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Finance, Innovation & Growth (FINNOV)

Survey of the Literature on Innovation and Economic Performance

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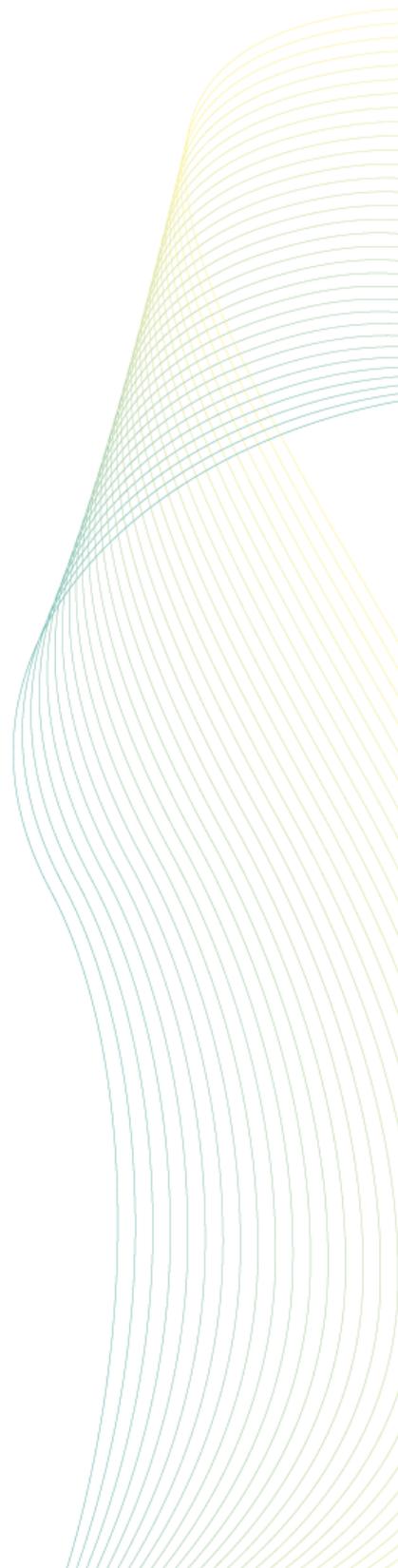
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Abstract:

Despite very strong differences in their treatment of technological change in economic theory, both the neoclassical and the more Schumpeterian (and evolutionary) economic approaches often assume that market selection rewards the most innovative firms. However, despite such strong assumptions, empirical evidence on whether innovative firms perform better than non-innovative firms remains inconclusive. If innovators do not grow more, does this imply that market selection fails? And does the different impact of innovation on industrial performance (measured by firm growth and profitability) and financial performance (measured by market value and stock returns) signal differences in how industrial and financial markets react to firm level efforts around innovation? This discussion paper reviews the literature on the interaction between innovation and economic/financial performance, and outlines the way that work within FINNOV Work Package 2 (SELECTION), Co-Evolution of Industry Dynamics and Financial Dynamics, will contribute to better understanding this interaction.

Key words: innovation, performance, market selection

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1. Introduction

Despite very strong differences in their treatment of technological change in economic theory, both the neoclassical and the more Schumpeterian (and evolutionary) economic approaches often assume that market selection rewards the most innovative firms: more innovative (and hence, more efficient) firms should outperform the less innovative ones, with higher growth, profits, and stock prices. This is because product innovation can create new markets and/or increase the market shares of innovators. Similarly, process innovations improve the productivity of innovators by cutting production costs. However, despite such strong assumptions, empirical evidence on whether innovative firms perform better than non-innovative firms remains inconclusive.

While the positive effect of innovation on financial performance, such as market value and stock prices, has been found to be more or less robust (Blundell et al., 1999; Griliches 1984; Hall et al., 2005; Toivanen et al., 2002), the empirical evidence for the impact of innovation on firm growth is more mixed and does not firmly confirm the assumption that innovative differences among firms lead to growth differentials. Dosi (2005) formulates this problem in the following words: “...*The impact of both innovativeness and production efficiency upon growth performances appears to be somewhat controversial...Contemporary markets do not appear to be too effective selectors delivering rewards and punishments according to differential efficiencies*” (p.25 and p.29).

If innovators do not grow more, does this imply that market selection fails? And does the different impact of innovation on industrial performance (measured by firm growth and profitability) and financial performance signal differences in how industrial and financial markets react to firm level efforts around innovation?

Industrial economists are faced with a related puzzle as one digs deeper into the time series properties of innovation and firm performance variables (such as profits, growth and productivity) as well as the relationship between these. While innovation and profits show some degree of *persistence* in their time series behaviour, firm growth lacks much persistence—sometimes seeming like a ‘random walk’. How can one reconcile the dissimilar dynamics of innovation and firm growth variables if the underlying assumption of market selection is that innovative behaviour of firms should translate to performance? Should not the persistent innovators grow more persistently?

As a starting point in addressing these puzzles in FINNOV Work Package 2 (SELECTION), *Co-Evolution of Industry Dynamics and Financial Dynamics*, this survey paper reviews the state of the art on market selection dynamics and the factors that shape the operation of the market selection mechanism.

2. Innovation and Market Selection

Friedman (1953) argued that the survival of firms depends on their ability to maximise profits. He argued that firms that fail to maximise profits will eventually be driven out of the market. While it is not unreasonable to assume that more profitable firms will grow at the expense of the less profitable, the “profit maximisation” principle stands out as an unrealistic means of describing what “fitness” entails (See Nelson and Winter, 2002 for a detailed critique of Friedman and followers). Fitness is the *relative*-rather than absolute- efficiency of firms upon which firm growth and survival is determined. Dosi and Nelson (1994) argue that fitness is determined by a combination of several different efficiency criteria at the firm level, the *cash flow situations, accounting profits, investor expectations regarding profitability, relative quality of products, prices and after-sales servicing, delivery delays and marketing networks* being some of these. In this picture, innovation stands as a crucial factor that can improve the fitness of a firm through boosting several of these dimensions of firm efficiency.

The market selection processes that choose the winners and losers based on their relative efficiency, supposedly favour those who operate more efficient technologies. Firms operating less efficient technologies have lower profits and consequently, less money to fund their growth. As the industry evolves, the market shares of the inefficient firms converge to zero and they are driven out of the market (Beker, 2004). Freeman (1995) holds that the fastest growing firms have larger capacity for a flow of incremental innovations and occasional radical innovations. Bigsten and Gebreeyesus’ (2008) find empirical evidence showing that most productive and efficient firms are more likely to grow fast and through this process, resources are *“reallocated from less to more productive firms”*. Shiferaw (2007), using the same data set as Bigsten and Gebreeyesus (2008), adds that firm investments into technological capabilities enhance firm level efficiency, which in turn, allows the firm to perform better than other firms (with lower investments).

Kiyota and Takizawa (2006) find that market selection works gradually to eventually drive the inefficient firms out of the market. *“Gradual declines in productivity ultimately cause the exit of firms from the market, which implies the existence of the ‘shadow of death’”* (Kiyota and

Takizawa, 2006; p.2). Griliches and Regev's (1995) and Bellone et al.'s (2005) results also confirm that 'continuously below the average' efficiency results in firm exit.

Of course, the degree to which market selection is tolerant to *temporary losses of efficiency* determines the time horizon in which inefficient firms are driven out (Bellone et al., 2005). Innovation is a very uncertain, expensive and lengthy process, with R&D projects (if successful) taking up to 20 years to come to fruition. Thus too short a time horizon may lead to the failure of the most innovative firms that undertake the biggest risks with a view of long term gains. At the other extreme, very slow operating of the selection mechanism will lead to efficiency losses on the whole as the market takes too long to reallocate the resources to more productive firms. Geroski and Mazzucato (2002) show that the capital market eases the selection pressures on innovative firms by providing them with the means to survive until their innovative products make it to the market. If the capital market does its job well by financing the most innovative firms, myopic selection in product markets may allow innovative firms with long time horizons to be rewarded rather than punished.

Product innovations play a significant role in market selection as consumers base their purchase decisions on the merits and quality of the products in question (Geroski and Mazzucato, 2002). On the other hand, process innovations contribute to the efficiency of firms by reducing production costs. Bellone et al.'s (2005) results indicate that the product-innovation based efficiency counts more for the small firms while for the large firms, productivity (achieved via process innovations) is the key criterion based on which market selection rewards the winners.

Yet, it is not always clear that market selection works as smoothly as anticipated. Indeed, there are growing concerns that selection does not quite do the job of correctly rewarding the most innovative and efficient firms in industrial markets. For instance, Tamagni (2007) shows that the firms that exit the Italian markets are not always the least efficient and the slowest growing firms (See also Nishimura et al. 2005 for a similar result for Japan). Bottazzi et al. (2002) find that market selection operates rather gently on the 'near-average' firm but "*... its role, it seems, is mainly to cut out the very worst performers*".

Below we look at the relationship between innovation and market selection further, taking industrial markets and financial markets separately.

2.1 Market Selection in Industrial Markets: Innovation, Profitability and Firm Growth

The empirical evidence on the impact of innovation on profits and firm growth (indicators of firm performance in industrial markets) is mostly mixed especially for the latter. Geroski et al. (1993) find a small positive impact of firm (successful) innovations on profit margins. Geroski and Machin (1992) point out the persistent and significant differences in profitability of innovators and non-innovators. Freel (2000) argues that such profitability differences among innovators and non-innovators are contingent on several factors such as firm size and industry characteristics. Leiponen (2000) also finds persistent differences in determinants of profitability for innovators and non-innovators: factors such as patenting and educational competencies positively affect the profitability of innovators while such factors have no significant (or even negative) effects on the profits of non-innovators. Stoneman and Kwon (1996) find in a sample of UK firms that those firms which fail to adopt new technologies experience reduced profits while the adopters of new technologies gain an annual gross profit of 11% above the mean profit of the sample firms. While there seems to be a relationship between innovation and profitability, these studies fail to consistently establish the exact nature of the relationship. Contradictory findings such as in Robson and Bennet (2000), for example, do not find any evidence of profitability growth for a sample of innovating small UK firms.

The empirical results regarding the effect of innovation on firm growth is even more mixed than that on profits. While some studies confirm that more innovative firms grow more, others fail to see such a clear relationship. Adamou and Sasidharan (2007) find that firms which have higher R&D intensity ratios (i.e. R&D/sales) grow faster. Also, Yasuda (2005) shows that R&D expenditures per employee have a positive impact on firm growth. Yang and Huang's (2005) work on Taiwan's electronics industry confirms that R&D is an important determinant of firm growth. Foray et al. (2007) argue that R&D expenditures are positively correlated with sales growth while Del Monte and Papagni (2003) show that R&D has a positive impact on firm growth but this is more pronounced in traditional industries than in the most 'high-tech' ones. Geroski and Toker (1996) find that innovations of the 209 large UK firms in their sample have a positive impact on annual turnover while Geroski and Machin (1992) identify that the firms that produced at least one 'major innovation' in their sample grew faster than firms that never did.

On the other hand, the literature also presents counter evidence regarding the impact of innovation on firm growth. Heshmati and Lööf (2006) find no significant impact of R&D expenditures on firm growth for 931 Swedish firms. Kirchoff et al. (2002) also find no causal relationship between increased R&D expenditures of universities and economic growth in a region. Oliveira and Fortunato (2005) find that physical investments have a much higher impact on boosting firm growth compared to R&D investments. More interestingly, this holds

more strongly for 'hi-tech' firms. Bottazzi et al. (2001) find that innovations do not determine the sales growth of the pharmaceutical firms. Almus and Nerlinger (1999) conclude that firm growth is only affected by firm size and age and not by the innovative activities of the firms. Brouwer et al. (1993) find that innovative activities only boost the growth of above-the-average R&D spenders.

There are also instances where studies show that innovative activities have a negative impact on firm growth, most commonly caused by the inability of the high cost of research to be recovered through increased sales or profits (Folkeringa et al., 2004). Coad and Rao's (2006, 2007) findings reveal the positive impact of innovative activities (R&D and patenting) on firm growth is limited to the fastest growing firms—for the others it often plays a negative role (the intuition here is that for those firms that R&D does not lead to a successful new product or process, it is simply a very large cost). Results in Brouwer et al. (1993) suggest that while product related R&D leads to positive growth, process-related R&D causes negative growth. Teece (1986) argues that there is no obvious reason why we should assume that innovations will translate into higher revenues or market shares for innovators. He gives several examples of firms whose innovations were very important and first to the market but they could not maintain their market lead due to a lack of "complementary" assets such as marketing, distribution and business networks.

Thus the innovation-firm growth literature is far from presenting a clear cut picture on whether and how firm growth is affected by innovations. The mixed results could suggest that innovation has no significant impact for firm growth, or maybe that innovations *only* affect the growth of *a certain subset of firms* with certain characteristics. If the latter case is true, one would fail to identify a clear significant relationship between firm growth and innovation unless different types of firms, innovations and industries are considered separately. Work Package 2 aims to focus on these firm and industry level characteristics upon which market selection rewards the innovators. We plan on doing this at the level of both product and financial markets. It is to the latter that we turn to next.

2.2 Market Selection in Financial Markets: Innovation and Financial Performance

Profits and firm growth rates discussed above reflect the *actual* performance of firms in industrial markets. Market value and stock prices instead reflect *expected* profits and growth—as determined in financial markets. Studies that look into the impact of innovation on stock prices build on the *efficient market hypothesis* which assumes that the prices traded in the market reflect all known information and hence, the firms' innovative potential is captured by these prices.

Various studies that focus on the effect of innovation on the *level* of stock prices come principally from the applied industrial economics literature that models growth, innovation and stock prices over the industry life-cycle (Jovanovic and MacDonald 1994; Jovanovic and Greenwood 1999; Mazzucato and Semmler 1999) and the work on market values and patents (Pakes 1985; Griliches, Hall and Pakes 1991; Hall, et al., 2005). For example, Jovanovic and MacDonald (1994) make predictions concerning the evolution of the average industry stock price level around the “shakeout” period of the industry life-cycle. Focusing on the US tire industry, they build a model which assumes that an industry is born as a result of a basic invention and that the shakeout occurs as a result of one major refinement to that invention. They predict that just before the shakeout occurs, the average stock price will fall because the new innovation precipitates a fall in product price which is bad news for incumbents. Building on this work, Jovanovic and Greenwood (1999) also link stock prices to innovation by developing a model in which innovation causes new capital to destroy old capital (with a lag). Since it is primarily incumbents who are initially quoted on the stock market, innovations by new start-ups cause the stock market to decline immediately as rational investors with perfect foresight foresee the future damage to old capital (competence destroying innovations in the words of Tushman and Anderson 1986).

Another body of literature that looks at the relationship between innovation and the stock market is that which builds on Tobin’s Q to study the relationship between market values and patents (Pakes 1985; Griliches et al., 1991). Pakes (1985) starts with the presupposition that looking at patents and stock prices is a way to better understand the relationship between inducements to engage in inventive activity, the relationship between inventive inputs and outputs, and the effects of those outputs. The reasoning is that if patent statistics contain information about *shifts in technological opportunities*, then they should be correlated with current changes in market value since market values are driven by the expectations about future growth. The question investigated is ‘to what degree the stock market valuation of a firm is a good proxy for inventive output’ (Pakes 1985). To do so, he investigates the relationship between the *number* of successful patent applications of firms (*unweighted* by citations), a measure of the firm’s investment in inventive activity (R&D expenditure), and an indicator of its inventive output (stock market value of the firm). He finds that indeed unexpected changes in patents and R&D are associated with large changes in the market value of a firm. Yet there is a large variance to the increases in the value of the firm that are associated with a given patent. This is most likely due to the skewed distribution of the value of patents that has been found in the innovation literature. Griliches, Hall and Pakes (2001) make use of patent citation data to account for this large variance in the value of patents. This study finds that while a reasonable

fraction of the variance of market value can be explained by R&D spending and/or the stock of R&D, patents are informative above and beyond R&D, only when *citation weighted* patents are used (unweighted patent numbers are less significant). Using a Tobin's q equation, they find a significant relationship between citation-weighted patent stocks and the market value of firms where market value increases with citation intensity, at an increasing rate. The market premium associated with citations is found to be due mostly to the high valuation of the upper tail of cited

The studies discussed so far relate stock price dynamics to innovation mainly by linking changes in the stock price *level* to innovation, rather than linking changes in *volatility* of stock prices to innovation. As is well known, a proxy for risk in the Capital Asset Pricing Model is the standard deviation of returns. As innovation is one of the main sources of risk and uncertainty faced by firms, there are reasons to believe that the relationship between innovation and stock prices will be found especially in relation to the volatility not the level of stock prices (or both due to the relationship between risk and return). And since innovation is not just risky but truly uncertain, in the Knightian sense, this is even truer. Yet very few studies provide insights into the relationship between innovation and volatility of stock prices.

One well known study that links stock price volatility to innovation is Shiller (2000), where it is shown that 'excess volatility', the degree to which stock prices are more volatile than the present value of discounted future dividends (i.e. the underlying fundamentals that they are supposed to be tracking according to the efficient market model), peaks precisely during the second and third industrial revolutions. He suggests that it is in uncertain situations such as those characterized by radical technological change, that current information about 'fundamentals' (i.e. current profits, dividends etc.) are less useful for making predictions about future market values.

Other studies suggest that there has been no trend increase of aggregate stock price volatility (Schwert 1989; 2002) except for during particular periods of 1970's and the 1990's. However, the increase did not persist following these periods. Firm specific volatility has, on the other hand, experienced a trend increase over the last 40 years (Campbell et al. 2001). Based on these insights, Mazzucato and Semmler (1999) and Mazzucato (2002; 2003) study the relationship between innovation and stock price volatility at the *firm level* over the *industry life-cycle* when the characteristics of innovation are changing (Gort and Klepper, 1982). These studies (focused on the auto and computer industries) find that both idiosyncratic risk and excess volatility were highest precisely during periods in which innovation was the most radical and market shares the most unstable.

Mazzucato and Tancioni (2008) find that the relationship between innovation and stock price volatility is rather mixed, and holds more strongly for the most innovative and the least innovative industries (e.g. biotechnology and textiles). Research in FINNOV'S Work Package 2 will contribute to this literature by using firm level innovation data to test whether innovation is related to the level and volatility of stock prices, and how this relationship is affected by firm size, the type of innovation in question and the phase of the industry life-cycle.

3. Persistence and Fat Tails

To better understand the relationship between innovation and firm performance measures, one needs a good understanding of the time series behaviour of these variables, which often do not follow the assumption of a 'normally' distributed variable. Understanding how innovation relates to this 'non normality' (e.g. fat tails) is one of the core objectives of Work Package 2 in FINNOV. As one of the factors that may lead to 'fat tailed' distributions is the persistency of innovation, both at the firm level but also at the level of the aggregate economy (e.g. as highlighted by Schumpeter in his notion of innovation coming in clusters and waves), we start this section reviewing the literature on 'persistency'.

The innovation literature finds some degree of persistence in innovation and profits, and less so in growth rates. Persistence of innovation and profits refers to the degree to which innovating firms at any given time will continue to innovate and firms with above average profits will continue to make higher than average profits in the following periods. Innovative persistence and persistent profitability have important implications for firm growth as they can trigger dynamic increasing returns which result in lumpy growth (i.e. not in small, identical and incremental steps) and persistent correlated growth for the innovators and for firms with above average profits (Cefis, 2003; Malerba et al., 1997). Hence, if there is persistence in innovations and firm profits, one would expect these to show up as persistence in firm growth differentials. Yet, as discussed above, firm growth studies consistently report a lack of persistence in firm growth behaviour which is most puzzling for industrial economists.

There is general consensus that innovation persists over time at the firm level even though the persistence tends to weaken when one inspects innovation over longer periods of time (e.g. more than 5 years). Geroski et al. (1997) find that very few firms are persistent innovators. They show this finding is robust to how one measures innovation; either with patent data or the count of firms' *major innovations*. Cefis and Orsenigo (2001) and Cefis (2003) confirm the results of Geroski et al. (1997) that very few firms are truly persistent innovators. As these firms account for the majority of innovations in most sectors, they argue

that in fact there is persistence in innovative activities. Non-innovators are also persistent: their probability of starting to innovate is very low if they have never innovated in the past. Peters' (2006) results show very high levels of persistence in innovation activities for both service and manufacturing firms and for both the innovating and non-innovating firms. Alfranca et al. (2002) also conclude that there is a significant degree of persistence in the innovation activities of food and beverage companies and that old innovators are the most likely candidates to introduce new innovations. Raymond et al. (2006) do not find any evidence for persistent innovation activities among the Dutch manufacturing firms.

Persistence in innovative activities results from a range of factors. The first and most important one of these is the path dependent nature of organisational routines in which the firm specific innovative behaviour and capabilities are rooted (Nelson and Winter, 1982). Nelson and Winter (2002) argue that organisational routines provide a basis for behavioural continuity due to a number of reasons such as irrational resistance to change, high costs of learning and relearning the routines and the possibility of organisational conflict that would arise as a result of major changes in routines. Hence, firm-specific innovative capabilities which emerge from firm-specific routines show a large degree of continuity and persistence.

It is difficult for less innovative firms to effectively and fully imitate the organisational routines of very innovative firms due to the tacit nature of these routines. Tacitness hinders one to clearly observe the underlying structures of routines and hence learning and imitation are not easy. Moreover, changing certain routines related to innovation would also require major changes in other routines throughout the organisation due to the complex interdependence of the routines (Nelson and Winter, 1982; Teece et al., 1997). As a result "*... Innovations intrinsically 'characterize' a firm in that it creates a structural difference between innovating and non-innovating firms*" (Cefis and Ciccarelli, 2005; p. 43).

The second reason for the persistence of innovations is that sunk costs associated with building an R&D facility encourages the firm to invest into R&D continuously (Sutton, 1991, 1999). This persistent R&D expenditure behaviour leads to persistent innovations. Thirdly, firms often undertake multiple R&D projects. Hence, even when a single project delivers results/innovations with irregular intervals, the sum of all R&D projects is likely to deliver outputs at a regular interval (i.e. yearly) leading to persistent innovations at the firm level. Fourthly, the positive feedback between innovation and profits leads to persistence in innovations. Firms that earn high profits due to their innovations can reinvest these earnings back into the innovative activities which will likely deliver new innovations (Cefis and Ciccarelli, 2005). Finally, firms that have invested in innovations in the past are more likely to

innovate in the future as a result of the positive feedback effects resulting from absorptive capacity (Cohen and Levinthal, 1989,1990).

Innovative persistence needs to be understood in the context of industry evolution and the changing characteristics of the innovation regime. In early stages of the industry life cycle innovations are more radical, innovative activities are distributed across a wide population of firms, while in the later stages of the industry life cycle a new innovation regime dominates in which the rate and magnitude of innovation tapers off, innovations become more cumulative and the innovators are mostly large firms (Abernathy and Utterback, 1978; Agarwal and Gort, 1996; Gort and Klepper, 1982; Klepper, 1996, 1997; Londregan, 1990; Malerba, 2007; Mazzucato, 1998, 2002). The earlier stages of the industry life cycle are characterised by less persistence in innovations while the level of persistence increases in the later stages of the industry evolution with the dominance of large firms. The innovative persistence literature documents that large firms tend to be more persistent in their innovative activities compared to small firms (Cefis, 2003; Cefis and Orsenigo, 2001; Rogers, 2004) with the exception of Japan where small firms are found to be more persistent innovators (Cefis and Orsenigo, 2001). Duguet and Monjon (2004) find that small and large persistent innovators are very different in terms of the origins of persistence: small persistent innovators rely on *operational learning by doing* while large persistent innovators rely on *formal R&D*.

The firm profitability literature similarly suggests that there is a strong tendency for profits to persist. The empirical debate on the degree to which profits persist at the firm level starts with Mueller's (1977) study which shows a high level of persistence in profits of American manufacturing firms. Jacobsen's (1988) study of medium and large American firms also reveals a degree of persistence in profits even though the author interprets this as a "disequilibrium process" on the way to convergence of profits. Goddard et al. (1997), on the other hand, find that profit rates are rather stationary for a sample of 335 UK firms and there is no evidence of converging to a common rate in the sample. Cable and Jackson (2008) show that 60% of the firms in their sample display non-eroding long run profit persistence. Similarly, Odagiri and Yamawaki (1986) and Odagiri and Maruyama (2002) rule out the possibility of convergence and claim that profits are highly persistent in the case of Japan. In a comparison of large European firms, Geroski and Jacquemin (1988) find that profits above and below the norm tend to persist especially for UK firms whereas the profitability patterns in Germany and France show less persistence and more unpredictability. Cubbin and Geroski (1987) relate the persistence of profits to firm level heterogeneity and this is confirmed in industry specific studies such as Robert (1999) while Glen et al. (2001) emphasise the relevance of geographical boundaries in determining the persistence of profits as they find profits to persist less in emerging economies in comparison to advanced

economies. Gschwandtner (2005) finds that profit persistence does not only occur for surviving firms but applies also to exiting firms.

Unlike in the case of profits and innovations, with the exception of some studies (Abbring and Campbell, 2003, Chesher, 1979; Bottazzi et al., 2005; Contini and Revelli, 1989; Saito and Watanabe, 2006; Wagner, 1992) most of the firm growth literature finds almost no persistent structure in firm growth (Chan et al, 2003; Dunne and Hughes, 1994; Geroski, 1998; Hart and Oulton, 1996 and 1997; Reichstein and Dahl, 2004; Sing and Whittington, 1975). Even in cases, where growth is found to be persistent, the level of persistence is much lower than what one would expect to conclude that success breeds success and failure breeds failure. It is thus very difficult to reconcile the evidence for dynamic increasing returns arising from the persistent behaviour in innovation and profit rates with the lack of this persistence in growth rates (and market shares)?

One would also expect to find persistent firm growth due to the heterogeneity and cumulative nature of firm specific characteristics and activities. Firms' R&D spending levels, technical knowledge, success in adopting and using innovations, productivity levels, the input combinations and the products as well as the firm-specific strategies in investing, pricing, R&D etc. are widely diverse even within very narrowly defined markets (Silverberg et al., 1988). More importantly, these differentials do not disappear with the passage of time (Dosi et al., 1997). Hence, firms are far from converging to a "representative firm" as firm specific organisational routines and the path dependent development of capabilities ensure that the diversity is maintained (Nelson and Winter, 1982). Then, why do these persistent firm level differences not lead to persistent firm growth differentials? For instance if more successful innovators grow faster than others, shouldn't growth persist because the innovative characteristics of firms persist?

The lack of persistence is even more puzzling when one thinks of the robust evidence for fat tails in growth rate distributions. Firm growth rates do not follow a Gaussian distribution (as would be produced by a stochastic growth process) but display tent-like structures with significantly fatter (or heavier) tails compared to the Gaussian distribution (Axtell, 2001; Bottazzi and Secchi, 2005; Bottazzi et al., 2008; Coad and Rao, 2006; Dosi, 2005; Reichstein and Jensen, 2005). Fat tails imply that extreme growth events happen more frequently and the Pareto and Subbotin family distributions seem to fit the growth data much better than the Gaussian distribution. Evidence for fat tails is often interpreted as evidence for lumpy growth (instead of an iid. growth process) which results from economies of scale and scope, clustering of technological innovations and the increasing returns due to network

externalities, knowledge accumulation, innovation activities and the self-reinforcing effects of the creation of managerial talents (Bottazzi and Secchi, 2005; p.19; Dosi, 2005).

Fat tails have also been found to be prevalent in stock return data—against the basic assumption in the Efficient Market Hypothesis which assumes that share prices move like a random walk, in which the market makes unpredictable and uncorrelated steps. Authors such as Mandelbrot and Taleb (2005) claim that the actual distribution of returns appear to be much ‘fatter’ than the normal distribution implies. This is because financial markets often make very large giant steps (high sigma events which are far from rare) which are correlated one with another. These events, such as the fall of the NASDAQ on Black Monday in 1987, or the sudden rise of the CISCO share price in the 1990, have major effects on market outcomes. The key point here is that not only do people have cognitive limitations as emphasised by the behavioural finance theorists, but that they have been wrongly trained in their MBA finance courses to disregard big market moves as being near to impossible. They claim that while the bell curve works well for the study of physical variables like height and weight, it works terribly for finance.

In fact, the emphasis on the ‘non-normal distribution’ of returns complements the results of behavioural finance. This is because one of the main reasons that large events may occur is due to the effect of positive feedback dynamics emphasised by behavioural finance theorists, where, for example, one person’s decision influences another person’s decisions so that any error by the first will turn into an error made by the second (correlated errors). In fact, average returns are important only in situations in which there is a reversion to the mean dynamic. Positive feedback will cause the types of important, and less rare, outliers that cause fat tails.

While not testing the relationship between innovation and fat tails in different performance variables, the recent industry dynamics literature has in fact suspected that innovation might be a likely factor that might cause the persistent dynamics to emerge and thus drive the lumpy growth process. The *disharmonious and lopsided* nature of innovations that often come in waves would imply that the growth opportunities in a market are not identical, some being extremely large compared to the rest (Freeman, 1995; Schumpeter, 1934). The heterogeneous nature of growth opportunities results in some firms (e.g. successful and persistent innovators) experiencing extreme growth because the market opportunities they capture are extraordinarily large. Coad (2006) argues that the fat tails emerge due to indivisibility of the lumpy resources used for growth instead of the factors suggested by Bottazzi and Secchi (2005) that would lead to increasing dynamic returns and autocorrelated firm growth.

Work Package 2 will contribute to this literature by exploring whether innovation dynamics can really be related to the emergence of fat tails in growth, profits and stock prices. Specifically we plan to look at the distribution of growth rates and stock returns for different sample of firms, industries, and over different innovation 'landscapes' (radical vs. incremental change).

4. **Future directions**

The puzzles raised in this literature review motivate the research to be undertaken in FINNOV Work Package 2 (SELECTION), *Co-Evolution of Industry Dynamics and Financial Dynamics*. The goal of this research is to uncover what firm level characteristics are necessary for firms to reap benefits from their innovative activities. And how these characteristics differ across sectors and across periods in the industry life-cycle. We are particularly interested in the degree to which variables like firm size, the persistency of innovation, the technological area of innovation and collaborative activities affect the ability of firms to translate the efforts around innovation (R&D, patenting) into growth and better stock price performance. We are thus also interested in the degree to which market selection, both industrial and financial, reward innovators rather than penalise them.

As the dynamics that affect industrial markets are different from financial markets, we will treat these markets separately, but also in relation to each other. For example, if we find that certain firm characteristics are necessary to be in place for R&D spending to affect growth (e.g. fast growing firms, persistent patenters), we will look at whether these characteristics are also necessary to be in place for R&D (and patents) to affect market value and stock returns, and if not, why not?

While this approach will bring important insights into our understanding of the unresolved innovation-firm growth relationship, it will also help to disentangle seemingly more straight forward relationships such as that between innovation and market value. Some recent studies highlight that there are differences in how financial markets value innovation *in different industries and for different types of firms*. For example, Hall et al. (2005) find differences in market valuation of innovation between sectors: elasticity tests show that the marginal effect of an additional citation per patent on market value is especially high in R&D intensive industries such as the pharmaceutical industry. Similarly, Hall and Oriani (2006) highlight the variation in how innovation affects market value across different types of firms: their findings suggest that the market only values R&D in *certain types* of Italian and French firms, specifically those in which no single shareholder holds more than one third of the firm.

Some firm characteristics (among many) that would potentially modify the innovation-firm performance relationship include firm size (small/medium/large), patenting behaviour (patentees/non-patentees), persistence in innovation activity, tendency of firms to self cite their patterns (an indicator of the degree to which a firm builds on its own knowledge (Trajtenberg et al., 2002)), generality and originality of the patenting activity (i.e. a measure based on the qualitative differences in citations made and received (Trajtenberg et al., 2002)), degree of involvement in inter-firm research collaborations, firms' R&D and advertisement spending patterns (above/below the industry average and persistence in spending behaviour). We will build directly on these studies to see how financial performance measures are affected by innovation for firms with different characteristics, in different sectors, and different periods in the industry life-cycle.

We also need to explore to what degree one can generalize the operating principles of market selection across industries. Is, for example, innovative persistence as important in how market selection rewards innovators in different industries with different characteristics? A useful comparison would be cross checking the operations of market selection across Pavitt's sectoral taxonomy to identify which firm characteristics underlie the market selection dynamics in different sectors. Similarly, one needs to identify whether the operating principles of market selection change (for both industrial and financial markets) as an industry progresses through its life cycle to see whether a firm characteristic (e.g. size, R&D collaborations) becomes more important at a certain stage of the industry life cycle.

Similarly, we are interested in the degree to which divergences from normality in the distribution of performance variables are related to firm specific innovation characteristics, and industry specific dynamics. We need to better understand whether non-Gaussian characteristics are created by certain firms, only in certain periods of the industry history and just for some industries. And how these relationships differ between financial markets and industrial (product) markets.

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