, public policy, consisting of tax incentives for firms performing R&D expenditures and issuing securities in the stock market. Linking public policies for innovation to the stock market might help to reduce the problems of discretionality and the monitoring of public expenditure used to finance R&D and technical innovation.

Keywords: investment, intertemporal firm choice, capital structure, financing policy

JEL classification: D92, G32

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1 Introduction

The first basic element characterizing the expenditure in R&D is the fact that the link between expenditure in R&D and technological innovation is wrought with significant uncertainty. Positive externalities for firms that have not borne the initial costs of R&D are determined by the nature of public goods characterizing technological knowledge. Technological spillovers and the appropriability of knowledge limit the effectiveness of patents that do not always constitute a totally satisfactory instrument for the firm undertaking potential investments in R&D. For these reasons, a consolidated literature in the field promotes the role of public investments in R&D for product innovation. Another basic element is the fact that technical innovation—by affecting both the technology of the production process and consumer demand—can deeply alter market characteristics and the context in which competition takes place.

The analysis of the (non) success of the Schumpeterian approach in explaining the process of technical innovation is beyond the scope of this paper, but it might be interesting to note that Rosenberg (1982, 2000) provides wide historical and empirical evidence for the US, which suggests that technological innovation in many industries has been successfully introduced by the new entrants rather than incumbent dominant firms. From the point of view of the policymaker (and clearly in case of developing countries), the question appears rather complex. According to the literature, large-scale investments in R&D and innovation need to be covered by public investments, due to strong externalities and spillovers. However, the particular portion of R&D expenditure analysed by Rosenberg and performed by marginal 'new entrant' firms, raises two sets of difficulties. First of all, in highly concentrated markets, oligopolistic dominant firms tend to create barriers to entry against the new entrants who (in Rosenberg's analysis) might be potential carriers of new technology and who face highly uncertain payoffs. Under these circumstances, expected profits of the potential entrants must be significantly high in order to trigger entry and generate new technology. In this specific situation, the role of public investments and public incentives for innovation is not trivial. It is rather difficult to assess the projects that deserve being funded since the decision is, to a large extent, subjective, arbitrary, and characterized by information asymmetries as well as by the obvious problems of monitoring and moral hazard for receiving public incentives. Furthermore, even with the best of intentions there is an intrinsic problem of time inconsistency—what could appear at first to be a good research project might not always turn into a good invention. This constitutes the free-rider problem, an important argument in favour of public investment in R&D. But what about innovations by new entrants and those associated to market dynamics and configuration? Barriers to entry could generate a distortion in the process of invention and reduce the R&D incentives.

The main policy proposal of this paper consists of reducing one kind of distortion (barriers to entry) by moderating another kind of distortion (tax distortion) through the use of tax incentives for firms that conduct successful innovation.

Financial markets play a very relevant role for the entry of potential carriers of new technology. In particular, in transition economies and developing countries the size and efficiency of financial markets constitute a key factor for the efficient allocation of resources.

Table
R&D expenditure in % of GDP
Year 2001

Country	All sectors	Private firms
Belgium	2.2	1.6
Denmark	2.4	1.7
Germany	2.5	1.8
Spain	1.0	0.5
France	2.2	1.4
Italy	1.1	0.6
Netherlands (year 2000)	1.9	1.1
UK	3.0	1.3
Japan (year 2000)	3.0	2.1
US	2.7	2.1

Source: Baussola (2003).

To understand the relevance of the link between efficient financial markets and technological innovation, one might consider the case of Italy. A former G8 country, Italy suffers from an unsatisfactory level of R&D expenditure and is witnessing a lively debate on the causes of its industrial decline. The country has always been characterized by (i) a relatively imperfect system of juridical protection for small shareholders, (ii) rather undeveloped financial markets (at least compared to bank intermediation), (iii) a relatively small number of public companies, (iv) significant concentration and rigidities in the market for entrepreneurial control not necessarily associated with the market for shares.[1]

In addition, many companies (small as well as large) have been controlled by the same family of entrepreneurs for several generations. Buckhart, Panunzi and Shleifer (2002) point out that, on the one hand, this ownership feature reduces the agency problems since it is characterized by the relationship between owners and managers while on the other hand, it raises very relevant problems concerning the selection process of executive managers because these tend to be appointed on the basis of family links rather that on the basis of their professional abilities. A similar situation is also apparent in the less efficient financial markets with a relatively small number of public companies, where strong bias and disincentives of external shareholders and investors create problems in investment financing. Furthermore, Santarelli and Vivarelli (2002) and Lotti, Santarelli and Vivarelli (2001) note that the birth of new firms is, statistically speaking, very significant in Italy, but these new entrants are in general very small, have a high probability of exit and have historically been supported by very unselective and distortionary policy incentives. Incentives are strongly oriented toward the production of traditional commodities in the industrial sector, but are rather weak in all hi-tech sectors where size and scale economies pay a relevant and strategic role. According to many analysts, this is possibly one of the main causes of the decline of the Italian industry.

1 Hostile takeovers have historically been extremely rare and therefore the controlling groups of shareholders have a complete control of their companies.

2 The model

In a world of financial market imperfections due to information asymmetries, the internally generated cash flow constitutes a cheaper source of finance than borrowing or issuing new shares. The behaviour of the share price and capital gains may affect the dividend policy of the management which in turn impacts on the firm's financial structure by determining the rate of retention of profits, subsequently affecting the volume of investments financed by internal finance. All of these are factors that may have relevant implications for the standard intertemporal investment decision. If the firm's financial structure is affected by profits retention and if the cost of financial capital is affected by the firm's financial structure, then to the extent that the (firm specific) discount factor is assimilated to the cost of financial capital, a causal link for the firm's intertemporal investment decision is established between its profits, financial structure and discount rate for the future profits. Timing in the coordination process between financial and investment decisions is essential for the definition of flow variables. For this reason we introduce here a discrete-time optimal control model with a recursive structure, with financial markets imperfections and diverging incentives between the management and external shareholders.

In this model, financial and real investment decisions take place simultaneously. The goods market is assumed to be imperfectly competitive, although perfect competition can be a particular case. On the basis of the assumptions summarized in the previous section, the management is assumed to be able to decide how to allocate the firm's cash flow once the creditors are repaid and shareholders have been remunerated consistently with a yield that depends on the average market yield of the shares. Average market yield of the shares will, of course, influence the remuneration owners expect to receive from their financial investments. Furthermore, given that the managers are assumed to fully control the firm and its cash-flow allocation, the actual amount of dividends paid to the shareholders is the result of an implicit negotiation between management and external shareholders. It can be affected by a number of factors related in general to the existing relationship between management and external shareholders. In particular, the management may or may not have the incentive to reveal information on the firm's profitability. If this is the case, the stock price might not react (at least in the short run) to changes in the profitability of the firm. On the other hand, if we allow for the possibility of speculative bubbles (at least in the short run), and if we admit that in the short run the share price might overshoot its theoretical level as implied by the net present value of future profits, we must include this fact in the rational financial choice of the management.

The model is formalized with the optimal control approach in order to explicitly refer to the standard results of the investment model and to emphasize how different the results can be by simply introducing some common assumptions of financial market imperfections, risk premium on the remuneration of finance raised by the firm, which may be affected by information spreading regarding the outcome of R&D expenditures carried out by the firm. In order to take into account the relevance of timing in real and financial decisions (which cannot be accounted for over a continual time period in an optimal control model), we introduce a recursive structure for the intertemporal problem of the firm's investments.

The capital is installed at time t-1, and is funded with financial sources raised by the firm at time t-1, reflecting remuneration or expected remuneration at time t. Investment decisions, the production process (generating the profits π_t) as well as payment of interest on borrowed capital and dividends on own capital take place at time *t*. Φ^*_t is the weighted average of the cost of own capital and borrowed capital, established at time *t*-1 and paid at time *t*.[2]

We assume that the time horizon of the decisionmakers (the management) corresponds to their expected residual time *m* of being in control in the company. This assumption is actually as arbitrary as assuming that the time horizon is infinite. Expectational equivalence is assumed to hold.

The problem of the firm may be represented in the following way:

$$V_t = \sum_{t=1}^{m} \{[\, E(\pi_t(k_{t-1}|\nu^*, \omega l^*)) - I_t] \cdot [1/(1+\Phi^*_{t-1})^{t-1}]\} \qquad (1)$$

where $\pi_t(k_{t-1}|\nu^*, \omega l^*)$ is defined as the (strictly concave) maximum value function, conditional on the parameter ν^* (describing possible shocks on profits) and on the labour costs $\omega\, l^*$). In what follows, we assume ν^* and ωl^* to be given and will omit them in the rest of the paper.[3]

k_{t-1} is the capital installed at time $t-1$, I_{t-1} is the amount of investments decided at time *t* that will contribute to determining the stock of capital at time *t*+1.

Φ^*_{t-1} represents the minimized cost of financial capital at time $t-1$: we return to this variable below when defining one of the constraints.

The maximand (1) is subject to the following constraints:
Law of motion of investments

$$I_t = k_t - (1-\delta)\, k_{t-1} \qquad (2)$$

with $0 < \delta < 1$ being the rate of capital depreciation;

Flow of funds constraint:

$$I_t = \pi_t(k_{t-1}) - \Phi^*_{t-1}\, k_{t-1} + \Delta B_t + \Delta E_t \qquad (3)$$

Balance sheet constraint:

$$k_t = E_t + R_t + B_t \qquad (4)$$

Where B_t is the outstanding debt at time '*t*', ΔB_t its variation between time *t*-1 and time *t*, E_t the outstanding shares valuated at their issuing price, R_t the accumulated reserves,

2 For the discrete-time extension and applicability of Pontryagin maximum principle with finite time horizon, see Seierstad and Sydsæter (1987: 207-10 and 370-7) and Tu (1991).

3 To support this sort of *ceteris paribus* assumption, we can think of a labour market characterized by a simplified efficiency wage mechanism in which wages and employment are fixed in the short run and are affected mainly by macroeconomic factors

i.e., the past non-distributed profits, Φ^*_{t-1} the (optimized) cost of financial capital, defined as the weighted average of debt and internal finance as follows:

$$\Phi^*_t = \min\,[\mu\,[r^f_t + \phi(\mu_t)] + (1-\mu)\,i_t] \qquad (5)$$

where i_t represents the cost of internally generated own capital, defined below, r^f_t is the risk-free interest rate, $\phi(\mu_t)$ is the risk premium on the interest rate on the firm's borrowing, which is assumed to be a monotonically increasing function of the gearing ratio $\mu_t = B_t/k_t$, and Φ^*_t represents the minimum value function of the firm's financial cost minimization problem.

The rate of discount of future profits is the (optimized) cost of finance that contains a risk premium function of the gearing ratio and therefore (given the assumptions of the model) of the firm's profits. We can define it then as $\phi(\pi_t)$ and $\Phi^*_t = \Phi^*_t\,[\phi(\pi_t)]$. Intuitively speaking, one can easily see that by allowing unexpected random shocks on the profits, the higher the profits, the less likely is the firm to go bankrupt.

At every time t the firm optimizes its financial structure by choosing the optimal gearing ratio $\mu_t = B_t/k_t$ that minimizes the cost of financial capital, defined as the weighted average between the borrowed and internally generated finance. Φ^*_t obviously represents the rate at which the firm can raise external finance for its investments, and can transfer resources from time t to time t+1 .

The optimized financial structure determines the rate of discount appearing in the intertemporal problem, which is conditional on the flow of non-distributed profits of the previous period. In this way the 'firm specific' rate of discount is recursively determined as a function of the lagged stock of physical capital and lagged cost of financial capital.

i_t is defined as follows:

$$i_t = D^* / (E_0 + R_t) \qquad (6)$$

where the issuing price (at time 0) of the N firm's shares is:

$$E_0 = p_{s,0} \cdot N_t$$

R_t, the non-distributed profits of all the previous years, from the starting year t=0, are defined as follows:

$$R_t = \sum_{i=0}^{t} W_i$$

and

$$D^* = r^*_{s,t} \cdot p_{s,t} \cdot N_t - \Delta p_{s,t}\, N_t$$

Where, again,

- $r^*_{s,}$ = the yield on the firm's share at time t;
- $p_{s,t}$ = the share price;
- $\Delta p_{s,t}$ = its variation with respect to time $t-1$;
- N_t = the number of existing shares.

In other words, given the share price, the short-run capital gain and the (exogenous) yield $r^*_{s,t}$ that the management allows for its shareholders, we can determine the amount of paid dividends. In this regard, we could have two possible situations: the first (and extreme) one is the standard neoclassical investment model; the second one corresponds to a situation in which the management pays dividends strictly in an amount consistent with the market yield of the shares and the share price might not always reflect (in the short run) the net present value of future profits.

In order to have the standard neoclassical investment model with efficient financial markets:

i) Share prices must adjust perfectly and instantaneously to the value implied by the profits;

ii) Cash flows (net of adjustment costs of investments) are to be entirely exhausted as interest and dividend payments (i.e., no agency problem and no incentive for the managers to keep the cash flow—as far as possible given the yield on shares—within the firm).

In all the other cases, the stock price in the short run may diverge from the value implied by the net present worth of future profits. This is our assumption in the remainder of the paper.

If stock prices were to be affected by the endogenous propagation of expectations (as, for instance, in Kurz's 'rational beliefs' theory), then the share price would be subjected to a number of shocks and would follow a path apparently uncorrelated (or only very weakly correlated) in the short run to actual profits.

In order to explain the 'irrational exuberance' of some years ago, many mainstream authors (for instance, Miller, Weller and Zhang 2002) had to invoke a theory of some sort of long-lasting bubble in order to justify the puzzle of the Nasdaq index in 1996-2001. In this context, again stock prices in the 'short run' would be exogenous with respect to 'real' profits even though the 'short run' in this case would be as short as a decade.

On the other hand, even without being as sceptical as Kurz on the efficiency of financial markets, if one admitted that stock prices may diverge for a sufficiently long enough period from the value implied by the profits of firms, managers may lack the incentive to reveal all information regarding the firm's profitability and they may prefer not to exhaust profits into dividends and interest payments.

Under these assumptions, we can consider the share price to be exogenously determined in the short run.

Note that for the shareholder the yield on shares is given by:

$$r^*_{s,t} = [D^*/(p_{s,t} \cdot N_t)] + (\Delta p_{s,t} / p_{s,t})$$

while for the management the cost of capital is affected by the (exogenous) book value $p_{0,t} \cdot N_t$ of the shares. However, for a given (and exogenous) value of $(\Delta p_{s,t} / p_{s,t})$, it is easy to verify that if $(\Delta p_{s,t} / p_{s,t})$ were subject to shocks, these would have an impact on the dividend policy and consequently on the firm's financial structure and investment decisions. Note that due to the assumptions made here regarding the control of the cash flow by insiders, once the shares have been issued, their market value is relevant to the managers only to the extent that it contributes to determining their dividend policy. For this reason, the notation ΔE_t or E_t is different from the notation employed to indicate the value of newly issued shares.

The above assumptions generate not only a recursive structure in the problem but also a certain persistence of the influence of past profits on the discount rate. The extent of this persistence is implicitly limited by the rate of capital depreciation δ.

Since the internally generated finance is predetermined (by the non-distributed profits at time $t-1$), by choosing the value X_t of the newly borrowed finance, the firm also determines the maximum amount of feasible new investments at time t and the gearing ratio at time t, which will be incorporated in the new debt contracts issued by the firm in order to finance a part of its investments.

Let us now analyse the minimum value function Φ^*_t. Assuming that the second-order conditions are satisfied, the first-order conditions are the following:

$$d\Phi^*_t/dt = r^f_t + \phi(\mu_t) + \mu_t \phi'(\mu_t) - i_t = 0$$

The above equation (stating that in equilibrium the marginal cost of borrowing equals the marginal cost of the internally generated finance) can be simplified by assuming that $\xi = \phi(\mu_t) + \mu_t \phi'(\mu_t)$ can be rearranged into a monotonically increasing and invertible function of μ_t. One can easily verify that this is always true if $\phi(\mu_t)$ is convex in μ_t, as we are assuming henceforth in the model.[4] In this case we get:

$$\mu_t = \xi^{-1}(i_t - r^f_t) \tag{7}$$

In other words, this means that the gearing ratio is an increasing function of the difference between the cost of own capital i_t and the interest rate on risk-free assets r^f_t, because, for a given r^f_t, the higher the cost of own capital, the higher the incentive for the firm to borrow by increasing the gearing ratio. At each time, by choosing the level of debt, the managers simultaneously affect the investments (i.e., the control variable), the financial structure and the cost of finance.

By looking at the constraints (2), (3)′ and (4), one immediately sees that they both are dynamic equations putting into relation two flow variables I_t and $X_t = \Delta B_t$ with the state variable k at two different moments in time $t-1$ and t.

In particular, while I_t relates the state variables k_{t-1} and k_t to a given rate of discount Φ^*_t, X_t does the same job and determines in addition (together with k_t) the

4 This would be true also if $\phi(\mu_t)$ were concave but with a second derivative sufficiently small in absolute value, i.e., if its curvature is 'relatively flat'. However, the assumption of convexity for $\phi(\mu_t)$ is rather general, since it could capture the situation in which highly-indebted firms would have to pay an extremely high risk premium on borrowed capital. Furthermore, if the analytical form of $\phi(\mu_t)$ were such that it tended asymptotically to infinite when μ_t approaches 1, one could reproduce the case of credit rationing by introducing appropriate analytical form and parameters for the function $\phi(\mu_t)$.

optimal rate of discount. In other words, in contrast to the conventional neoclassical intertemporal investment models, it is not I_t but X_t that acts as a control variable in this context.

Since we know from (3)′ that $\pi_t\ (k_{t-1}) - I_t = \Phi^*_{t-1} \cdot k_{t-1} - X_t$, we may express (1) in terms of the control variable X_t and the state variable k_{t-1}, while by putting together the two constraints (3)′ and we can eliminate I_t and express the intertemporal constraints also in terms of X_t. Therefore the firm's problem can be redefined as follows:

$$V_t = (\Phi^*_{t-1} \cdot k_{t-1} - X_t) + \sum_{t=1}^{m} \{[\Phi^*_t \cdot k_t - X_{t+1}] \cdot [1/(1+\Phi^*_t)^t]\} \tag{8}$$

s.t.

$$k_t = (1-\delta)\, k_{t-1} + \pi_t \left(k_{t-1}\right) - \Phi^*_{t-1} \cdot k_{t-1} + X_t$$

if one allowed for shocks in the profit function $\pi_t(k_{t-1}|\,\nu^*, \omega l^*)$, for instance, by letting ν^* be subjected to shocks, these would be transferred to the rate of discount of future profits from the next period on. In addition, as we can see again from (5), (7) and (4), the firm's discount rate is affected by the share price and its variations. In other words, a financial shock modifying the optimal dividend policy of the firm's managers would also modify the cost of own capital, the optimal gearing ratio, and, as a consequence, the discount rate. Of course, the specific nature of these causal links would depend on the nature of the relationship between π and p, i.e., how efficient the financial market is and how fast and efficiently information spreads from the profits of the firm to its stock price.

3 A slightly unconventional result

We are now able to write the discrete Hamiltonian as follows:

$$H_t = (\Phi^*_{t-1} \cdot k_{t-1} - X_t) + \sum_{t=1}^{m} \{[\Phi^*_t \cdot k_t - X_{t+1}] \cdot [1/(1+\Phi^*_t)^t]\} +$$

$$+\ \lambda_t(X_t - k_t + (1-\delta)\, k_{t-1} + \pi_t\ (k_{t-1}) - \Phi^*_{t-1} \cdot k_{t-1})$$

where

$$\Phi^*_i = \Phi^*_i\ (\mu_i\ (i_t - r^f_t))$$

and

$$i_t = (r^*_{s,t} \cdot p_{s,t} \cdot N_t - \Delta p_{s,t} N_t) \,/\, [E_0 + \sum_{I=0}^{t} (\pi_i\ (k_{i-1}) - \Phi^*_{i-1} \cdot k_{i-1})]$$

The definition for i_t allows us to clarify the link between profits, information spreading, share prices and dividend policy. For instance, if the managers lack incentives to reveal information on the profitability of the firm, the share price might not react (at least in the short run) to increases in profits. Therefore, the numerator of i_t would not change and the denominator would increase. This means that an increase in π_i (k_{i-1}) would be associated to a reduction in the cost of own capital and, hence, on the average cost of capital.

On the other hand, if an increase in the firm's profitability determines an increasing and persistent capital gain, the numerator of i_t would be small again: in other words, own capital would become relatively cheap (as long as $\Delta\, p_{s,t}$ increases) since the management, due to capital gains, would need to pay less dividends to external shareholders to keep them happy.

Given the assumptions we made on the cost of own capital and determination of dividends, any shock to the exogenous share price would be transferred to the dividends and hence to i_t and the optimal financial structure μ, which determines (through (7)) the rate of discount of future profits. In other words, by substituting (5), (6), and (7) into (4), Φ^*_i could be defined as the following generical function:

$$\Phi^*_t = \Phi^*_t \left(\mu_t (r^f_t,\, r^*_{s,t},\, \pi_t) \mid p_{s,t},\, \Delta p_{s,t}\right)$$

Assuming now that the regularity conditions for H_t are satisfied, an easy and straightforward application of the Tu definition of the 'discrete maximum principle' (Tu 1991: 261-4) yields the following results:

$$\partial H_t / \partial X_t = 0 \;\; \Rightarrow \;\; \lambda_t = 1 \qquad (9)$$

$$\partial H_t / \partial k_{t-1} = \lambda_t$$

which imply

$$(\partial\pi_t / \partial k_{t-1}) - \delta = (\partial\Phi^*_t / \partial W_t) \cdot ((\partial\pi_t / \partial k_{t-1}) - \Phi^*_{t-1}) \cdot [\Phi^*_t \cdot k_t - X_{t+1}] \cdot [1/(1+\Phi^*_t)^2] -$$
$$- [1/(1+\Phi^*_t)]\, (\partial\Phi^*_t / \partial W_t) \cdot ((\partial\pi_t / \partial k_{t-1}) - \Phi^*_{t-1}) \cdot k_t + \qquad (10)$$
$$+ \sum_{i=t+1}^{m} \{[1/(1+\Phi^*_i)^i](\partial\Phi^*_i / \partial W_i) \cdot ((\partial\pi_i / \partial k_{i-1}) - \Phi^*_{i-1}) \cdot [(\Phi^*_i \cdot k_i - X_{i+1}) \cdot (1/(1+\Phi^*_i)) - k_i]\}$$

The left-hand side of (10) is, of course, the marginal profitability of capital, net of the rate of depreciation of k. The right-hand side of (10) is composed of three addends, one for each row. The first one can be considered as the effect of how modifications in the discount rate generated by a change in the state variable affect the way in which the future values of the net financial flows $\Phi^*_t \cdot k_t - X_{t+1}$ are discounted.

The second addend (second row) describes how the same modifications in the discount rate again modify the flow of dividends and interest rates that have to be paid on the future capital k_t (which, given the balance sheet constraint of the firm, is equal to the financial capital $B_t + R_t$). The third addend (third row) represents the total of the two above-mentioned effects for the remaining future periods.

Intuitively we can assume that any shock to the profit function on the left-hand side of the above equation (i.e., any shock affecting the functional link between profits and capital such as technology shocks, but also shocks in the market structure or in the degree of competition among firms) determines both the shock on the cost of financial capital, and a second shock on the rate of discount of future profits. This happens because in imperfect financial markets, the cost at which the management is able to raise funds is bound to be affected by the risk premium and by the cash flow. In addition, the converse is also true: any (exogenous in this framework) shock to the discount rate (caused, for instance, by a speculative bubble increasing share prices) affects the cost of external finance (since the managers need to pay less dividends to shareholders in order to keep them happy) and hence the rate of discount, by increasing the right-hand side of the above equation. All of this brings about a modification in the marginal profitability of capital, in the left-hand side of the above equation.

Equation (10) can be rearranged as follows:

$$(\partial \pi_t / \partial k_{t-1}) - \delta =$$

$$= (\partial \Phi^*_t / \partial W_t) \cdot ((\partial \pi_t / \partial k_{t-1}) - \Phi^*_{t-1}) \cdot (1/(1+\Phi^*_t)) \cdot [(\pi_t - I_t - (1+\Phi^*_t)\, k_t) \cdot (1/(1+\Phi^*_t))]$$
$$+ \sum_{i=t+1}^{m} \{[1/(1+\Phi^*_i)^i](\partial \Phi^*_i / \partial W_i) \cdot ((\partial \pi_i / \partial k_{i-1}) - \Phi^*_{i-1}) \cdot [(\pi_i - I_i - (1+\Phi^*_i)\, k_i) \cdot (1/(1\ \Phi^*_i))]\} \quad (11)$$

The expression $(I_t + (1+\Phi^*_t)k_t)$ might be interpreted as the total capital absorption (i.e., capital stock plus investments) plus capital remuneration at time t. Since the marginal profitability of capital associates a change in profits to a change in the stock of capital, the first line of (11) contains the difference between profits and capital absorption and remuneration $\pi_t - I_t - (1+\Phi^*_t)k_t$.

The term $((\partial \pi_t / \partial k_{t-1}) - \Phi^*_{t-1}) \cdot (1/(1+\Phi^*_t))$ is the present value of the spread between $(\partial \pi_t / \partial k_{t-1})$ and $(\partial \pi_t / \partial k_{t-1})$ that would be obtained if nothing changes at time t+1. The term $[(\pi_t - I_t - (1+\Phi^*_t)\, k_t) \cdot (1/(1+\Phi^*_t))]$ is the present value of the difference between profits at time t+1 and capital absorption and remuneration at time t+1.

The term $(\partial \Phi^*_t / \partial W_t)$ is the impact of the firm's wealth on the risk premium and hence on the capital cost. Therefore the marginal profitability of capital (net of depreciation) may be decomposed into $(\partial \Phi^*_t / \partial W_t) \cdot ((\partial \pi_t / \partial k_{t-1}) - \Phi^*_{t-1}) \cdot (1/(1+\Phi^*_t))$ and $[(\pi_t - I_t - (1+\Phi^*_t)\, k_t) \cdot (1/(1+\Phi^*_t))]$ as well as their future net present discounted values. Generally speaking, (11) could be interpreted as a link between the marginal profitability of the capital and the financial value of the firm.

In other words, the portion of marginal profitability of capital not paid out by the management as remuneration for shares and debt, has an impact on the firm's financial reserves, and hence on the discount rate of future profits and on the value of the firm.

The results presented here diverge slightly from the conventional neoclassical investment model because the assumptions made with regard to the cash flow control of the managers, the fact that the market for shares is not necessarily associated with the market for the firm's control, and, finally, financial market imperfections (and imperfect adjustment of the share price to the value implied by the discounted future profits) introduce a causal link between the flow of profits, the firm's financial structure and the rate of discount of the future flow of profits. This can be interpreted as an 'inside-the-firm' channel of transmission of financial shocks to real investments. This framework could also help explain some recent empirical results claiming that the inclusion of appropriate measures for stock market yields and capital gains would make the internal cash flow statistically non-significant in investment regressions based on firms' panel data (for instance, Gomes 2001). In fact, to the extent that both current profits and stock prices simultaneously contribute to determining the (endogenous) rate of discount of future profits, they could turn out to be statistically co-determined and simultaneously correlated with investments through the firm specific rate of discount of future profits. If the firm enjoys a long period of high profits and its stock price overshoots the value implied by the profits (like in the excess volatility case *à la* Shiller) so that the firm experiences increasing capital gains for an extended period (as in the 'irrational exuberance' case), the results become even stronger. In other words, an increasingly overvalued share price makes the internally generated finance cheaper because it allows the managers to pay out less in dividends (and still keep the shareholders satisfied since they are remunerated by the capital gain). This could contribute to the explanation as to why some recent empirical analyses (e.g., Gomes 2001) find that introducing appropriate measures for stock market prices in an investment regression seems to reduce the statistical significance of the internally generated cash flow.

4 Interpretation of the results and policy considerations

The model suggests a feedback mechanism between profits, the cost of capital and the firm's investments. With imperfect financial markets, the stock price (due to imperfect information and the incentive of management not to fully reveal privileged information on the profitability of the firm) may, in the short run, deviate from the value implied by the discounted future dividends. Obviously the nature and characteristics of this feedback depend on the assumption made regarding the relationship between future profits, the price of the firm's shares, the yield on shares and how the cost of finance is affected by the behaviour of stock prices (i.e., whether and how the risk premium on firm's finance reacts to the information revealed by the behaviour of stock prices).

The efficiency and the level of development of financial markets play a crucial role in the process of economic growth, to the extent that they finance technological innovation. In this regard, a very relevant piece of information with regard to the developing countries could be provided through further empirical research on the link between financial market efficiency, credit market efficiency, intensity in R&D expenditure and growth. In particular, the model shows a 'double channel of transmission' of shocks to investments. By simplifying the feedback mechanism between profits and the cost of financial capital, it has been shown that the interaction between financial and investment decisions introduces an additional 'financial' channel of causation between profits and real investments. This financial channel can potentially amplify the effects of an exogenous shock in a firm's profits on its investments.

The model can also be used to analyse the effects of public policy for encouraging innovation and investments in R&D. Of course, the main bulk of innovation policies should be based on public investment. However, obvious potential exists for innovation policies associated with concentrated markets where innovation is conducted by potential entrants and is bound to affect the market structure (and make it more competitive). This would consist of tax incentives for firms that have (i) documented a certain level of expenditure in R&D (for instance, beyond a certain threshold defined as a percentage of its sales), (ii) registered patents (thus providing evidence of product innovation), (iii) issued shares on the local stock market beyond a certain threshold of their own capital (thereby contributing to the increased size of the market for control by firms and to the size of the stock market in general) and (iv) have attained positive profits for a specific time period after issuing shares. These, in terms of our model, would have a double impact on the level of investments in R&D.

First of all, there is an impact on the flow of profits. Technological innovation in itself would increase the profit flow of the firm that has made R&D investments, thereby increasing the firm's payoff if the R&D investment was fruitful.

Furthermore, a second impact could be achieved through a reduction in the cost of finance that is carried over by the process of information spreading taking place in financial markets and which would convey knowledge of successful investment in R&D. The subsequent reduction in risk premium (both on debt and stock issued by the firm) would reduce the discount factor of the future flow of profits. This would also increase the incentive for investing in the capital that was the object of successful expenditure in R&D.

Policy promoting tax incentives should be preferred to direct public investments, as tax incentives would minimize the problem of monitoring the quality of investments and management ability. Firms interested in benefiting from this fiscal advantage would need to face 'stock market valuation'. Examination of the stock price pattern would enable policymakers to assess and monitor the effectiveness of innovation policies. Thus the tax advantages for firms complying with the above mentioned requirements would help to reduce the degree of discretionality of public investment. In addition, given the existence of asymmetric information in financial markets, this would generate a 'virtuous circle' based on self-selection. Firms confident of the quality of their R&D investments would have an incentive to take advantage of the capital gains in the stock markets that would, in addition, trigger a tax reduction. Tax distortion on capital allocation would be reduced in innovative sectors. Furthermore, in institutional contexts where financial markets are not fully developed and very few public companies exist, the incumbent companies would act to increase the size of financial markets. Finally, in some 'bank oriented' financial systems where financial markets are not yet widely extended (see Allen and Gale 2000 in this regard) and the market for control by firms is not always linked to the market for shares, policies consisting of tax incentives for R&D expenditures for the issuance of stock market shares could create a positive externality, through the increase in the size and competition of the financial markets, thereby creating an actual and effective market for control by firms. As argued by the Rosenberg studies (2000, 1982), a wide historical and empirical evidence for the US seems to suggest that in many industries technological innovation has been successfully introduced by the new entrants rather than the incumbent dominant firms. If this is the case, the above mentioned mechanism of fiscal incentives would motivate both new firms to enter the market and incumbent dominant firms (usually already well present in the stock markets) to increase their expenditure in R&D in association with issuing new shares.

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