University of Turin

Department of Economics "Cognetti de Martiis"

Out of Equilibrium Profit and Innovation

Cristiano Antonelli (cristiano.antonelli@unito.it)
Giuseppe Scellato (giuseppe.scellato @polito.it)

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Via Po, 53 – 10124 Torino (Italy)
Tel. (+39) 011 6704917 - Fax (+39) 011 6703895
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WORKING PAPER SERIES

OUT OF EQUILIBRIUM PROFIT AND INNOVATION

Cristiano Antonelli e Giuseppe Scellato

Dipartimento di Economia "S. Cognetti de Martiis"

LEI & BRICK - Laboratorio di economia dell'innovazione "Franco Momigliano"
Bureau of Research in Innovation, Complexity and Knowledge, Collegio Carlo Alberto

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OUT OF EQUILIBRIUM PROFIT AND INNOVATION[1]

Cristiano Antonelli
Dipartimento di Economia, Università di Torino
BRICK (**B**ureau of Research in **C**omplexity, **K**nowledge, **I**nnovation), Collegio Carlo Alberto.

Giuseppe Scellato
Politecnico di Torino
Dipartimento di Sistemi di Produzione ed Economia del'Azienda
C.so Duca degli Abruzzi 24, 10129 Torino, Italy
giuseppe.scellato @polito.it
Tel: + 39 0115647211
Fax: + 39 0115647299

ABSTRACT.

Innovation is the result of intentional decision-making that takes place in out-of-equilibrium conditions. The farther is profitability from the average and the deeper the out-of-equilibrium conditions. The farther away is the firm from equilibrium and the stronger the likelihood for innovation to take place. The hypothesis of a U-relationship between levels of profitability and innovative activity, as measured by the rates of increase of total factor productivity, is articulated and tested. The evidence of a large sample of 7000 Italian firms in the years 1996-2005 confirms that a strong causal relation holds between the quadratic specification of profitability and the growth rates of total factor productivity. The results are robust to different approaches to evaluate productivity growth rates.

KEY-WORDS: ENDOGENOUS TECHNOLOGICAL CHANGE, OUT-OF-EQUILIBRIUM, PROFITABILITY, INNOVATION, TOTAL FACTOR PRODUCTIVITY.

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1. INTRODUCTION

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Technological change is usually treated either as the product of exogenous events, such as scientific breakthroughs or discoveries, or as the automatic and spontaneous outcome of learning. Consistently, much economics of innovation focuses mainly if not exclusively the analysis of the consequences of technological change.

This paper elaborates the view that technological change is the endogenous result of intentional action. As such there is scope for a full-fledged economics of innovation, that is, the study not only of the consequences of innovation, but also of its determinants.

Innovation is not only the cause of out-of-equilibrium conditions, but also the consequence of out-of-equilibrium. Firms innovate when out-of-equilibrium conditions prevail and, in so doing, keep away the system from equilibrium. On the opposite, when the system gravitates near-by equilibrium conditions, firms have lesser incentives and opportunities to introduce innovations: hence the system converges towards stable equilibrium conditions.

The introduction of innovations is the result of a complex sequence of intentional decision-making. The decision to innovate, however, cannot be treated with the standard maximization procedures. The outcomes of innovations are hard to predict, and the actual chances of introduction of successful innovations are subject to radical uncertainty. The appreciation of the role of intentional decision-making in the generation of new knowledge and new technologies leads to the identification of the notion of creative reaction. The conditions for creative reaction are provided by the mix of incentives and opportunities that emerge when firms are found in out-of-equilibrium conditions. More specifically, we contend that out-of-equilibrium conditions are identified by levels of profitability below and above the average: in both cases the firm and the system are not in equilibrium. Firms innovate when either change is induced by emerging failures and generally by the mismatch between expectations and actual market conditions, or by emerging opportunities that take place in well-identified institutional conditions.

Consistently with the dominant view that technological change is exogenous a large literature has explored the relationship between innovation and profitability where the attention focuses upon the consequences of innovation upon profits. Much less attention has been paid to the reverse causal relationship[2]. This paper explores the role of profitability as a determinant of innovative activity.

A consistent and coherent frame of analysis can be elaborated by integrating different and yet complementary strands of literature that share the view that technological change is endogenous and that the decision to innovate is an intentional and relevant component of economic decision-making.

Specifically, the new appreciation of some neglected facets of three such approaches provides complementary components for an integrated economics of the role of profitability as a causal factor of innovative activities: a) the reappraisal of the Marxian analysis of the role of the decline in profitability in pushing firms to innovate, b) the reconsideration of the Schumpeterian analysis of the extra-profits associated with the corporation as an institutional engine for continual introduction of innovations and c) the implications of the behavioral theory of failure-induced decision-making. Building upon such elements the paper elaborates and tests empirically the hypothesis that a non-linear relationship between profits and innovation is at work.

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2 Since the seminal contributions of Schmoockler (1966) and Scherer (1982) few studies have addressed the role of demand in pushing technological change. Here, however, here we take a different perspective, focusing on the dynamics of profitability as a key determinants of innovation (Saviotti, 2001; Crespi and Pianta, 2007).

The rest of the paper is organized as it follows. Section 2 collects the different building blocks of the analysis of the causal relations between profitability and innovation is addressed. Section 3 provides an integrated framework and puts forward the working hypotheses. Section 4 presents the model, provides information on the data and tests the hypotheses. The conclusions summarize the theoretical and empirical results of the paper.

2. THE BUILDING BLOCKS

2.1. THE MARXIAN LEGACIES

According to a well-established tradition of analysis, Marx contributed the first elements of the theory of induced technological change. The introduction of new capital-intensive technologies is the result of the intentional process of augmented labour substitution. When wages increase, capitalists are induced to introduce new technologies that are embodied in capital goods. Hence technological change is introduced with the twin aim of substituting capital to labor so as to reduce the pressure of unions and increasing the total efficiency of the production process (Marx, 1867).

John Hicks (1932) and Fellner (1961) extracted from the analysis of Karl Marx the basic elements of the theory of the induced technological change: firms are induced to change their technology when wages increase. Technological change is considered an augmented form of substitution: technological change complements technical change. Binswanger and Ruttan (1978) eventually articulated a more general theory of induced technological change: firms introduce new technologies in order to save on the production factors that are relatively more expensive. Such production factors can be labor, as much as energy or even capital in specific circumstances. The induced technological change approach has been criticized by Salter (1966) according to whom firms should be equally eager to introduce any kind of technological change, either labour- or capital-intensive, provided it enables the reduction of production costs and the increase of efficiency.

An important facet of the Marxian analysis is missing in the induced technological change approach. The analysis of the Marxian contribution by Rosenberg (1976) highlights the limitations of the induced technological change approach and helps to understand the key role of profitability. Firms try and contrast the decline in their profitability, stemming from the increase in wages, with the introduction of technological innovations. Starting from a common reference to Marx, Hicks paved the way to a tradition of analysis that focuses the role of the changes in the prices of production factors in inducing technological innovations, Rosenberg, instead, stresses the role of the decline in profitability as the focusing mechanism that pushes firm to undertake innovative activities. According to Rosenberg firms innovate in order to restore the levels of profitability (that have been undermined by the raise in wages). According to Hicks firms react to the increase in wages (and the related decline in profitability). As Nathan Rosenberg (1969) argues Marx provides elements to build much a broader inducement hypothesis, one where the levels of profitability are a cause of endogenous technological change. This line of analysis has received much less attention in the economics of innovation, and yet it provides a clear replay to Salter's arguments

2.2. THE SCHUMPETERIAN LEGACIES

Business cycles and innovation cycles

The Rosenberg-Marx line of analysis is fully consistent with the appreciation of the role of creative reaction in economic history, elaborated by Schumpeter in *Business Cycles* (1939). Here Schumpeter suggests that the gales of innovations peak in the periods of decline of the rates of profitability and growth. After a sustained phase of expansion, the decline in the opportunities for further growth of output and profits induces firms to innovate. Hence the business cycle and the innovation cycle are specular. In periods of expansion the rates of introduction of innovations decline. When profitability and growth are high, firms exploit and refine the technological innovations introduced in the periods of crisis. Technological change is characterized by the introduction of minor and incremental innovations. On the opposite, major breakthroughs take place when the search for new technologies acquires a strong collective character. When the rates of growth are lower, and the profitability declines, in fact, many firms try and react by means of the systematic search for new ideas. The generalized decline in profitability and the complementarity among individual search activities stemming from the intrinsic indivisibility of knowledge and favors the emergence of collective knowledge pools and hence the chances of introduction of radical innovations. The causal relationship between profitability and innovation acquires in *Business Cycle* an aggregate dimension.

Firm size and innovation incentives

In *Capitalism socialism and democracy* Schumpeter identifies the large corporation as the driving institution for the introduction of innovations. The corporation is itself an institutional innovation that favors the introduction of technological innovations for many reasons. As a large literature has stressed, the corporation can use the barriers to entry as a barrier to imitation. The risks of uncontrolled leakage of proprietary knowledge in fact are reduced when the innovator enjoys the benefits of economies of scale and absolute cost advantages so that new competitors might imitate but cannot actually enter the market place. Cutthroat competition risks to reduce the incentives to introduce technologies for the intrinsic non-appropriability of knowledge and the high risks of imitation and entry of new competitors that can take advantage of opportunistic behavior. Some intermediary levels of workable competition, comprised between the extremes of monopoly and perfect competition, among large firms might favor the rate of introduction of innovations. Oligopolistic market structures and the large size of firms are viewed as positive factors able to sustain the rates of introduction of innovations (Scherer, 1967 and 1970; Dasgupta and Stiglitz, 1980; Fisher and Temin, 1973; Link, 1980).

The well-known Schumpeterian trade-off has been elaborated on these bases: the static inefficiencies, both in the allocation and production of resources, stemming by monopolistic or oligopolistic market structures can be compensated by the dynamic efficiency stemming from the faster rates introduction of innovations that large corporations can engender.

Market structure and innovation

The so-called Schumpeterian hypothesis recently received new attention in the context of the new growth theory. This new literature has investigated the relationship between competition and innovation with contrasting results. Aghion and Howitt (1992) at first confirmed the Schumpeterian hypothesis according to which there is a negative correlation between competition and innovation, as measured by the intensity of R&D efforts. Subsequently Aghion and Howitt (1999), however, changed their mind and elaborated the view that competition should push firms to innovate. Finally Aghion et al. (2004) elaborated a compromise, suggesting that an inverted U shaped relation between competition and R&D expenditures might apply. The original findings of Scherer (1967) and Dasgupta and Stiglitz (1980) were confirmed after a long debate.

In this context, much attention has been paid to investigating the relations between competition and innovation, but very little analysis has been dedicated to the relation between profitability and innovation. While there is some obvious over-lapping between the two issues, there are many other factors at play.

On the one hand, the relevance of inter-industrial and international dynamics where demand cross-elasticities among a variety of products that are classified in an array of different industries that are based in many different countries reduces the correlation between the domestic market structures of given industries and the profitability of the firms. Moreover high profits can be engendered by the introduction of innovations even in competitive markets. Losses or profits below the average may be the result of mistakes and errors. More generally the variance of profits can be regarded as an indicator of the intensity of the selection process that wipes out firms that have not been able to select the correct combinations of quantities and prices.

As soon as we abandon the hypothesis that firms are always able to spot the 'correct' combinations identified by stable equilibria and we accept the hypothesis that firms decision-making is based upon routines based upon trial and errors and rules-of-thumb of different kinds, elaborated to operate in changing market conditions perturbed by continual (endogenous) alterations of both technologies and preferences, the relationship between market structure and profits become less and less consistent.

Financial constraints and innovation

It seems that the analysis of the relations between profits and innovation makes it possible to grasp some important aspects pertaining the provision of financial resources for innovation, and the problematic matching between scientific and technological knowledge and business competence, that are at the basis of an enlarged Schumpeterian hypothesis.

An important aspect of the Schumpeterian analysis has been lost in the old and new debates about the so-called Schumpeterian hypothesis The key role attributed to Schumpeter to the corporation as an innovative institution able to improving the relationship between finance, knowledge, competence and innovation has received much less attention than other facets of the Schumpeterian analysis (King and Levine, 1993).

Yet Schumpeter is very clear in stressing the role of the corporation as a superior allocation and selection mechanism that reduces the inefficiency of financial markets in the provision of funds to innovative undertakings and increase the matching between competence and resources available to develop new technologies. Schumpeter regards the corporation as a hierarchical system that makes it possible the coordinated working of internal markets where financial resources matched with competence can be fueled towards risky but innovative undertakings (Schumpeter, 1942 and 1947).

When perfect competition applies in product markets, financial markets perform very poorly in the allocation of resources for innovative activities. Severe credit rationing afflicts the working of financial markets for innovative projects. Financial institutions are reluctant to fund research and innovative activities conducted by incumbents and the eventual start-up of new innovative firms because of the radical uncertainty that characterize both the generation and the exploitation of innovations. Perspective lenders and investors are worried by the combined high levels of risk that stem from:

a) the intrinsic ignorance of rational decision-makers with respect to the un-chartered fields that innovations might open. High levels of competence that are necessary to assess, evaluate and select the different potential technological innovations that are daily proposed by perspective entrepreneurs,

b) the high mortality of new ventures. Experience teaches that large proportion of activities that have been funded with their own money will not succeed. Serendipity plays a key role in such matters: the actual delivery of successful innovations can be predicted only to a limited extent. Often innovations are

actually generated with great delays with respect to planning and apply to different fields with respect to expectations;
c) the non-appropriability of knowledge. Innovations, occasionally generated, will be rarely appropriated by the inventor, especially if he enters a competitive market with low barriers to entry and to imitation. The chances that the stream of profits earned in a short lead-time makes it possible to repay the credits and remunerate the capital invested are low. Even in the case of a successful generation, lenders have good reasons to worry about dissipation stemming from uncontrolled leakages of proprietary knowledge. The rapid imitation by competitors, both incumbent and new entrants, risks to limit the time stretch during which innovators can command profits above the norm and hence the chances to capitalize on the innovations introduced. As a consequence worthy inventive activities and innovative projects are considered too risky by lenders and are sorted out in financial markets (Stiglitz and Weiss, 1981).

Lenders bear the risks of failure both in the generation and exploitation of innovations, but cannot participate into the benefits of success. At best lenders can retrieve the funds that had been advanced augmented by an interest rate that incorporates a risk premium. Lenders however cannot take advantage of the flow of extra-profits that are generated by successful innovators. On the opposite, the provision of funds in the form of equity enables the full participation to the benefits of success. Equity finance can participate into the bottom tail of the highly skewed distribution of positive returns stemming from the introduction of new technologies (Hall, 2002).

The new understanding about the asymmetry between debt and equity in the provision of funds for research activities elaborated by Stiglitz (1985) paves the way to a new appreciation of the role of the Schumpeterian corporation in fostering the rate of introduction of innovations.

A share of extra-profits earned by large incumbents with barriers to entry can be retained by the managers and invested in research and development activities finalized to the introduction of innovations. The present levels of dividends are reduced but the market value of the corporation is increased by the expectations of the future profits stemming from the introduction of innovations. Capital gains compensate for the decrease in the levels of dividends (Chandler 1962, 1977, 1990).

Within the corporation the resources extracted by the extra-profits match the competences of skilled managers and the vision of potential entrepreneurs. The Schumpeterian corporation can reduce the intrinsic failure of competitive markets in the allocation of resources to research, in the identification of the proper level of rewards and hence incentives to the introduction of innovations. The corporation is an effective institution able to substitute the financial markets in the provision and allocation of funds to innovative activities because it combines financial resources and learning with entrepreneurial vision within competent hierarchies, provided that extra-profits can be earned and a consistent share is directed towards the generation and introduction of innovations (Penrose 1959.

Here it is clear that the higher are the profits and the larger the opportunities to use a share to fund research activities and hence to increase the rates of introduction of new technologies.

2.3. FAILURE-INDUCED TECHNOLOGICAL CHANGE

The notion of innovation as a form of creative reaction is well grounded in the economics of innovation literature and can be traced back to Joseph Schumpeter (1947). The behavioural theory of the firm has provided solid foundations to this approach.

In the behavioural theory of the firm, innovation is an out-of-equilibrium conduct that takes place when out-of-equilibrium conditions prevail. In equilibrium conditions firms are reluctant to innovate because of the intrinsic uncertainty that characterizes both the generation and exploitation of technological knowledge. Innovation is induced by the failure to reach the levels of performance that each firm has defined as satisfactory.

According to James March (March and Simon, 1958; Cyert and March, 1963), firms are induced to the take the risks associated with the introduction of innovations when performances fall below some minimum levels that have been identified as a threshold. In this tradition of analysis, firms are not profit maximizers. Firms are able to rely upon procedural, as opposed to substantive, rationality: firms use satisfying procedures and identify satisfactory levels of performances. Firms are risk adverse and hence reluctant to change their routines, their production processes, their networks of suppliers, their products and their marketing activities. Firms can overcome their intrinsic inertia and resistance to change only when the actual levels of performance fall below some thresholds. At this time a failure-induced mechanism of change is set for and firms are more ready to take the risks associated with innovation (March and Shapira, 1987).[3]

Behavioral analyses of the firm have provided a rich theoretical frame that makes it possible the reconciliation of theories of failure-induced change and threat-rigidity. This theory explicitly links the cognitive psychology that underlies the characteristics of risk-seeking behavior and the implications of threat-rigidity

[3] As Nooteboom (2003: 225) notes "discovery is guided by motive, opportunity and means. One needs an accumulation of unsatisfactory performance to generate motive; to overcome one's own inertia or that of others in organization. In markets, one also needs an opportunity of demand and/or technology. And one needs insights into what source and how to incorporate them in present competence".

when facing the need to change the routines of organizations (March and Simon, 1958; March, 1988; Ocasio, 1998)[4].

In order to re-establish the minimum levels of performance that are considered to be satisfying, firms activate new routines, search for new technologies already available, explore new possible technologies. Innovation is induced by failure (March, 1991).

The localized technological change approach elaborates this frame and shows how the mix of failure-inducement and opportunities that emerge in out-of-equilibrium conditions both in factor and product markets induce firms to change not only their techniques but also their technologies with the introduction of innovations (Atkinson and Stiglitz, 1969; David, 1975; Antonelli, 1999 and 2008).

3. Profitability and innovation: The hypothesis of a U-shaped relationship

The integration of the augmented induced technological change approach based upon the appreciation of new facets of the Marxian legacy with a revised version of the Schumpeterian tradition, and the failure-induced innovation hypothesis elaborated by the localized technological change approach provides the basic tools to analyze the relationship between profits above and below the norm, interpreted as indicators of out-of-equilibrium conditions, and innovation.

Firms are pushed to innovate and hence to search for new products and processes by the combined effects of incentives and opportunities that emerge when out-of-equilibrium conditions prevail. The levels of profitability are a clear and

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[4] See Greve (1998) who examines how performance feedback affects the probability of risky organization. His empirical analysis in the radio broadcasting industry shows the consequences of shortfalls of performances on the probability of strategic change and their strong sensitivity to social and historical aspiration levels.

non-ambiguous indicator of the proximity to equilibrium conditions. While normal profits signal that the system is in equilibrium, both profits below and above the norm signal that the firm is away from equilibrium conditions. The larger is the variance of the levels of profitability and the stronger the conditions of out-of-equilibrium at the system level. The larger is the difference between the specific profit levels of each firm and the normal profitability and farther away are the local conditions from equilibrium.

When the profits are below the norm and actually fetch negative values in absolute terms, firms understand that their survival is at stake. The low levels of profitability engender risks of survival that push firms to try and innovate. The intentional and explicit generation of new technological and organizational knowledge becomes necessary. To do so firms are induced towards an array of new routines such as the funding of research and development activities, the valorization of the tacit knowledge acquired by means of learning processes, the exploitation of external sources of new technological knowledge, the adoption and creative adaptations of new production processes and new products[5].

At the other extreme it is clear that high levels of profits provide firms with the opportunity to take advantage of the failure of competitive markets in the generation and exploitation of technological innovations. The resistance to change is much lower when organizations are performing and the abundance of resources makes it possible to identify the perspectives for new profitable ventures. Here change is intrinsically intertwined with growth and development, hence with new opportunities of upgrading for the members of the organization and for decision-makers. Firms with high levels of profits are often characterized

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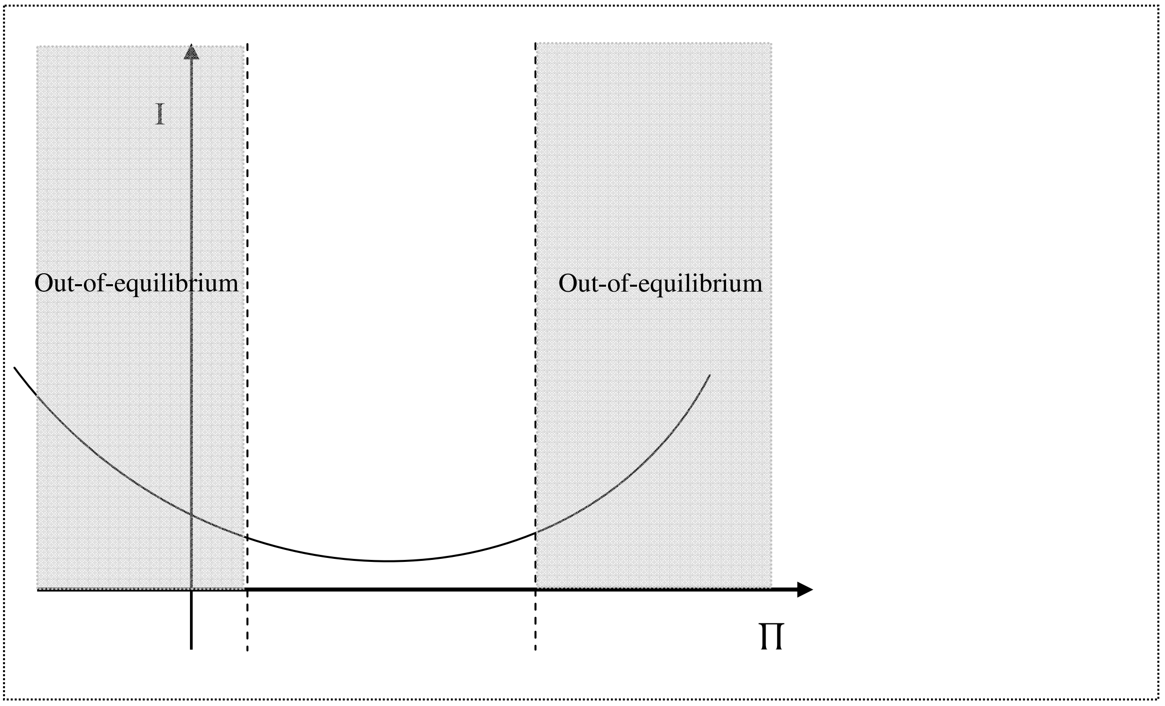
5 Antonelli (1989 and 1990) has provided empirical evidence upon the role of failure inducement mechanisms in the processes of introduction and adoption of technological and organizational innovations in the Italian economy at the end of 80s, at a time when the economic performances of most firms where threatened by falling performances at the system level

by dynamic capabilities and flexible organizations that have already being able to generate new technological knowledge and to introduce technological innovations. High profits signal much more than monopolistic rents: they identify conditions of turbulence and out-if-equilibrium that firms are facing (March and Simon, 1958; Penrose, 1959).

When profits are in the norm, firms have neither the incentives nor the opportunity to try and innovate. Internal resources to finance research and development and the eventual introduction of new prototypes are missing. At the same time inertia and resistance to change are not questioned, as managers do not feel the need to change the current state of their activities. The opportunity costs of risky undertakings whose failure might compromise the equilibrium of the company are very high. Product and factor markets should be close to condition of perfect competition: hence firms have little opportunities to exploit their innovations. Knowledge can hardly be appropriated and imitators can benefit of the knowledge generated by third parties. Credit rationing limits the access to financial resources that are necessary to generate new technological knowledge and to introduce technological innovations (Fazzari and Petersen, 1993; Bloch, 2005).

The causal relationship between profitability and innovation can be specified by a quadratic function: with low profits, below the average, including losses, firms have a strong incentive to innovate; with high profits above the norm, firms have important opportunities to fund research activities and hence innovate; firms with normal profits miss both incentives and opportunities. The basic argument is that combination of incentives and opportunities provides the basic mix of determinants to innovate. In the first case a failure inducement mechanism is at work: firms are induced to try and change their technologies and their organization when profits fall below a minimum threshold and their survival is put at risk. In the second case, incentives are lower but the opportunities for firms that enjoy extra-profits are strong. Firms can fund risky activities with a share of extra-profits and hence overcome the severe rationing of financial markets in the provision of resources for undertaking innovative activities. Firms with extra-profits moreover can guide internal markets by means of competent hierarchies so as to match financial resources, competence and innovative ideas. Firms with normal profits have both lesser incentives and opportunities to innovate.

FIGURE 1.
THE QUADRATIC RELATIONSHIP BETWEEN PROFITS AND INNOVATION



The relationship between profit and innovation is shaped in Figure 1 where we set forth the basic hypothesis that the rates of innovation are higher the farther away firms are from equilibrium conditions. The grey regions identify the conditions of out-of-equibrium, as measured by the levels of profitability with respect to average values, where profitability is below and above the average.

With low profits, fetching negative values, firms have a strong failure-induced incentive to innovate. Their survival is at risk. All the resources need to be mobilized in order to change the current state of activities and introduce technological and organizational innovations that make it possible to increase their total factor productivity.

Firms with profits in the average have no incentives and no opportunities to innovate. Rational decision-making inhibits the assumption of actions in domains that are characterized by radical uncertainty such as innovative undertakings, for the well-known problems of unpredictability both in their generation and exploitation.

Finally when firms enjoy extra-profits, at levels that are above the normal profitability, managers have the opportunity to fund research and innovative activities with their own internal funds. After payments of hefty dividends, managers can retain sufficient funds to undertake innovative projects designed to stretch the duration of market power. Extra-profits provide the opportunity to fund innovative activities and signal the existence of barriers to entry that increase de-facto the chances of appropriability of the stream of benefits stemming from the introduction of successful innovations.

4. EMPIRICAL ANALYSIS

4.1 DATA

In this section we introduce our empirical methodology to assess the relationship between firm level profitability and innovation, using an original dataset containing balance sheet accounting data for a sample of Italian Manufacturing companies.

The dataset includes financial accounting data for a large sample of manufacturing companies, observed along years 1996-2005. The data have been extracted from the AIDA database provided by Bureau Van Dick, which reports accounting information for public and private Italian firms with a turnover larger than 0.5 millions of Euros. The companies included in the analysis have been founded before year 1995, they are registered in a manufacturing sector according to the Italian ATECO classification, and they are still active by the end of year 2005. The introduction of the latter condition implies that we do not consider market exit/entry.

We have included all the companies with at least 15 employees at the end of fiscal year 1995. In order to drop outliers due to possible errors in the data source, we computed a set of financial ratios and yearly growth rates of employees, sales and fixed capital stock. After a manual checking we eventually dropped 45 companies which showed unreasonable data. We ended up with a balanced panel of 7020 companies. All financial data have been deflated according to a sectoral two-digit deflator using year 2000 basic prices. In annex 1 we report the sectoral composition of the dataset.

4.2 MODELS AND RESULTS

This section presents the different steps of the empirical analysis. The identification of the variables precedes the econometric test.

The measure of innovativeness

The rates of increase of productivity both computed as total factor productivity (TFP) and Tornquist productivity are good measure of the levels of innovativeness of the firms. This is especially true with respect to the Italian system where, although the levels of formalized R&D activities and patent are low, much innovation based upon informal research activities, tacit knowledge and learning, takes place. Hence we assume that the bottom line increase of efficiency at the firm level is the ultimate indicator of the wide array of interrelated effects of the introduction of changes in products, processes, markets, organization and inputs (Parisi, Schiantarelli, Sembenelli, 2006).

In order to account for the important role of all changes in the input mix, we have both computed firm level total factor productivity and a Tornquist productivity measure that includes as inputs also materials and services.

The measure of total factor productivity

In order to compute firm-level TFP we have firstly estimated a set of Cobb-Douglas production functions with constant returns to scale for each industry included in the sample, so to obtain the correct levels of output elasticity of labor and capital. After the assignment of each firm to an industry we have computed TFP for company i in year t according to the following expression:

$$TFP_{i,t} = \frac{Q_{i,t}}{L_{i,t}^{\beta} K_{i,t}^{1-\beta}} \tag{2}$$

Where:

$Q_{i,t}$:deflated value added

$L_{i,t}$:average number of employees

$K_{i,t}$:fixed capital stock.

Fixed capital stock has been computed using a perpetual inventory technique according to which the first year accounting data, i.e. year 1996 in our case, are used as actual replacement values. The subsequent yearly values of fixed capital are computed using a depreciation parameter δ, assumed equal to 6.5%, and adding deflated yearly investments. The investment parameter ($I_{i,t,}$) has been computed as the yearly variation in net fixed capital in companies' balance sheets plus yearly amortizations. Hence, the time series of fixed capital is defined as follows:

$$K_{i,t} = (1-\delta)K_{i,t-1} + I_{i,t} / p_t$$

In order to identify the parameter β at industry level to compute equation 2, we have estimated for each industry the following equation:

$$Log\left(\frac{Q_{i,t}}{K_{i,t}}\right) = \beta \times Log\frac{L_{i,t}}{K_{i,t}} + \alpha_i + \alpha_t + \varepsilon_{i,t} \qquad (3)$$

We have used a fixed effect estimator (Blundell and Bond, 2000; Olley and Pakes, 1996), where α_i is a firm specific effect and α_t is a time specific effect.

The measures of profitability and size

For each firm included in the sample we have computed a measure of size defined as the log of total assets and a measure of financial leverage defined as the ratio of total net debt to total assets. Companies' profitability has been evaluated in terms of return on total assets (ROA), defined as the ratio of earnings before interest and taxes to total assets. This measure of profitability should be relatively unaffected by changes in fiscal policies along the panel years. Since we assume that the elasticity of innovation, as captured by changes in total factor productivity, to changes in profitability is likely to take place after a time lag, we have averaged the levels of size, leverage and profitability over a two years time period and then computed the TFP growth rate over the two following years. Here below we report the definition of the variables and in the Table 1 we show their summary statistics.

$\Delta TFP_{i,t}$	Growth rate of TFP between years t and t-2
$AvgROA_{i,t}$	Average level of ROA in years t and t-1
$AvgSIZE_{i,t}$	Average level of size in years t and t-1
$AvgLEV_{i,t}$	Average level of leverage in years t and t-1

Table 1 Summary statistics

Variable	Mean	st. dev.
AvGROA	0.077	0.086
AvgLEV	0.692	0.189
AvgSIZE	14.294	1.344
ΔTFP	0.046	0.342

The econometric test

In order to test our hypothesis, we use the following specification in which the growth rate of TFP between year t-2 and t is regressed against a set of covariates whose levels are averaged over the years t-2 and t-3.

$$\Delta TFP_{i,t} = \alpha_i + \beta_1 AvgLEV_{i,t-2} + \beta_2 AvgSIZE_{i,t-2} + \beta_3 AvgROA_{i,t-2} + \beta_4 AvgROA^2{}_{i,t-2} + \varepsilon_{i,t}$$

We initially regress the growth rates of TFP against the lagged measures of profitability, specifically testing for a quadratic functional form. The size of the firm is also included as a control variable. The model is estimated with both a fixed effect estimator and with instrumental variables. In the second case, the set of instruments includes the one year lagged values of all the independent variables. In the following table 2 we report our results.

Table 2 Testing the effects of lagged levels of profitability on TFP growth rate, Fixed effects and IV results.

	Fixed Effects		IV Estimator	
Number of firms	7020		7020	
$AvgROA_{i,t-2}$	-2.547	(0.034)	-2.758	(0.041)
$AvgROA^2{}_{i,t-2}$	4.656	(0.189)	5.034	(0.207)
$AvgSIZE_{i,t-2}$	0.089	(0.004)	0.112	(0.006)
Const	-1.133	(0.061)	-1.449	(0.100)

Robust standard errors in parenthesis

The results show that the lagged values of profitability are significantly related to the subsequent growth rates of total factor productivity according to a quadratic specification. Moreover, size turns to be positively related to subsequent total factor productivity growth rates.

Controlling for leverage

In order to control for the role of financial constraints and the structure of the capital, we expand our model introducing among covariates also the average level of leverage of the firms. The estimates in the following Table 2.a show how the level of financial leverage seems to exert a negative impact on the capability of the companies to introduce technological and organizational changes aiming at improving productivity levels. While the results of this model specification cannot be interpreted directly as evidence of the presence of financial constraints[6], still they stress the non neutrality of the capital structure on the subsequent innovation effort. For a company characterized by a high level of debt it might be difficult to raise additional external resources or to divert internal cash flow to investments in innovation and technology.

[6] Models on financial constraints typically analyses the dynamics of investment and cash flow testing the degree of substitutability between internal and external financial resources. See Scellato, (2007) and Crespi and Scellato (2007) for a review on this issue.

Table 2.a Testing the effects of lagged levels of profitability on TFP growth rate, accounting for leverage. Fixed effects and IV results.

	Fixed Effects		IV Estimator	
$AvgROA_{i,t-2}$	-2.581	(0.035)	-2.822	(0.041)
$AvgROA^2{}_{i,t-2}$	4.759	(0.190)	5.229	(0.207)
$AvgSIZE_{i,t-2}$	0.087	(0.004)	0.104	(0.006)
$AvgLEV_{i,t-2}$	-0.141	(0.023)	-0.279	(0.028)
Const	-1.005	(0.064)	-1.137	(0.104)

Robust standard errors in parenthesis

In general, the empirical evidence confirms the relevance of out of equilibrium profitability as a major driver of innovation efforts. Such inducement effect is clearly stronger for those companies experiencing a phase of contraction in profitability, or for companies with profitability above average level. Size exerts always a positive and significant effect. The U-shaped relationship between TFP growth rates and profitability shows a minimum level for values of ROA of around 30%, which represents for our sample a value significantly higher than average levels of profitability along the panel years (7.7%).

Tornquist productivity and profitability

In this section we apply a Tornquist index of total factor productivity. In this case we investigate to what extent the residual in productivity, after accounting for changes in capital, labor and intermediate input materials, can be explained by the quadratic specification of the past values of profitability and the by the size of firms. We move from the following specification:

$$LnY_{i,t} = LnA_{i,t} + \delta LnM_{i,t} + \beta LnK_{i,t-1} + \gamma LnL_{i,t-1} + \alpha_i + \eta_t + \varepsilon_{i,t}$$

Where Y equals total gross output (sales plus changes in final goods inventories), K is the fixed capital stock of the company, L is number of employees, M is a Tornquist index of deflated materials and services used in production and A is a firm specific measure of the state of technology at time t. Capital and labor levels are fixed according to their beginning of the period levels while we use period cost of materials and services. Moreover, the above equation includes firm specific, common and idiosyncratic stochastic shocks. Analogously to the previous section, we have used a perpetual inventory approach to compute yearly levels of fixed capital.

According to our hypothesis, we expect that the rate of technological progress, as represented by variations along time of the parameter A, depends on the innovation effort of the companies which in turn is a quadratic function of the previous level of profitability. In order to limit the risk of edogeneity of the regressors we have chosen to use four year lagged value of profitability[7]. This amount to state that, considering a two year time span for the change in A, the following relationship holds:

$$\Delta LnA_{i,t} = \phi + \chi AvgROA_{i,t-4} + \lambda AvgROA^2{}_{i,t-4}$$

Under the assumption of constant return to scale, it is possible to substitute the latter equations into the previous formula, obtaining the following expression where :

$$\Delta Ln\frac{Y_{i,t}}{L_{i,t-1}} = \phi + \chi ROA_{i,t-4} + \lambda ROA^2{}_{i,t-4} + \delta\Delta Ln\frac{M_{i,t}}{L_{i,t-1}} + \beta\Delta Ln\frac{K_{i,t-1}}{L_{i,t-1}} + \Delta\eta_t + \Delta\varepsilon_{i,t}$$

We test the above equations in order to check whether, after accounting for changes in capital stock and input materials, the variations in the residual change in productivity are explained by the quadratic specification of the lagged values of profitability. The above equation is estimated using fixed effects. In the following table we report our results.

[7] We have also tested a model in which we use two years lagged values of profitability, obtaining similar results.

Table 3 Tornquist productivity index: Testing the effects of lagged levels of profitability on productvity, fixed effects.

Dependent Variable $\Delta Ln \frac{Y_{i,t}}{L_{i,t-1}}$		
	Fixed Effects	
$\Delta Ln \frac{M_{i,t}}{L_{i,t-1}}$	0.7506	(0.001)
$\Delta Ln \frac{K_{i,t-1}}{L_{i,t-1}}$	0.094	(0.008)
$ROA_{i,t-4}$	-0.101	(0.012)
$ROA^2{}_{i,t-4}$	0.131	(0.025)
$Const$	0.002	(0.001)

Robust standard errors in parenthesis

We have also implemented two augmented versions of the previous model in which we also include size and leverage as explanatory variables of the changes in the parameter A. Also the new covariates enter the model at t-4. Results are reported in Table 4 and 4a.

Table 4 Tornquist productivity index: Testing the effects of lagged levels of profitability and size, fixed effects.

Dependent Variable $\Delta Ln \frac{Y_{i,t}}{L_{i,t-1}}$		
	Fixed Effects	
$\Delta Ln \frac{M_{i,t}}{L_{i,t-1}}$	0.7491	(0.001)
$\Delta Ln \frac{K_{i,t-1}}{L_{i,t-1}}$	0.097	(0.008)
$ROA_{i,t-4}$	-0.088	(0.012)
$ROA^2{}_{i,t-4}$	0.113	(0.025)
$SIZE_{i,t-4}$	0.005	(0.001)
$Const$	-0.079	(0.018)

Robust standard errors in parenthesis

Table 4a Tornquist productivity index: testing the effects of lagged levels of profitability, size and leverage , fixed effects.

Dependent Variable $\Delta Ln \frac{Y_{i,t}}{L_{i,t-1}}$		
	Fixed Effects	
$\Delta Ln \frac{M_{i,t}}{L_{i,t-1}}$	0.7491	(0.001)
$\Delta Ln \frac{K_{i,t-1}}{L_{i,t-1}}$	0.099	(0.008)
$ROA_{i,t-4}$	-0.103	(0.012)
$ROA^2{}_{i,t-4}$	0.133	(0.026)
$SIZE_{i,t-4}$	0.005	(0.001)
$LEV_{i,t-4}$	-0.058	(0.009)
$Const$	-0.035	(0.020)

Robust standard errors in parenthesis

The estimates shown in the two previous tables confirm the evidence obtained in the previous test where the measure of innovativeness was based upon TFP growth rates. In particular, the quadratic specification of the past level of profitability does exert a significant effect on subsequent changes in productivity even after accounting for the specific dynamics of intermediate production inputs. The evidence confirms that while firms with average profitability exhibit low levels of innovativeness, both firms with low levels of profitability, below the average and high levels of profitability, above the average, are much more keen to change their technology and to innovate.

5. CONCLUSIONS

The empirical evidence provided by the rich data set of a large data set of Italian firms for the years 1996-2005 confirms that the relationship between profitability and the rates of growth of both total factor and Tornquist productivity is U shaped.

The introduction of innovations takes place in out-of-equilibrium conditions and engenders out-of-equilibrium conditions. Firms with normal levels of profitability are less ready to change their technologies and their organization. Firms with profitability below the average are induce to change their technologies and their organization because the current performances are below expectations, survival is at risk: innovation is induced. Innovation is necessary in order to contrast the deterioration of performances. Firms with profitability above the average have the opportunity to commit resources to risky activities. High levels of profitability make available financial resources that can be matched within internal markets with managerial competence and screening capabilities. Firms can satisfy the expectations of shareholders with the payment of dividends and invest the surplus in the search for new technologies, new markets, new products and processes that may lead to enhanced rates of growth. The future increase of the value of the company will eventually benefit shareholders in terms of capital gains.

Firms with profits above the average can better hold the risks associated with innovative undertakings. Firms with profits below the average are already at risk: innovation is the extreme remedy that firms try and activate in order to reduce risks. In both cases firms in out-of-equilibrium conditions are keener to introduce innovations than firms close to equilibrium conditions. Firms in equilibrium conditions have lower levels of incentives and opportunities to try and innovate.

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ANNEX 1

Sectoral composition of the sample

Industry – ATECO Classification	**Number of companies**	**Percentage**
Food and beverages	561	8.0%
Textile	607	8.6%
Textile product industry	212	3.0%
Leather and leather products manufacturing	249	3.5%
Wood and wood products manufacturing	155	2.2%
Pulp, paper and paper products manufacturing	174	2.5%
Printing	193	2.7%
Chemical industry	401	5.7%
Plastics and rubber manufacturing	421	6.0%
Non-metallic mineral product manufacturing	390	5.6%
Metallurgy	275	3.9%
Metal products manufacturing	983	14.0%
Mechanical machinery and equipment manufacturing	1,078	15.4%
Computer and electronic manufacturing	24	0.3%
Electrical machinery and equipment manufacturing	287	4.1%
Telecommunication machinery and equipment	91	1.3%
Medical, optical and precision equipment	143	2.0%
Transportation equipment manufacturing	122	1.7%
Other transport equipment manufacturing	61	0.9%
Furniture	487	6.9%
Software	106	1.5%
Total	7,020	100.0%