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ON FIRM GROWTH AND INNOVATION. SOME NEW EMPIRICAL PERSPECTIVES USING FRENCH CIS (1992-2004)

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On Firm Growth and Innovation. Some new empirical perspectives using French CIS (1992-2004)

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Abstract

In the paper we wish to examine if the firms that innovate know a higher growth than the firm that do not. We use diverse waves of CIS for the French industries over the period 1992-2004 and carry out different models and new econometric methods (quantile regression). Our main findings are that innovative firms produce more growth than non innovative firms. The estimates show that the results are robust to the different types of models that we have implemented. Process innovators are more productive in terms of growth than product innovators when OLS and Random effects models are used. The reverse is true for Fix effect model and quantile regression. In the three growth equations estimated by GMM the coefficients related to innovation product are always higher. Our study does not give definitive results with respect to the magnitude of the effects of the type of innovation on firm growth.

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

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

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Introduction

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 mean through which new knowledge is transformed into economic growth. So "Innovation produces more growth" is the commonly accepted rationale for implementing an effective innovation policy at both the European level and the States level. When we look at the empirical evidence gathered over the 50 last years about the innovation/growth relationship *at the firm level*, it is a little difficult to find clear insights about the channels through which new bits of knowledge fuel the firm growth. Some rare studies do not find any relation between the two elements. Such results may be in accordance with the idea that a major mechanism by which innovation influences economic growth is the emergence of new industrial organizations (and finally new sectors) rather than the simple increase of the size of existing firms. Nevertheless it is hard to image that the economic growth would be due only to the creation of new organizations and not (at least partly according to the period of time) to existing firms growth.

The existence of a rich set of dense and consistent innovation surveys (CIS) appears as a mean for revisiting (at least to an empirical level of analysis) the relation between innovation and economic growth in order to provide fresh insights proving the existence of a plausible link between the two phenomena. In particular, CIS can be a useful source of information for analyzing some *open issues and missing links* related to the type of innovation and to the definition and measurement of the variables related to firm growth. The paper aims at filling these gaps by focusing on the French industry over the period 1992-2004. Our contribution lies in the use of diverse waves of CIS for the French industries and the application of new econometric methods (quantile regression for instance).

The paper is organized as follows. Section 2 identifies the open issues in the literature on innovation and firm's performances. The part 3 presents the data and part 4 sets out the methodology. The last part (5) provides our results. It appears very clearly they can offer new inputs for assessing, improving, may be re-thinking the Innovation Policy measures.

1. Survey of the literature and what we want to study

While the *theoretical literature* explains very well why innovation is a determinant of firm growth, *empirical studies* have more difficulties in identifying any strong link between the two (Coad, 2007). We can identify three groups of empirical studies addressing the innovation/growth[2] links.

A first set of empirical studies rests on the Gibrat's law framework. The "law of Proportionate effects" introduced by Gibrat (1931) argues that the firms size distribution is highly skewed, presumably following a log-normal function. This frame assumes that firm size follows a random walk. No deterministic factors could explain the differences in the extent of firm growth. It has been shown that the rates of growth of large and/or old firms[3] are very often erratic and consequently unpredictable (see Geroski, 1999). It means for instance that for large firms there is no deterministic impact of innovation activity on their growth. While earlier analysis conducted on samples of large and mature firms have supported the Gibrat's Law (Hart and Prais, 1956; Simon and Bonini, 1958; Hymer and Pashigian, 1962), a number of recent studies reveal departure from this law. They find that smaller firms tend to grow faster than their larger counterparts (Mansfield, 1962; Hall, 1987; Evans, 1987a, 1987b; Dunne et al., 1989; Dunne and Hughes, 1994; Hart and Oulton, 1996; Audretsch et al., 1999; Calvo, 2006). As a consequence, it is widely recognized that the Gibrat's Law cannot be assumed as a general law but only as a dynamic rule valid for large and mature firms (Sutton, 1997; Geroski, 1999). Thus its validity cannot be taken as granted ex ante (see Lotti, Santarelli and Vivarelli, 2009).

There is a large literature dealing very recently with the theoretical coherence and the empirical relevance of the Law (see among others the paper by Cefis et al., 2007). Suffice to say that the Gibrat's law is at odds with the new empirical studies underlying the existence and the persistence of heterogeneity in firms, including their performance (Colombelli and von Tunzelmann, 2010). For example, some empirical results challenging the Gibrat's Law highlight that growth rates are autocorrelated. Moreover, a stream of the literature has proved that firm growth follows a Laplace distribution. Recently Castaldi and Dosi (2009) show a certain variability on growth rates which appears to fall with firm size. They present robust evidence in favor of a Laplacian distribution of firm growth rates holding across sectors, across countries and across time periods. Yet, the literature still considers the Gibrat's Law as a useful benchmark for empirical purposes.

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

[3] An opposite findings is provided by Evans (1987a; 1987b). On a panel of US firms (over the period 1976-1982) he finds an inverse growth-age relationship.

We survey thereafter the studies dealing explicitly innovation/growth links at the firm level. A strand of the literature is inspired by the contribution of Mansfield's (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?". He first observes that the firms that carried out significant innovations grew more rapidly than the others; their average growth rate was more than the twice that the others. He noted that the estimated effect depended on the industry considered. He still argued that innovation has a greater impact on small firm's growth rate. This paper dealing with the "processes of firm formation, growth and decline" (according to the own words from Mansfield, 1962: 1043) sets up the very first empirical evolutionary approach of firm growth determinants. If many firms decline and exit, some shortly after entry, some others growth, innovate and build a capital of basic competencies (or capabilities) necessary to survive and go ahead. The idea of a positive links is confirmed by the works by Scherer (1965), Mowery (1983), Geroski and Machin (1992). These processes are at the core of evolutionary approach (Dosi, 2005; Nelson and Winter, 1982; Winter, 1984). Innovation is presumed good for growth and surviving but under conditions. Firms need to capture value from innovation (Teece, 1986) and in some sectors to implement further ways for improving their performance (economies of scale or scope for instance). In innovating a firm takes an advantage on its competitors. As a consequence the firm's market shares increase. It sets up the basic mechanism by which innovation is transformed into growth. Some authors argue there is a second way to produce growth with technological innovation (but as important as the first): the process of innovation tends to transform firm's core competences (Geroski et al., 1993; Lee, 2010). As a consequence the firm becomes more capable to innovate and/or to cope with the selection environment. In a sense we find here 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 empirical studies contributes to the debate on innovation and firms performances. A first example is the paper by Audretsch (1995) onto 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's surviving is lower than in industries for which innovation is less important. He indicates that entrants that survive have higher growth rates[4]. 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 of firm age and size. *Process innovation* in particular seems to have a distinctive effect on survival. Del Monte and Papagni (2001) with a sample of 500 firms, over the period 1989-1997 (drawn from the Mediocredito survey of Italian manufacturing) confirm the Gibrat's Law that firm size has a stochastic trend. But 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). Coad and Rao (2008) use a large sample of high-tech firms and find that growth may or may not relate to innovation activity (in fact patenting). 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 German firms use patents applications as for R&D activities. He performs a quantitative analysis evidencing that patent applications increase sales after a lag of 2 or 3 years along the type of patent system (national or European). This point tends to emphasize that the effects of invention on firm growth performance is not immediate but happen very soon once the invention has been implemented (it is important to note that a patent application does not mean invention is really already implemented). Corsino (2008) uses a new (and unique) type of data. He gathered information about new semiconductor devices commercialized during the period 1998-2004 by producers from around the world. His econometric analysis performed at corporate level, indicate that the most recent innovations affect significantly 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 recorded at corporate level. 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 could be pointed out. In general the studies give evidence in favor of a positive and significant relation between firm innovation and firm growth. This finding is consistent to the use of different proxies of innovation. As a consequence it is tempting to consider this finding as a stylized fact. Only few studies obtain

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

mitigated results as far as the relation innovation/growth is concerned[5]. Of course innovation is only one factor amongst others explanatory variables.

Yet some important issues are still open or neglected by the current literature:

1. Firstly, the issue of the type of innovation (product versus process innovation) is very poorly dealt with by the literature. Some studies note that new products have an impact (Roper, 1997); others take into account the two types (Mansfield, 1962). As a consequence it seems interesting to address correctly this topic by assessing the effect of each type of innovation in the same frame. From this point of view, the CIS can help us since they give a lot of information on the types of innovation (included for instance organizational innovations). The paper by Mohnen and Mairesse (2010) has recently demonstrated the richness of 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 originality of this paper is the use of additional and complementary indicator that are based on CIS. This enables us to test the robustness of the innovation effects on growth by changing the definition of innovation variables. For instance we can use as qualitative as quantitative variables.

3. One interesting finding is the importance of the industrial context. Innovation is very "industry context specific" (Dosi, 1988). As a consequence we always have to control for industry effects. But a very fascinating idea is delineated by Coad and Rao (2008) in their study when they note that innovation is more crucial for "rapid-growth" firms. In this perspective quantile regression becomes relevant if not essential (but of course it is one approach amongst several).

4. As some scholars have pointed out (in particular Geroski et al., 1997) the specification of the dependent variable is important and may be crucial. A lot of studies use indifferently an index of performance: value added rate of growth, sales growth, turn-over, and so on. It seems important to clarify this point in testing the sensitivity of the results to the definition of the growth variable.[6]

[5] For instance Bottazi et al. (2001) on worldwide firms of the drug sector does not find any relation between innovation and growth. The results of this study seem to be an exception that are may be due to the economic conditions of that sector having recently experienced a specific growth dynamic.

[6] Another difficult question that will not deal with here would deserve 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 in the short term or

It seems to us that these issues have not been adequately explored or documented in the literature dealing with the relation between innovation and firm growth, but are critical for correctly understanding how the relation works. The aim of the paper is to provide new materials for dealing with them.

2. CIS: dataset and variables

This empirical study focuses mainly on long term post-innovation growth performance of innovative firms that are differentiated in terms of their size and type of innovation; compared with non-innovative ones. The sample we use for the econometric analysis was constructed from two different sources; CIS and annual enterprise surveys[7] (hereafter, AES). By merging several waves of CIS and AES starting from the year 1992, we obtain an unbalanced panel of 1074 firms. The specific architecture of CIS requires some clarifications. As their different waves have not been conducted at regular intervals: (1) We do not cover the same sample of firms, (2) We get different survey with different measures of innovation. In this section we discuss how we dealt with these issues and provide a description of data sources and the information gathered from them.

2.1. Data sources

Our primary source of information is the CIS repeated over different years. The first three waves of CIS surveys, CIS2 (1994-1996), CIS3 (1998-2000) and CIS4 (2002-2004), have been conducted at regular intervals of four years. Since CIS4 (2002-2004) they are conducted every two years. The first part of surveys provides general information on companies, as their main activity codified in terms of manufacturing sectors industries or services (NACE Rev.1.1[8]), along with quantitative information as size and turnover. Then, the second parts of CIS are related to the introduction of product and process innovations, and give information on the different sources of innovation like co-operation and R&D.

Another fundamental source of data is the annual enterprise survey conducted since 1992. More precisely, AES is available for the period 1992-2000 and for the years 2002, 2004 and

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medium/long term? Geroski and Machin (1992) pointed out that the innovation effects on firm performance are realized vey soon after the firm innovates.

[7] They are conducted by Sessi, the Ministry of Agriculture (for IAA) and INSEE (the French public Institute of Statistics).

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

2005. This survey provides yearly information on the firm's balance sheet. In particular, it gathers information regarding the main firm economic indicators (employment, value added, investment, profitability, and so on).

In order to pool our final dataset we need to take into account that the different surveys provide diverse measures of innovation.

In all the CISs, a firm is considered as "innovative" if over a given period of time (the last three years) if it has introduced a new product or a new process. This information is gathered with set of (1) dichotomous variables that reveal whether the firm has produced or not an innovation during the period covered by the survey. Then, we also have (2) continuous variables that register the success rate of product and process innovations (firms are asked on the share in total sales of products and processes) that are continuous. (3) The last set of variables is dichotomous and continuous. They give information on the sources of information for innovations as co-operation and R&D investments.

In particular, 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. CIS3 and CIS4 also measure innovation with dummy and continuous variables but they distinguish innovations new to firm and innovations new to the market. They also provide the corresponding percentage of sales in the turnover for both types of innovations.

In order to prepare the dataset for the matching of the different waves, the information related to the innovation activities have been homogenised in CIS3 and CIS4 by reducing the diverse measures of innovation used to a unique dichotomous variable, taking value 1 if the firm has produced an innovation new to the market during the period covered by the survey. The merge among the diverse dataset has been realised by identifying each statistical unit by enterprise code (as the enterprise is the legal unit). This criteria of merging is weak, therefore, it generates a lot of dropouts from the sample when considering innovation activities.

Moreover, we need to consider that both surveys have not been conducted at regular intervals and that they do not cover the same sample of firms. To maintain time consistency and to keep only firms that are observed over the whole period, we decided to include information from CIS2 to CIS4 and from AES over the period 1992-2004. This strategy allows us to have three observations for the innovation-related variables reported in the CISs and also to calculate firms' growth rates without loosing observations. Our final panel comprises three time period as follows: t_1 going from 1994 to 1996, t_2 from 1998 to 2000 and t_3 from 2002 to 2004. Table 1 shows the structure of the dataset.

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	$Inno_3$	$Inno_2$

2.2. Variables

Similarly to previous works concerning firms' growth and innovation (Mansfield, 1962; Evans, 1987a, 1987b; Scherer *et al.*, 2000); to cite only a few among them) our study includes mainly industrial activities. Indeed, only two (CIS3 and CIS4) out of the three CIS we are using in this study include other sectors than industrial activities. As we kept only firms that are observed over the whole period our final dataset includes mainly industrial activities. Table 2 provides information on the whole data distribution by sector. Wood, paper and printing, chemicals and metals activities represent the majority of activities (about 12% each), while two other important sectors are machinery and electrical engineering (approximately 10% each).

Table 2. Total sample description: sample by branches by year

Branches	**Nace Rev 1.1**	**Sample**		
		Firms	**Obs**	**%**
Mining and quirying	10-14	9	27	0.84
Food and tobacco	15-16	0	0	0.00
Textiles	17-19	91	273	8.47
Wood/paper/printing	20-22	131	393	12.20
Chemicals	23-24	134	402	12.48
Plastic /Rubber	25	66	198	6.15
Glass/ceramics	26	61	183	5.68
Metals	27-28	136	408	12.66
Machinery	29	112	336	10.43
Electrical engineering	30-32	110	330	10.24
MPO instruments	33	42	126	3.91
Vehicles	34-35	96	288	8.94
Furniture/recycling	36-37	52	156	4.84
Energy	40-41	34	102	3.17
Total		**1074**	**3222**	**100**

All the other economic activities represented in our sample gather less than 10% observations. Table 3 shows the sample distribution by size at the beginning of the period under scrutiny. Our sample is mainly constituted by small firms with less than 50 employees and large firms with more than 250 employees (approximately 40% each); while medium sized firms represent only 20% of the sample.

Table 3. Total sample description: sample by size in 1996

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

2.2.1. Growth rates

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

We first define 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 the logarithm of firm turnover (deflated) at time t and $S_{i,t-1}$ its lagged value.

The second method is the compound average growth rate (CAGR), which takes into account that each of the time period covers more than one year:

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

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 around 20% for both the measures used but their standard deviation shows a great deal of variation is a lot larger 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 most basic information provided by CIS is a dichotomous variable that reveals whether the firm has produced or not an innovation during the period covered by the survey, and the type of innovation that was introduced (product or process). This set of variables reveals two different corporate strategies especially in manufacturing. While product innovations (Inop) are associated with more radical technologies and are expected to result in higher growth rates, because of the higher economic returns, process innovations are based on more defensive technological strategies (Inoc).Yet, the effects of product and process innovations are rather linked and lead the way of new types of products (Barras, 1990). We further constructed a set of dichotomous variables:

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

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

Inoc taking 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 percentage of innovative products and process share on the turnover (respectively Inoprod and Inoproc). However, while in general firms are able to quantify quite easily 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 decide to use only Inoprod and to drop Inoproc.

3. Methodology

We start our empirical analysis by testing whether innovative firms are different in growth rates from non-innovative ones. In order to do that we perform a two-sample mean comparison test. This test verifies the null hypothesis that the two groups of firms, innovating vs non-innovating ones, 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, in the comparison between the two groups 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[9].

Table 4. Mean comparison tests

	Group 0	*Group 1*		*Ha1*	*Ha2*
	Non-innovators	*Innovators*	t	p-value	p-value
Growth (mean)	0.012	0.065	-4.4504	0.000	0.000
CAGR (mean)	0.016	0.041	-3.9980	0.000	0.000
	Non-innovators	*Product innovators*			
Growth (mean)	0.029	0.066	-3.4143	0.001	0.000
CAGR (mean)	0.024	0.041	-3.0670	0.002	0.001
	Non-innovators	*Process innovators*			
Growth (mean)	0.029	0.065	-3.4034	0.001	0.000
CAGR (mean)	0.024	0.040	-2.9737	0.003	0.001

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

After we have tested that 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's growth poses some methodological issues in particular related to the distributional properties of firms' growth rates and their persistence over time. We discuss how we deal with these methodological issues in what follows.

In our empirical analysis we thus use a Gibrat-like model which includes firm size as an explanatory variable. The empirical literature uses two different specifications for testing the Gibrat's Law. As our aim is not to test the validity of the law but to verify the impact of

[9] The complex innovators (the firms that innovate in the product *and* in the process in the same time period) experiment a significant stronger growth rates than the simple innovators (the firms that innovate in the product *or* in the process in a single time period).

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 the Gibrat's Law:

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

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 and process innovation for firm *i* at time *t-1*. ω_j and ψ_t represent a set of industry 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 generalized 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 instruments variables in levels with lagged first-differenced terms. The authors demonstrated dramatic improvement in 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 the Gibrat's Law as follows:

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

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 firms' growth and innovation we estimate Equation (2) by means of quantile regressions. In the OLS and quantile regressions we also included 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). In order 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:

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

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.

Table 5. Summary statistics

Variable	*Obs.*	*Mean*	*Std. Dev.*	*Min*	*Max*
ln(Turn$_{i,,t}$)	3222	7.417175	1.756326	1.410513	14.49669
ln(Turn$_{i,t-1}$)	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

We start commenting on the results of estimations related to equation (1) that represents the Gibrat's law in its classical form (Table 6). Our results first confirm that small companies growth more than large ones as shown by the coefficient of Ln(Turn$_{i,t-1}$) that is found to be minor than 1 and significant at the 1%. Most importantly, the results confirm that innovation has a positive and significant impact on firms' 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 these kinds of innovation have a positive impact on firm growth. Finally, we test the sensitivity of the impact of product innovation on firm's growth to the definition of the innovation variable. The main result is that 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.

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(Turn$_{i,t-1}$)	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
R-squared/pseudo	.	.	.	.	.
Number of ID	1073	1070	1070	1072	600

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

Secondly, we perform robustness checks of our basic results by estimating equation (2) that allows to use alternative estimation techniques. In Tables 7 to 10 we provide the results of estimations that use diverse proxies for firm innovation and alternative measures of firms growth rates (log differences and CAGR). In Table 7 the innovation variable is *ino*. Our results first confirm that small companies grow more than large ones as shown by the negative and significant coefficient of Ln(Turn$_{i,t-1}$). Most important, innovation has a positive and significant impact on firms' rate of growth in all the estimation. This result is thus robust to the use of alternative estimators. By looking at the results of quantile regressions we find further evidence. In particular, innovation has a higher impact for high growing companies. The coefficient on the innovation variable is higher at the 75th percentile than in the other quantiles. This means that, when we consider the high-growth firms, innovative activity makes an important contribution to their superior growth performance.

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(Turn$_{i,t-1}$)	-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	.	0.0296	0.0422	0.0664	.	.	.
Number of ID			1070	1070	1070	1070						

Ino $_{i,t-1}$ is a dummy variable taking 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.

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 firm's growth to the definition of the innovation variable, we find that the results are less robust when we use the quantitative variable.

Table 8. Estimates of the 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(Turn$_{i,t-1}$)	-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		0.0290	0.0445	0.0668			
Number of ID			1070		1070							

Inop $_{i,t-1}$ is a dummy variable taking 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 the 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(Turn$_{i,t-1}$)	-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	.	.				.	.	.
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 the 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		
RIABLES							q25	q50	q75	q25	q50	q7
urn$_{i,t-1}$)	-	-	-	-	-	-	-0.00659*	-	-	-	-	-
	0.0203***	0.0119***	0.430***	0.265***	0.0276***	0.0185***		0.00825***	0.0148***	0.00313**	0.00442***	0.0077
	(0.00365)	(0.00218)	(0.0203)	(0.0116)	(0.00428)	(0.00271)	(0.00375)	(0.00195)	(0.00297)	(0.00144)	(0.00106)	(0.002
$_{i,t-1}$	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)	(0.004
stant	0.203***	0.120***	3.684***	2.266***	0.140*	0.0973**	-0.0921	0.0615	0.164	-0.0455	0.0325**	0.084
	(0.0637)	(0.0382)	(0.169)	(0.0967)	(0.0738)	(0.0471)	(0.0935)	(0.0631)	(0.109)	(0.0493)	(0.0140)	(0.04
ndustry	yes	yes	no	no	yes	yes	yes	yes	yes	yes	yes	yes
ear	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
ervations	2374	2374	2374	2374	2374	2374	2374	2374	2374	2374	2374	237
	0.072	0.065	0.328	0.347	0.126	.	0.0297	0.0414	0.0645	.	.	.
red/pseudo												
ber of ID			1072	1072	1072	1072						

Where Inoc is a dummy variable taking 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

Moreover, we perform further robustness checks of our basic results in Table 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.

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	GMM-SYS		GMM-SYS		GMM-SYS		GMM-SYS		GMM-SYS	
	Growth	CAGR	Growth	CAGR	Growth	CAGR	Growth	CAGR	Growth	CAGR
lag_growth	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)
lag_TURN	-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			0.0438***	0.0240***						
			(0.0122)	(0.00720)						
Inop					0.0399***	0.0196***				
					(0.0115)	(0.00668)				
Inoc							0.0444***	0.0241***		
							(0.0113)	(0.00653)		
lnINNOPROD									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
R-squared	.		.		.		.		.	
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

Summing up, the effect of innovation on firm growth seems to be robust to the specification of the innovation variable, the measure of growth rates and the type of estimation model.

5. Conclusion

Our empirical study based on CIS data enables us to complement usefully the literature on firm growth and to answer the four questions noted in section 2.

First of all innovative firms (whatever the type of innovation) produce more growth than non innovative firms as shown by mean comparison tests. As far as the issue of the type of innovation (product versus process innovation) is concerned the firms introducing process innovation have on average the same rate of growth of the product innovators (0.065 versus 0.066). The empirical analysis confirmed this evidence. Our estimates (with control variables) show that the results are robust to the different types of models implemented. Process innovators are more productive in terms of growth than product innovators (in others terms the coefficient related to process innovation is higher in the growth equation) when OLS and Random effects models are used. The reverse is true for Fixed effect model and quantile regression. In the three growth equations estimated by GMM the coefficients related to product innovation is always higher. To some extent our study does not give very definitive results with respect to the magnitude of the effects of the type of innovation on firm growth. Indeed while the coefficients for product and process innovation are quite similar we do not find strong evidence in favor of one type of innovation with respect to the other. It might be due to the fact that the two types of innovation seem complementary. The use of CIS present advantages: we can use quantitative variables at least for product innovation. Yet results of the regressions including the quantitative variables seems less robust to the use of alternatives estimation techniques. In lines with recent pieces of literature (see for instance Coad and Rao, 2008) quantile regression turns out to be relevant. Our computations indicate that for the firms having the highest growth rates the effects of innovation on their growth is stronger. This is particularly true in the case of product innovation.

In this paper we conduct for the first time in the field of innovation quantitative studies an analysis of the determinants of firm growth with two indicators for firm growth. Our study shows that the results that we obtained are definitively robust to the dependent variable measurement method.

The basic message for policy makers is that devoted more resources for 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 incentives devices for innovation are those that foster *R&D investments* (for instance, in many countries, taxes credit), by 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, innovation stands as an output. An interesting point for policy makers would be to analyze if their tool is effective. With respect to this objective we could add new variables in our panel model, for instance if the firms receive (or not) taxes credit, and check if the firms that receive public support know a higher growth. So in this frame it becomes possible to provide a better assessment of public technological support.

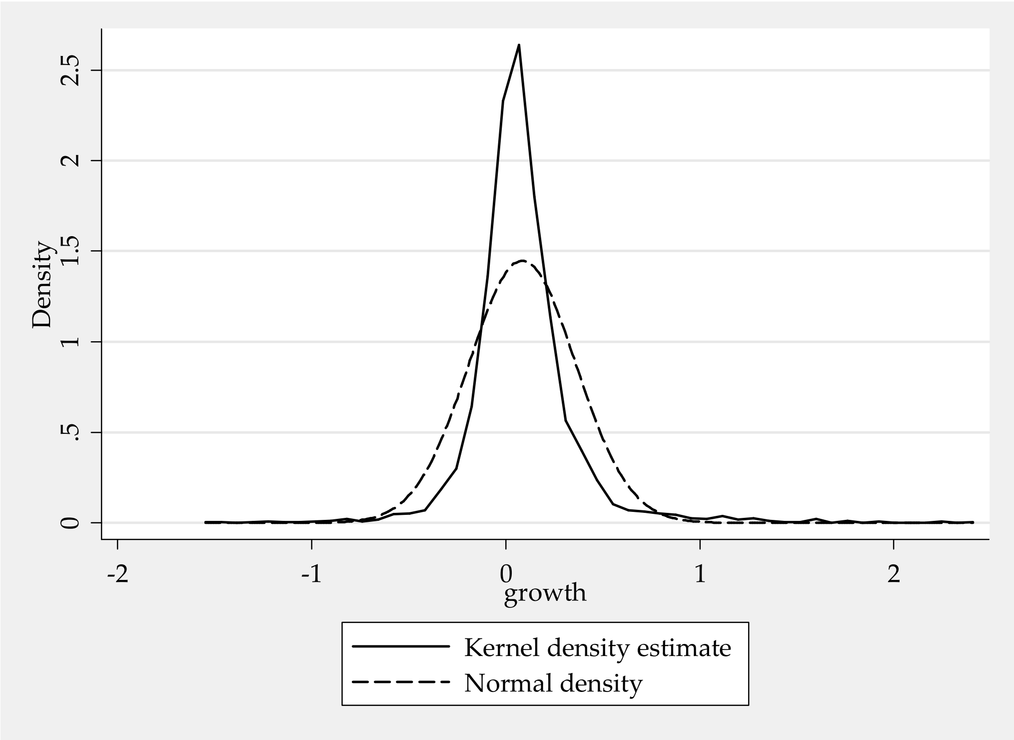
While the current study give new insights concerning the impact of innovation on firm performances in terms of growth, an interesting issue to be addressed in a future research is related with the persistence of innovation. Indeed one aspect that was not dealt with in the current study is that some firms innovate persistently and others do not. We have longitudinal data enable us to look at if the firms that persistently innovate produce more growth than sporadic innovators.

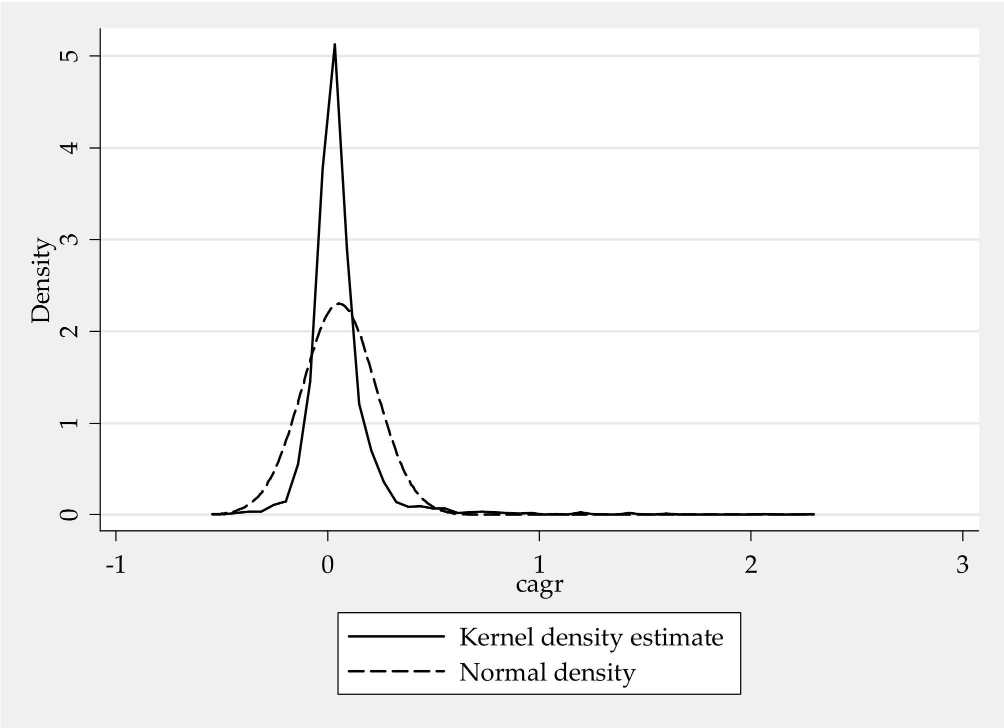
Appendix.

Table 0. Empirical studies on the relation between Firm Growth and Innovation

Study	**Country and time period**	**Kinds of data**	**Measure for Firm Growth**	**Measure for innovation activity**	**Main results**
Mansfield (1962)	USA, 1916-1954, Two industries	Individual data	Relative size variation	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, 1976-1982	Panels of 721firms	Number of innovations produced by each innovating	Growth rate	The number of innovations (number of patents) has no impact on corporate growth
Ernst (2001)	Germany	Panel of firms	Sales	Patent applications (German and European patent system)	Patents increase sales with a 2 or 3 years lag
Del Monte and Papagni (2003)	Italy, 1989-1997	Panel of 500 firms	Growth rate	Research Intensity	Correlation between Growth rate and Research Intensity
Cefis and Marsili (2005)	Netherland	Manufacturing Firms		Innovation	The innovating firms extend their life in the industry
Coad and Rao (2008)	Large sample (world) of high-tech firms	Sample of firms	Growth rate	Patent activity	Innovation more crucial for the growth of “rapid-growth firms"
Corsino (2008)	Worldwide firms from semiconductors 1998-2004	Unique and original data set on new semiconductor devices	Growth rate of sales turn over	Innovations counts	Product innovations affect firm growth
Cassia et al. *(2009)*	U-K	Study on entrepreneurial firms	Growth	Universities Knowledge Inputs and Outputs	Effects on firms growth

Figure 1. Growth rates distribution





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