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Abstract

In this paper we wish to examine if firms that innovate experience a higher rate of growth compared to firms that do not. Our analysis is based on different models and a recent econometric method (quantile regression) applied to several waves of community innovation surveys (CIS) for French industry in the period of 1992-2004. Our main findings are that innovative firms produce more growth than non-innovative ones. The estimation techniques give quite robust results as far as the effect of different types of innovation on firm's growth is concerned. Our results with quantile regression tell us that firms with the highest growth rates register a stronger coefficient in the innovation variable, a result that proves robust under the definition of the dependent variable measurement method.

Key words: Innovation, process and product innovator, firm growth, CIS.

JEL classification: D22, L20, L60, O31, O33

1. Introduction: Survey of the literature and research questions

One major argument put forward in favour of an innovation policy is that more innovations generate more growth that pushes the employment toward a higher regime of jobs creation. Innovation is the means by which new knowledge is transformed into economic growth. So the notion that innovation produces more growth is the commonly accepted rationale for implementing effective innovation policy in both Europe and America. While the *theoretical literature* explains very well why innovation is a determinant of firm growth, *empirical studies* have more difficulty identifying any strong link between the two (Coad, 2007).

A natural starting point for investigating the determinants of firm growth is the well-known Gibrat's Law framework. The "law of proportionate effects", introduced by Gibrat (1931), argues that the firm size distribution is highly skewed, presumably following a log-normal function. This frame assumes that firm size follows a random walk. No deterministic factors can explain the differences in firm growth. It has been shown that the rates of growth of large and/or old firms are very often erratic and consequently unpredictable (see Geroski, 1999). This means, for instance, that for large firms, there is no deterministic impact of innovation activity on their growth. It is widely recognised that Gibrat's Law cannot be assumed as a general law but only as a dynamic rule valid for large and mature firms (Sutton, 1997). Thus its validity cannot be taken as granted ex ante (Lotti, Santarelli and Vivarelli, 2009). A large literature has dealt recently with the theoretical coherence and empirical relevance of the Law (Cefis *et al.*, 2007; Coad, 2009). Suffice it to say that Gibrat's law is at odds with new empirical studies on the existence and persistence of heterogeneity in firms, including their performance (Colombelli and von Tunzelmann, 2010)[1]. Very recently, Bottazzi *et al.* (2011) discussed the properties of growth rate distributions in French manufacturing industry data. They found a significant heterogeneity of firm size across industries.

Among studies dealing explicitly with innovation/growth links at the firm level, much of the literature is inspired by Mansfield (1962). This work constitutes the first rigorous empirical assessment of the complex relationship between growth and innovation at the firm level. Mansfield asked, "How much of an impact does a successful innovation have on a firm's growth rate?" (Mansfield, 1962: 1042). He first observes that the firms that have carried out

[1] An exception is given by Del Monte and Papagni (2001). With a sample of 500 firms, over the period 1989-1997 (drawn from the Mediocredito survey of Italian manufacturing) they confirm the Gibrat's Law. They show that the growth rate of firms is positively correlated with research intensity (that we can consider as a proxy for firm innovation activity).

significant innovations grew more rapidly than the others and that their average growth rate was twice as important as the others. He also noted that the estimated effect depended on the industry under consideration and argued that innovation has a greater impact on small firms' growth rates. Dealing with, in Mansfield's words, the "processes of firm formation, growth and decline" (Mansfield, 1962: 1043), the paper sets up the very first empirical evolutionary approach of firm growth determinants. While many firms decline and exit, some shortly after entry, others grow, innovate and build their capital of basic competencies (or capabilities) necessary to survive and succeed. These positive links are confirmed by the works of Scherer (1965), Mowery (1983), and Geroski and Machin (1992) and found to be at the core of the evolutionary approach (Dosi, 2005; Nelson and Winter, 1982; Winter, 1984). Innovation is presumed to be good for growth and survival but only under certain conditions. Firms need to capture value from innovation (Teece, 1986) and, in some sectors, implement methods for improving performance (economies of scale or scope, for instance). Innovation creates an advantage for firms over competitors. As a consequence, a firm's market shares increase, which becomes the mechanism that transforms innovation into growth. Some authors argue that there is a second way to produce growth with technological innovation (though it is not as important as the first): the process of innovation, which can transform a firm's core competencies (Geroski *et al*., 1993; Lee, 2010). As a consequence, the firm becomes more able to innovate and/or cope with the selection environment. In a sense, this study reveals the two faces of R&D: innovation and learning (this idea stems from the famous analysis by Cohen and Levinthal, 1989).

A recent set of studies on different types of firms brings new empirical insights on the effects of innovation on firm performance. A paper by Audretsch (1995), for example, looks at the post-entry performance of new firms. He proves that in industries in which innovative activity plays an important role, the probability of a new entrant surviving is lower than in industries in which innovation is less important. He also finds that entrants that survive have higher growth rates[2]. Cefis and Marsili (2005) examine the effects of innovation on survival using data on Dutch manufacturing firms. They show that firms benefit from an innovation premium that extends their life in the industry, independent from a firm's age and size. Process innovation, in particular, seems to have a distinctive effect on survival. Cainelli *et al.* (2006), with CIS data for Italian service sectors, confirm that innovation activities have a

[2] Baldwin and Gellatly (2006) provide a rich analysis of an evolutionary approach but dealing only with small Canadian firms.

positive impact on firms' growth and productivity. Coad and Rao (2008) use a large sample of high-tech firms and find that growth may or may not be related to innovation activity (as measured by the patenting activity of firms). Using quantile regression techniques, they note that innovation is more crucial for the growth of "rapid-growth" firms. In the same vein, Cassia *et al.* (2009) give evidence that Universities' knowledge input and output are important determinants of UK entrepreneurial firm growth. Ernst (2001), in his study on the growth of German firms, performs a quantitative analysis and finds that patent applications increase sales after a lag of 2 or 3 years in a specific type of patent system (national or European). This point tends to emphasise that the effects of inventions on firm growth performance are not immediate but rather are seen soon after the invention has been implemented (it is important to note that a patent application does not mean that an invention is implemented). Corsino (2008) uses a new (and unique) type of data. He gathered information about new semiconductor devices commercialised during the period of 1998-2004 by producers from around the world. He performs an econometric analysis at the corporate level and finds that the most recent innovations more significantly affect firms' growth. Nevertheless, when the estimations are carried out at the business-unit level, the influence of product innovations on business-unit growth is higher than that found at the corporate level. Thus, he stresses the importance of the level of observation for the identification of an association between growth and innovation.

From this survey, some general findings can be observed. In general the studies give evidence in favour of a positive and significant relation between firm innovation and firm growth. This finding is consistent across the use of different proxies for innovation. As a consequence, it is tempting to consider this finding as a stylised fact. Only a few studies found mitigated results in the relationship between innovation and growth[3]. Of course innovation is only one factor among explanatory variables. Nevertheless, some important issues are still unaddressed or neglected by the current literature[4]:

1. First, the issue of the type of innovation (product versus process) is very infrequently addressed by the literature. Some studies note that new products have an impact (Roper, 1997); others take into account the two types of innovation (Mansfield, 1962). As a

[3] For instance Bottazi et al. (2001), in a study of worldwide firms of the drug sector, do not find any relation between innovation and growth. The results of this study seem to be an exception that might be due to the economic conditions that this sector has recently experienced.

[4] Table 0 gives a summarized view of the main studies.

consequence, it may be interesting to address this topic by assessing the effect of each type of innovation in the same frame. From this point of view, the data drawn from the CIS can be helpful because it provides a great deal of information on the types of innovation (including, for instance, product and process differentiation). The paper by Mohnen and Mairesse (2010) has recently demonstrated the richness of the data collected through CIS.

2. We find in the literature different specifications for product and process innovations, and for innovation proxies (R&D, patent). To cope with this problem, one of the main original contributions of this paper is the use of additional and complementary indicators based on CIS. This enables us to test the robustness of innovation's effects on growth by changing the definition of innovation variables. For instance, we can use qualitative as well as quantitative variables for innovation (for example, the share of innovative products and marginally modified products in turnover).

3. One interesting issue is delineated by Coad and Rao (2008). They note that innovation is more crucial for "rapid-growth" firms. Given this perspective, quantile regression becomes essential if we are to test the effects of innovation on firm growth rate.

4. As some scholars have noted (in particular Geroski *et al*., 1997), the specification of the dependent variable is important and may be crucial. Many studies are indifferent in choosing their index of performance, citing value-added rate of growth, sales growth, or other factors. It seems important to clarify this point in testing the sensitivity of the results to the definition of the growth variable.[5]

It seems to us that these issues have not been adequately explored or documented in the literature that deals with the relation between innovation and firm growth but that they are critical for correctly understanding how this relation works. With this paper we want to contribute to the literature by providing new materials for dealing with these issues. The paper aims at filling these gaps by focusing on the French industry over the period of 1992-2004. Our contribution lies in the use of diverse waves of CIS for the French industries and the application of new econometric methods on this research question (quantile regression).

The paper is organised as follows: Section 2 presents the data and our variables, Section 3 sets out the methodology, Section 4 provides our results, and Section 5 concludes the paper.

[5] Another difficult question that will not be dealt with here warrants more attention: the timing of the innovation effects (noted in particular by Mansfield 1962 and Geroski and Machin, 1992) is of a crucial importance for explaining the effects on growth (see Coad, 2007). Are these effects relevant for the short term or medium/long term? Geroski and Machin (1992) noted that the innovation effects on firm performance are realised vey soon after the firm innovates.

2. Data description

This empirical study focuses mainly on long term post-innovation growth performance of innovative firms that are differentiated in their size and type of innovation compared with non-innovative ones. The sample we used for the econometric analysis was constructed from CIS data and completed with the annual enterprise survey[6] of 1992. We obtain an unbalanced panel of 1074 firms that covers four periods of time. In this section we discuss how we dealt with the dataset and provide a description of data sources and variables we have gathered from them.

2.1. Data sources and description

Our analysis is based on a data set obtained from the merger of three waves of CIS, in particular CIS2 (1994-1996), CIS3 (1998-2000) and CIS4 (2002-2004). We have collected information that enables us to construct variables measuring the rate of growth of firms from the period of time we wish to study and their innovation activities in the same time interval. We have used the information provided in CIS questionnaires on turnover, the number of employees and activity (identified with NACE codes[7]). This information is available every second year, for each three years time period, in CIS. To capture innovation activity, a set of questions is asked to determine if the firm has innovated or not in the three years prior to each survey. As a result, these surveys provide information on product and process innovators for the following periods: 1994-1996, 1998-2000 and 2002-2004. The merger of the three datasets was accomplished by identifying each statistical unit by its enterprise code (the enterprise is the legal unit), and retaining it in the final data set firms that answered to all three CIS. We restrict our analysis to the sample that resulted from the merger.

Because some information on turnover and size is missing in the CIS for 1992, another set of data is used to provide more information about firms obtained from the merger of the three waves of CIS. We use the annual enterprise surveys to complete this missing 1992 information, notably for turnover, size and industrial activity. We obtain a total of 1074 firms in manufacturing with 20 or more employees in the following three time periods: t1, spanning

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[6] The "enquête annuelle enterprises" are French surveys conducted by Sessi, the Ministry of Agriculture (for IAA) and INSEE (the French public Institute of Statistics). These longitudinal datasets provide yearly information on French firms' balance sheets for firms that have 20 employees or more.

[7] The European Union's industrial classification of economic activities, recognized by the Accounting Economic System (National Institute of Statistics).

from 1994 to 1996; t2, spanning from 1998 to 2000 and t3, spanning from 2002 to 2004 (see table 1 showing the structure of the dataset).

Table 2 provides information on the whole data distribution by sector. Wood, paper and printing, and chemical and metal activities represent the majority of activities (approximately 12% each), while two other important sectors are machinery and electrical engineering (approximately 10% each). All the other economic activities represented in our sample account for less than 10% of the observations.

Table 3 shows the sample distribution by size at the beginning of the period under scrutiny. Our sample mainly consists of small firms with less than 50 employees and large firms with more than 250 employees (approximately 40% each). Medium-sized firms represent only 20% of the sample.

As a consequence, and similar to previous works concerning firms' growth and innovation (Mansfield, 1962; Evans, 1987a, 1987b; Scherer *et al.*, 2000), our study includes exclusively industrial activities. Indeed, only two (CIS3 and CIS4) out of the three CIS we use in this study include sectors other than industrial activities. Because we kept only firms that are observed over the whole period, our final dataset includes mainly industrial activities.

2.2. Variables

2.2.1. Growth rates

For each year, starting from 1994, we computed firm growth rates following two different methods.

We first define a firm's rate of growth as the log-difference of size:

$$Growth_{i,t} = \ln(S_{i,t}) - \ln(S_{i,t-1}),$$

where $S_{i,t}$ is firm turnover at time t, which has been deflated by using the French GDP deflator (base year 2000) drawn by Thomson Datastream, and $S_{i,t-1}$ is its lagged value[8].

[8] Firms' growth can actually be measured by relying on different size indicators, such as sales, employment or assets. However, as Table 0 suggests, the stream of literature related to this paper analyzing the effects of innovation on firms' growth adopts sales as a proxy for size. Moreover, while the links between innovation and employment, as well as those between innovation and assets, are undoubtedly important, they refer to rather different theoretical backgrounds aimed at capturing different dynamics, which are not the focus of this paper.

The second method is the compound average growth rate (CAGR), which returns a theoretical growth rate, assuming a steady growth over the period t_0-t_n, and hence takes into account that each time period covers more than one year[9]:

$$CAGR_{i,t} = \left(\frac{Turn_{i,tn}}{Turn_{i,t0}} \right)^{\frac{1}{tn-t0}} - 1$$

Figure 1 shows the distribution of firms' growth rates. As evidenced by the figure, the empirical distribution of the growth rates for our sample seems closer to a Laplacian than to a Gaussian distribution. This is in line with previous studies analysing the distribution of firm growth rates (Bottazzi *et al*., 2007; Bottazzi and Secchi, 2003; Castaldi and Dosi, 2009). In particular, the mean growth rate for the whole period is approximately 20% for both measures used, but their standard deviation shows a great deal of variation because of the large time span (1992-2004). Consequently, it can be useful to analyse the distribution of growth rates as a function of innovation distribution. We expect that innovation has a positive impact on firms' growth.

2.2.2. Innovation

The goal of our analysis is not to operate an extensive overview of corporate growth of the firms interrogated in the CIS samples but to observe interactions between innovation and growth. Consequently, the definitions of our innovation variables are crucial.

Two main variables are used: the first one measures product innovation, while the second measures process innovation. In all the CIS, a firm is considered as "innovative" if, over a given period of time (the last three years), it has introduced a new product or a new process. This information is gathered with a set of

(1) dichotomous variables that reveal whether or not the firm has produced an innovation during the period covered by the survey.

(2) continuous variables that register the success rate of product and process innovations (firms are asked the share in total sales of products and processes) that are continuous.

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[9] The log-difference is the most widespread measure of sales growth in the literature. However, in our case, some drawbacks can arise due to the fact that the different times at which firms are observed are not consecutive years. For this reason we also propose to adopt the CAGR index, which nonetheless provides a measure assuming a steady growth rate. We think that it is worth observing the both of them.

For instance, CIS2 measures innovation with dummy variables on product and process innovation and continuous variables that register the share in total sales of product and processes.

While product innovations are associated with more radical technologies and are expected to result in higher growth rates because of higher economic returns, process innovations are based on more defensive technological strategies. Yet, the effects of product and process innovations are indirectly linked and lead the way for new types of products (Barras, 1990). We further constructed a set of dichotomous variables:

Ino, taking the value 1 if the firm has introduced *either* product *or* process innovation;

Inop, taking the value 1 if the firm has introduced a product innovation; and

Inoc, taking the value 1 if the firm has introduced a process innovation.

A second set of information on innovation provided by CIS is quantitative and estimates the share of innovative products and marginally modified products on the turnover (Inoprod and Inoproc, respectively). However, while in general, firms are able to quite easily quantify the share of turnover due to product innovation, they are usually less able to give the same information for process innovation. For this reason we use only Inoprod, dropping Inoproc.

3. Methodology

We start our empirical analysis by testing whether innovative firms have different growth rates compared to non-innovative ones. To this end, we perform a two-sample mean comparison test. This test verifies the null hypothesis that the two groups of firms, both innovating and non-innovating, have the same mean. We define innovating firms as those that have introduced either a product or a process innovation over the period under scrutiny. As we are also interested in disentangling the role of product and process innovation, we further distinguish between product and process innovating firms. The results of the mean comparison test are shown in Table 4. The test rejects the null hypothesis of equal means between innovators and non-innovators. The same null hypothesis is also rejected between non-innovators and product innovators, innovators and process innovators. These results suggest that innovating firms generally perform better than non-innovating ones[10].

After we have tested whether innovation can be considered a source of growth differentials, we proceed analysing the effects of innovative activities on firm growth. The study of the determinants of firm growth poses some methodological issues, in particular as they relate to the distributional properties of growth rates and their persistence over time. A discussion of how we address these methodological issues follows.

In our empirical analysis, we use a Gibrat-like model that includes firm size as an explanatory variable. The empirical literature uses two different specifications for testing Gibrat's Law. As our aim is not to test the validity of the law but to verify the impact of innovation on firms' growth, we use both specifications in order to check for consistency and robustness of our results to the use of different specifications and estimations techniques.

The first specification in order to model the growth of firms' turnover as a function of firm innovation follows the original logarithmic representation of Gibrat's Law:

$$\ln\left(S_{i,t}\right) = \lambda_1 + \lambda_2 \ln\left(S_{i,t-1}\right) + \lambda_3 Ino_{i,t-1} + \sum \omega_j + \sum \psi_t + \varepsilon_{i,t} \quad (1)$$

where $S_{i,t}$ and $S_{i,t-1}$ represent the turnover (deflated) for firm *i* at time *t* and *t-1*, respectively, $Ino_{i,t-1}$ is product or process innovation for firm *i* at time *t-1*. ω_j and ψ_t represent a set of industry[11] and time dummies, respectively, controlling for macroeconomic and time fluctuations. The inclusion of the lagged dependent variable in the model requires dynamic estimation techniques. We have a large N and small T panel data set. Following the literature on dynamic panel estimators (Arellano and Bond 1991; Blundell and Bond 1998; Bond 2002), equation (1) is estimated using the generalised method of moments (GMM) methodology. In particular, we use the GMM-System (GMM-SYS) estimator developed by Blundell and Bond (1998) in order to increase efficiency. This approach uses instrumental variables in levels with lagged first-differenced terms. The authors demonstrated a dramatic improvement in the performance of the system estimator compared to the usual first-difference GMM estimator developed by Arellano and Bond (1991).

Transforming Equation (1), we obtain an alternative specification of Gibrat's Law as follows:

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[10] The definition of the non-innovators group does change when we distinguish product and process innovators.

[11] The industrial context is important because innovation is "industry context specific" (Dosi, 1988). As a consequence, we have to control for industry effects

$$Growth_{i,t} = \lambda_1 + \lambda_2 \ln(S_{i,t-1}) + \lambda_3 Ino_{i,t-1} + \omega_i + \sum \psi_t + \varepsilon_{i,t} \quad (2)$$

Equation (2) can be estimated using traditional panel data techniques implementing the fixed effect estimator. As a robustness check, we also estimate the model using OLS. Finally, in order to provide further evidence on the relationship between firm growth and innovation, we estimate Equation (2) by means of quantile regressions. In the OLS and quantile regressions we also include a set of industry dummies in order to control for sectoral specificities.

A second methodological issue to be taken into account in our analysis is related to the serial correlation in annual growth rates of firms. While the debate on this issue is still open, previous works have found evidence of persistency in growth rates (Chesher 1979; Geroski *et al*. 1997; Bottazzi and Secchi 2006; Coad 2007; Coad and Hölzl 2011). To control for any growth autocorrelation, we also test an additional specification by including the lagged growth rates as an explanatory variable. Thus, an alternative specification of our model is the following:

$$Growth_{i,t} = \lambda_1 + \lambda_2 Growth_{i,t-1} + \lambda_3 \ln(S_{i,t-1}) + \lambda_4 Ino_{i,t-1} + \sum \omega_j + \sum \psi_t + \varepsilon_{i,t} \quad (3)$$

As Equation (3) includes the lagged dependent variable among the explanatory variables, it is estimated using the GMM-System (GMM-SYS) methodology discussed above.

4. Results

Descriptive statistics are presented in Table 5. The results of the econometric estimations are shown in Tables 6-12, where we show results using different equations, estimation techniques and variables. On the whole, the coefficients that we yield when we use Growth as a dependent variable are higher than when we use CAGR. This can also be interpreted with the help of Table 5, where descriptive statistics are reported. Actually, since CAGR is calculated on the basis of an assumption of steady growth, it provides a relatively smooth picture of the growth process versus that observed with the log-difference indicator. Indeed, the average value of CAGR is lower than that of Growth. For this reason, the effects of innovation on CAGR look a bit smooth as well.

We start by commenting on the results of estimations related to equation (1) that represent Gibrat's law in its classical form (Table 6). Our results first confirm that small companies grow more than large ones, as shown by the coefficient of $\text{Ln}(S_{,t-1})$, which is found to be less than 1 and significant at the 1%. Most importantly, the results confirm that innovation has a positive and significant impact on firm rate of growth. Indeed, the variable *Ino*, which takes value 1 if the firm has introduced either product or process innovation, is positively and significantly ($p<0.05$) related to the firm rate of growth. We also wanted to figure out the nature of innovation's impact on firm growth. When we consider product (Inop) and process innovation (Inoc) separately, we find that both types of innovation have a positive impact on firm growth. Finally, we test the sensitivity of the impact of product innovation on firm growth to the definition of the innovation variable. After changing the specification of the variables related to innovation (quantitative versus dummy variable), we observe that the significant and positive impact disappears when we express innovation as a quantitative variable.

Secondly, we perform robustness checks of our basic results by estimating equation (2), which allows us to use alternative estimation techniques. In Tables 7 through 10, we provide the results of estimations that use diverse proxies for firm innovation and alternative measures of firm growth rates (log differences and CAGR). In Table 7, the innovation variable is *Ino*. First, our results confirm that small companies grow more than large ones, as evidenced by the negative and significant coefficient of $Ln(S_{i,t-1})$. And second, and more importantly, our results confirm that innovation has a positive and significant impact on firm rate of growth in all estimations, a result robust to the use of alternative estimators. We find further evidence in the results of quantile regressions. In particular, innovation has a higher impact for high-growth companies. The coefficient on the innovation variable is always higher at the 75^{th} percentile, except in the case of process innovations, where the coefficient is higher only at the 50^{th} percentile. This means that when we consider high-growth firms, innovative activity makes an important contribution to their superior growth performance (in line with the findings by Coad and Rao, 2008).

If we turn our attention to product innovation (Table 8 and 9) and process innovation (Table 10), we find similar and even more robust results. Again, when we test the sensitivity of the impact of product innovation on a firm's growth to the definition of the innovation variable, we find that the results are less robust when we use the quantitative variable. The difference with the previous estimation is clearly due to the differences in the nature of the variables (quantitative vs. categorical). Moreover, the results can be biased by the difficulty that firms may have in quantifying the share of their turnover that is due to the commercialisation of product innovations. Nonetheless, the significant coefficients in Table 9 suggest that the results are in line with the previous estimations, although less strong.

Moreover, we perform further robustness checks of our basic results in Tables 7 to 10. In particular, we use two alternative measures of firm growth: log differences and CAGR. All the results are robust to these different measures.

We finally change the model by controlling for the autocorrelation of growth rates (Table 11). While we do not find any serial correlation in annual growth rates of firms for our sample, our results on the relationship between innovation and growth are also confirmed when we use this alternative specification[12].

Finally, when we look at the tables, the signs of coefficients across the different estimation techniques (OLS, FE, RE and quantile) are robust for all of the considered variables. The only exception is the *Inoprod* variable (i.e., the quantitative variable), the coefficients of which are sometimes not significant across some of the reported estimations. These results are in line with the peculiarity of this variable, and it is not thought to compromise the overall validity of our empirical results.

5. Conclusion

Our empirical study based on French CIS data (over the period 1992-2004) enables us to complement the literature on firm growth and to answer the issues noted in the introduction. Our main findings are:

1. Innovative firms (whatever the type of innovation) produce more growth than non-innovative firms.

2. The estimation techniques give quite robust results for the qualitative innovation variables. The only exception is the Inoprod variable that is the quantitative innovation variable. The use of a quantitative variable for product innovators sometimes results in nonsignificant outcomes due to the peculiarity of this variable.

[12] All in all, the coefficients on product/process innovation are consistent with the previous estimations. The differences between CAGR and Growth remain due to the peculiarities of the two variables.

3. We use two indicators for firm growth. Our study shows that the results we obtain are definitively robust to the dependent variable measurement method. In general, the coefficients are higher with Growth than with CAGR.

4. The results of the quantile regressions are in line with recent studies (Coad and Rao, 2008): for firms with the highest growth rates, the effects of innovation on growth are stronger.

The lesson for policy makers is that an incentive to devote more resources towards pushing or pulling innovation is good for firm growth. So our study tends to confirm the rationale underpinning innovation policy in relation to economic growth. Nevertheless, the main incentive devices for innovation are those that foster R&D investments (tax credits, for instance, in many countries). In contrast, we argue here that innovation produces more economic growth. R&D investments and innovation are two different phenomena. The first is the input of the innovation process, whereas innovation is the output. An interesting experiment for policy makers would be to analyse if their tool is effective. With respect to this objective, we could add new variables in our panel model (whether, for instance, firms receive taxes credits and whether those that do experience higher growth). Within the framework, it becomes possible to provide a better assessment of public technological support.

While the current study provides new insight on the impact of innovation on firm performance in terms of growth, it would be interesting to address the persistence of innovation in future research. Indeed, one aspect that was not dealt with in the current study is whether some firms innovate persistently while others do not. We have longitudinal data that enable us to determine whether the firms that persistently innovate produce more growth than sporadic innovators.

Appendix.

Table 0. Empirical studies on the relation between firm growth and innovation

Study	**Country and time period**	Measure for firm size and growth rate (Type of data)	**Measure for innovation activity**	**Main results**
Mansfield (1962)	USA, 10 enterprises and 10 aggregated industries (1916-1954)	Minimum efficient size, **relative size variation** **(Individual data)**	Successful innovations determine if a firm is an innovator or not	The firms that carried out significant innovations grew more rapidly than the others
Geroski et al.(1993)	U-K large quoted firms (1976-1982)	Profit margins and indirect measure of size: market concentration (Panel of 721 firms)	Number of innovations produced by each innovating firm	The number of innovations (number of patents) has no impact on corporate growth
Ernst (2001)	German machine tool manufacturers (1984-1992)	Sales (panel of 50 firms)	Patent applications (German and European patent system)	Patents increase sales with a 2 or 3 years lag
Del Monte and Papagni (2003)	Italian manufacturing firms (1989-1997)	Return on sales (panel of 500 firms)	Research Intensity	Correlation between Growth rate and Research Intensity
Cefis and Marsili (2005)	Netherland manufacturing firms (1996-2003)	Survival time (panel of 3 275 manufacturing firms)	The introduction of an innovation on the market and innovation type	The innovating firms extend their life in the industry
Coad and Rao (2008)	Large sample (world) of high-tech firms (1963-1998)	Total sales (panel of 4012 firms in high-tech sectors)	Innovativeness index (measure of patent activity and R&D expenditures)	Innovation more crucial for the growth of "rapid-growth firms"
Cassia et al. (2009)	U-K public companies (1995-2006)	Total sales (Panel of 200 firms)	Universities, Knowledge, Inputs and Outputs	Effects on firm growth
Corsino and Gabriele (2010)	Worldwide firms from semiconductors (1998-2004)	Total sales (panel of 95 firms)	Innovations counts	Product innovations affect firm growth

Table 1. The structure of the final panel

year	**Time**	**Growth$_t$**	**Growth$_{t-1}$**	**Inno$_t$**	**Inno$_{t-1}$**
1992-1994	T0	G_0	.	.	.
1994-1996	T1	G_1	G_0	Inno$_1$	.
1998-2000	T2	G_2	G_1	Inno$_2$	Inno$_1$
2002-2004	T3	G_3	G_2	Inno$_3$	Inno$_2$

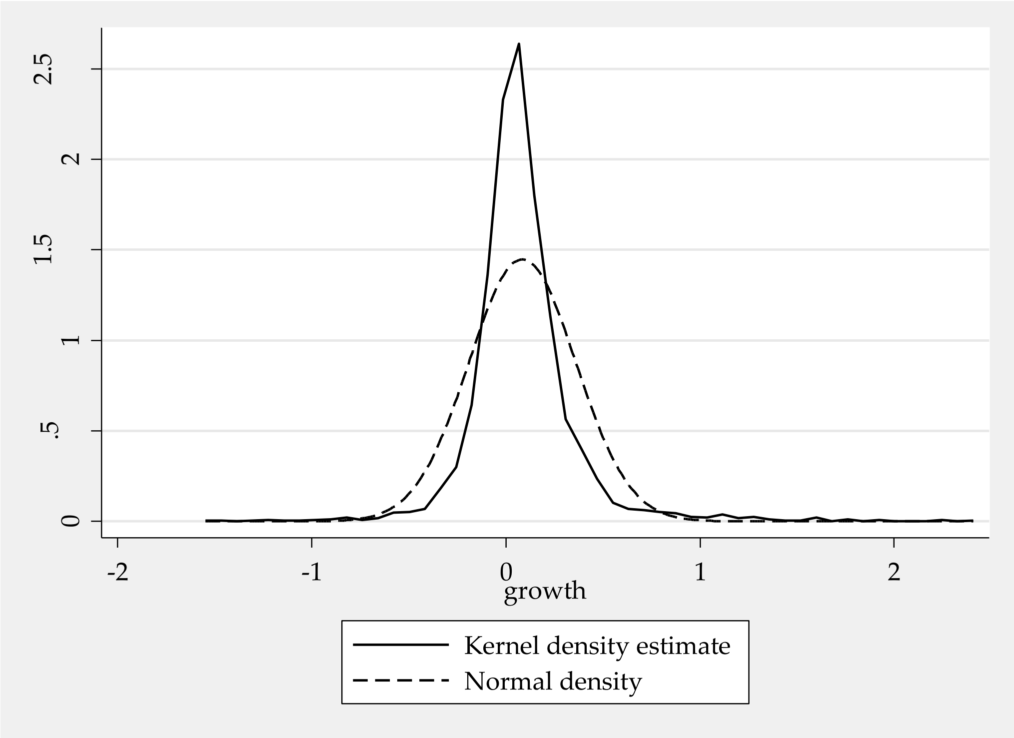
Table 2. Total sample description: sample by branches

Branches	Nace Rev 1.1	Sample	
		Firms	%
Mining and querying	10-14	9	0.84
Food and tobacco	15-16	0	0.00
Textiles	17-19	91	8.47
Wood/paper/printing	20-22	131	12.20
Chemicals	23-24	134	12.48
Plastic /Rubber	25	66	6.15
Glass/ceramics	26	61	5.68
Metals	27-28	136	12.66
Machinery	29	112	10.43
Electrical engineering	30-32	110	10.24
MPO instruments	33	42	3.91
Vehicles	34-35	96	8.94
Furniture/recycling	36-37	52	4.84
Energy	40-41	34	3.17
Total		**1074**	**100**

Table 3. Total sample description: sample by size

Size class	Sample	
	Total	
	Obs	%
20-	1077	33,43
20-49	169	5,25
50-99	251	7,79
100-249	358	11,11
250-499	517	16,05
500-999	492	15,27
1000 +	358	11,11
Obs	3222	100

Figure 1. Growth rates distribution



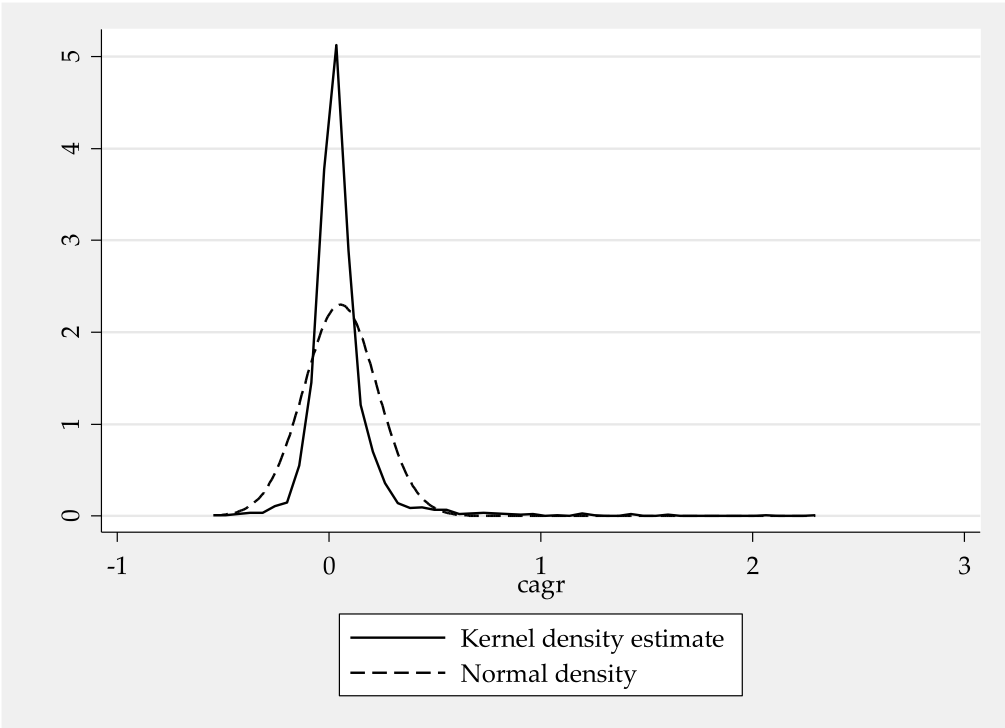


Table 4. Mean comparison tests

	Group 0	*Group 1*		*Ha1*	*Ha2*
	Non-innovators	*Innovators*	t	p-value	p-value
Growth (mean)	0.021	0.062	-3.7665	0.000	0.000
CAGR (mean)	0.019	0.039	-3.3711	0.000	0.000
Obs.	895	1395			
	Non-innovators	*Product innovators*			
Growth (mean)	0.021	0.066	-3.8462	0.000	0.000
CAGR (mean)	0.019	0.041	-3.4241	0.000	0.000
Obs.	895	992			
	Non-innovators	*Process innovators*			
Growth (mean)	0.021	0.065	-3.8478	0.000	0.000
CAGR (mean)	0.019	0.040	-3.4308	0.000	0.000
Obs.	895	1085			

Note: H0: mean(Group 0) - mean(Group 1)=0;
Ha1: mean(Group 0) – mean(Group 1)=0;
Ha2: mean(Group 0) – mean(Group 1)<0

Table 5. Summary statistics

Variable	*Obs.*	*Mean*	*Std. Dev.*	*Min*	*Max*
$ln(S_{i,,t})$	3222	7.417175	1.756326	1.410513	14.49669
$ln(S_{i,t-1})$	2822	7.591357	1.600403	2.633156	14.48141
Growth	2822	0.0854136	0.2754607	-1.516976	2.377159
Lag_growth	2750	0.1577891	1.512188	-3.521861	10.91398
CAGR	2822	0.0545427	0.1733176	-0.531626	2.282415
Ino	2390	0.6355649	0.4813721	0	1
$Inop_{i,t-1}$	2380	0.4331933	0.4956209	0	1
$Inoc_{i,t-1}$	2397	0.5127242	0.4999424	0	1
$Inoprod_{i,t-1}$	1025	-2.490742	1.123468	-4.61512	0

Table 6. Estimates of the growth of firms' turnover (equa. 1).

VARIABLES	(1) GMM-SYS	(2) GMM-SYS	(3) GMM-SYS	(4) GMM-SYS	(5) GMM-SYS
$Ln(S_{,t-1})$	0.986***	0.976***	0.977***	0.975***	0.927***
	(0.0155)	(0.0150)	(0.0148)	(0.0146)	(0.0328)
$Ino_{i,t-1}$		0.0352**			
		(0.0154)			
$Inop_{i,t-1}$			0.0307**		
			(0.0136)		
$Inoc_{i,t-1}$				0.0394***	
				(0.0136)	
$Inoprod_{i,t-1}$					0.0138*
					(0.00793)
Constant	0.0694	0.113	0.250**	0.117	0.565**
	(0.0942)	(0.104)	(0.114)	(0.0878)	(0.235)
D_Industry	yes	yes	yes	yes	yes
D_Year	yes	yes	yes	yes	yes
Observations	2822	2367	2357	2374	1015
Number of ID	1073	1070	1070	1072	600

*Notes:**** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

Table 7. Estimates of the growth rate (equa. 2).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS		FE		RE		Quantile					
	Growth	CAGR	Growth	CAGR	Growth	CAGR	Growth			CAGR		
VARIABLES							q25	q50	q75	q25	q50	q75
Ln($S_{,t-1}$)	-0.0211***	-0.0123***	-0.430***	-0.264***	-0.0284***	-0.0189***	-0.00674***	-0.00879***	-0.0163***	-0.00311**	-0.00453***	-0.00870***
	(0.00371)	(0.00222)	(0.0203)	(0.0117)	(0.00435)	(0.00275)	(0.00241)	(0.00226)	(0.00380)	(0.00154)	(0.00119)	(0.00225)
Ino $_{i,t-1}$	0.0451***	0.0253***	0.0317**	0.0148*	0.0481***	0.0270***	0.0312***	0.0252***	0.0389***	0.0150***	0.0130***	0.0208***
	(0.0114)	(0.00684)	(0.0148)	(0.00848)	(0.0118)	(0.00708)	(0.00613)	(0.00783)	(0.00682)	(0.00450)	(0.00450)	(0.00670)
Constant	0.0927**	0.0545**	3.680***	2.264***	0.137***	0.0960***	-0.0234	0.0450**	0.131***	-0.0126	0.0231**	0.0683***
	(0.0377)	(0.0226)	(0.169)	(0.0968)	(0.0454)	(0.0289)	(0.0261)	(0.0203)	(0.0278)	(0.0128)	(0.0104)	(0.0183)
D_Industry	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes	Yes
D_Year	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	Yes
Observations	2367	2367	2367	2367	2367	2367	2367	2367	2367	2367	2367	2367
R-squared/pseudo	0.073	0.065	0.329	0.347	0.1274	0.124	0.0296	0.0422	0.0664	0.0322	0.0457	0.0711
Number of ID			1070	1070	1070	1070						

Ino $_{i,t-1}$ is a dummy variable taking the value 1 if the company has introduced either a new product or a new process on the market.
Notes: *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

Table 8. Estimates of firm growth rate (measured by growth and GAGR)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS		FE		RE		Quantile					
	Growth	CAGR	Growth	CAGR	Growth	CAGR	Growth			CAGR		
VARIABLES							q25	q50	q75	q25	q50	q75
Ln(S) $Ln(S_{,t-1})$	-0.0204***	-0.0117***	-0.430***	-0.264***	-0.0273***	-0.0179***	-0.00468	-0.00991***	-0.0144***	-0.00228	-0.00498***	-0.00782***
	(0.00366)	(0.00220)	(0.0204)	(0.0117)	(0.00431)	(0.00273)	(0.00329)	(0.00281)	(0.00376)	(0.00190)	(0.00146)	(0.00158)
$Inop_{i,t-1}$	0.0413***	0.0212***	0.0329**	0.0124	0.0424***	0.0211***	0.0312***	0.0325***	0.0367***	0.0153***	0.0163***	0.0202***
	(0.0109)	(0.00654)	(0.0139)	(0.00797)	(0.0113)	(0.00678)	(0.00945)	(0.00882)	(0.0110)	(0.00580)	(0.00344)	(0.00493)
Constant	0.0957**	0.0553**	2.803***	1.734***	0.281***	0.181***	-0.0611	0.128***	0.258***	-0.0298	0.0646***	0.137***
	(0.0378)	(0.0227)	(0.134)	(0.0770)	(0.0770)	(0.0490)	(0.0731)	(0.0302)	(0.0686)	(0.0420)	(0.0190)	(0.0270)
D_Industry	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes	yes
D_Year	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	2357	2357	2357	2357	2357	2357	2357	2357	2357	2357	2357	2357
R-squared/pseudo	0.072	0.064	0.329	0.346	0.126	0.121	0.0290	0.0445	0.0668	0.0315	0.0479	0.0717
Number of ID			1070	1070	1070	1070						

$Inop_{i,t-1}$ is a dummy variable taking the value 1 if the company has introduced a new product on the market.
Where *Growth* is measured using the first difference equation
*Notes:**** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

Table 9. Estimates of firm growth rate (measured by growth and GAGR)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS		FE		RE		Quantile					
	Growth	CAGR	Growth	CAGR	Growth	CAGR	Growth			CAGR		
VARIABLES							q25	q50	q75	q25	q50	q75
Ln($S_{,t-1}$)	-0.0224***	-0.0133***	-0.365***	-0.218***	-0.0271***	-0.0197***	-0.00731	-0.0132***	-0.0197***	-0.00373	-0.00663**	-0.0106***
	(0.00579)	(0.00345)	(0.0344)	(0.0187)	(0.00629)	(0.00407)	(0.00844)	(0.00402)	(0.00644)	(0.00440)	(0.00258)	(0.00236)
Inoprod $_{i,t-1}$	0.0136**	0.00984**	0.0130	0.00667	0.0129*	0.00843**	-0.00263	0.00784**	0.0141**	-0.00131	0.00391***	0.00757**
	(0.00672)	(0.00401)	(0.0104)	(0.00567)	(0.00682)	(0.00408)	(0.00670)	(0.00317)	(0.00585)	(0.00380)	(0.00147)	(0.00383)
Constant	0.332***	0.205***	3.400***	2.022***	0.244*	0.176**	0.0459	0.112	0.293***	0.0236	0.0537	0.154**
	(0.0944)	(0.0563)	(0.304)	(0.165)	(0.136)	(0.0867)	(0.195)	(0.146)	(0.0887)	(0.0841)	(0.0745)	(0.0697)
D_Industry	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes	yes
D_Year	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015	1015
R-squared/pseudo	0.096	0.093	0.298	0.327	0.133	0.145	0.0344	0.0616	0.1008	0.0302	0.0572	0.0946
Number of ID			600	600	600	600						

Inoprod $_{i,t-1}$ is the share of product innovation on turnover,
where *Growth* is measured using the first difference equation.
*Notes:**** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

Table 10. Estimates of firms growth rate (measured by growth and GAGR)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS		FE		RE		Quantile					
	Growth	CAGR	Growth	CAGR	Growth	CAGR	Growth			CAGR		
VARIABLES							q25	q50	q75	q25	q50	q75
$Ln(S_{,t-1})$	-0.0203***	-0.0119***	-0.430***	-0.265***	-0.0276***	-0.0185***	-0.00659*	-0.00825***	-0.0148***	-0.00313**	-0.00442***	-0.00775***
	(0.00365)	(0.00218)	(0.0203)	(0.0116)	(0.00428)	(0.00271)	(0.00375)	(0.00195)	(0.00297)	(0.00144)	(0.00106)	(0.00255)
$Inoc_{i,t-1}$	0.0421***	0.0233***	0.0301**	0.0158**	0.0453***	0.0257***	0.0310***	0.0220***	0.0252**	0.0151***	0.0115***	0.0127***
	(0.0108)	(0.00648)	(0.0132)	(0.00758)	(0.0110)	(0.00660)	(0.00742)	(0.00797)	(0.0114)	(0.00304)	(0.00399)	(0.00490)
Constant	0.203***	0.120***	3.684***	2.266***	0.140*	0.0973**	-0.0921	0.0615	0.164	-0.0455	0.0325**	0.0849*
	(0.0637)	(0.0382)	(0.169)	(0.0967)	(0.0738)	(0.0471)	(0.0935)	(0.0631)	(0.109)	(0.0493)	(0.0140)	(0.0439)
D_Industry	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes	yes
D_Year	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	2374	2374	2374	2374	2374	2374	2374	2374	2374	2374	2374	2374
R-squared/pseudo	0.072	0.065	0.328	0.347	0.126	0.124	0.0297	0.0414	0.0645	0.0326	0.0451	0.0694
Number of ID			1072	1072	1072	1072						

Where Inoc is a dummy variable taking the value 1 if the company has introduced a new process on the market.
*Notes:**** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

Table 11. Estimates of the firms' growth rate measured by growth and GAGR (equa. 3)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	GMM-SYS		GMM-SYS		GMM-SYS		GMM-SYS		GMM-SYS	
	Growth	CAGR	Growth	CAGR	Growth	CAGR	Growth	CAGR	Growth	CAGR
growth $_{t-1}$	0.0315	0.00288***	0.0566	0.00315***	0.0565	0.00311***	0.0587	0.00314***	0.159*	0.0425
	(0.0355)	(0.000216)	(0.0358)	(0.000170)	(0.0360)	(0.000162)	(0.0357)	(0.000163)	(0.0942)	(0.0613)
$Ln(S_{,t-1})$	-0.0332***	-0.0196***	-0.0326***	-0.0183***	-0.0319***	-0.0177***	-0.0321***	-0.0180***	-0.0329***	-0.0207***
	(0.00458)	(0.00326)	(0.00495)	(0.00319)	(0.00466)	(0.00292)	(0.00482)	(0.00309)	(0.00794)	(0.00473)
Ino $_{i,t-1}$			0.0438***	0.0240***						
			(0.0122)	(0.00720)						
Inop $_{i,t-1}$					0.0399***	0.0196***				
					(0.0115)	(0.00668)				
Inoc $_{i,t-1}$							0.0444***	0.0241***		
							(0.0113)	(0.00653)		
lnINNOPROD $_{i,t-1}$									0.0149**	0.00827**
									(0.00754)	(0.00421)
Constant	0.256***	0.121***	0.278***	0.101***	0.267***	0.0987***	0.267***	0.162***	-0.0141	0.142**
	(0.0716)	(0.0227)	(0.0724)	(0.0211)	(0.0747)	(0.0240)	(0.0729)	(0.0294)	(0.198)	(0.0612)
Observations	2750	2750	2334	2334	2324	2324	2341	2341	1001	1001
Number of ID	1073	1073	1070	1070	1069	1069.	1072	1072	598	598

*Notes:**** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

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