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Firm Growth and Persistence of Chance: Evidence from Portuguese Microdata

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Abstract

Considering a dynamic firm growth model with serial correlation this work studies the effects of R&D activities and investment, both physical and R&D, on the growth of firms. The main hypotheses maintain that firms with a strong commitment to R&D have higher rate of growth and investment has a positive effect on firm growth. We investigate such relations with reference to an unbalanced panel data set of Portuguese manufacturing firms over the period 1990 to 2001. We find that a systematic tendency for smaller firms to grow more quickly is the main reason why firm growth is not entirely stochastic.

JEL classification: L11, L13, C23.

Key words: Firm growth, R&D, GMM system estimator.

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1. Introduction

It is well known that if the growth rate of each firm in an industry is unrelated to its current size (or equally, if logarithmic firm sizes are subject to a series of random shocks) the outcome is a skewed firm size distribution, which tends to become increasingly concentrated over time. Gibrat (1931) first examined the implications of a stochastic multiplicative growth process of this kind. Gibrat's law of proportionate growth has been the focus of several empirical studies over quite a few decades. According to this law, the growth rate of a firm is independent of its current size and its past growth history. Although some earlier findings lend support to Gibrat's law (e. g. Hart and Prais, 1956; Simon and Bonini, 1958) the most common finding in recent studies seems to be that the growth rates of new and small firms are negatively related to their initial size. Thus, Gibrat's law fails to hold, at least for small firms (Dunne and Hughes, 1994; Mata, 1994; Hart and Oulton, 1996; Audretsch, Klomp and Thurik, 1999; Audretsch, Santarelli and Vivarelli, 1999; Almus and Nerlinger, 2000; Goddard et al, 2002). One limitation of most of these studies is that they only look at the relation between firm growth and the initial firm size, thereby ignoring the possible effect that past growth history or serial correlation could have on the firm growth. According to the evolutionary approach to firms' growth there is an implication of some serial correlation in growth. This finding contrasts with Gibrat's stochastic model, which assumes that the proportionate growth of firms is independent of previous periods.

The main contribution of this paper is to shed some light on industrial dynamics in Portugal. We take into account the role of persistence of chance in the growth process. This important point has been discussed by previous researchers, but the full size distribution, including the smallest firms has been neglected. The relationship between firm growth, initial firm size and growth persistence has not yet been analysed by means of micro-level data sets, dynamic panel data models and advanced econometric methods (GMM-system estimator). To analyse the differences between the growth patterns of small and medium and large firms we did a breakdown of size. In addition, because the high-tech sector has an above-average growth potential, a sub-sample of high-tech firms is also considered. Finally, because firm growth is not quite stochastic or random we consider some systematic factors, such as R&D intensity and investment, both physical and R&D, which could have some influence on firms' growth.

The paper unfolds as follows. Section 2 reviews the stochastic and evolutionary literature on the growth of firms. Section 3 presents an empirical growth model that incorporates serial correlation and some systematic factors which may have some influence on firms' growth, whilst Section 4 describes our sample and presents some descriptive statistics. Section 5 comments on the results, and Section 6 draws come conclusions.

2. Stochastic and evolutionary growth theory

In the context of stochastic growth theory, the growth rate of firms is stochastic in nature and unpredictable; it cannot be explained by other variables (Gibrat's Law). It has three main propositions: (i) that firms of different size classes have the same average proportionate growth; (ii) that the dispersion of growth rates about the common mean is the same for all size classes; and (iii) that there is no serial correlation in growth rates.

Gibrat's law suggests that even in the absence of efficiency advantages, market power and regulatory anomalies, industries may tend to become more concentrated because of random influences. These random influences may include managerial talent, innovation, changes in demand or taste, organizational structure, and of course, luck. According to this law, growth is unrelated to firm size, and large and small firms therefore have equal probabilities of attaining a particular growth rate within any given period. Over time, however, some firms will be lucky and tend to enjoy an above average share of high growth rates, while others are unlucky and tend to remain the same size or decline. Concentration can therefore be expected to increase naturally over time, with the eventual result being a skewed firm size distribution. From this viewpoint, Gibrat's law represents a challenge for applied economists. Indeed, applied economists are usually unwilling to renounce attempts at analysing an economic phenomenon of great relevance, such as the growth of firms.

Stochastic growth also underpins the model of the evolution of industry proposed by Jovanovic (1982). Jovanovic (1982) develops special cases of his model of firm learning in which Gibrat's law holds at least for mature firms or for firms that entered the industry at the same time. In his model each firm's cost curve is subjected to randomly distributed, firm-specific shocks. Over time a firm learns about the effects of these shocks on its efficiency. Firms experiencing favourable shocks grow and survive.

Others do not grow and may decline, and even leave the industry. His model also results in small firms having higher, but more variable, growth rates and higher failure rates than large firms. If his theoretical model is a true reflection of the evolution of firms, then empirical studies which omit firms' deaths are likely to overestimate the growth rates of small firms relative to large firms. Jovanovic's model has a particularly rich set of testable predictions concerning the life cycle patterns of growth. The most general version of his model predicts that firm growth decreases with firm age, keeping firm size constant. Under certain assumptions concerning technology and the distribution of ability his theory implies that firm growth is independent of firm size for mature firms or for firms in the same age cohort[1].

Sutton (1997) develops a new model of stochastic firm growth, and surveys the literature since Gibrat (1931). His discussion relates to the industry level in manufacturing, rather than to the aggregate level of all firms, and is in the context of economic theories of market behaviour, including the game-theory literature. Nevertheless, his new model of the stochastic growth of firms can be related to the aggregate of all firms. After all, many firms are multi-product and overlap many industries. His new model uses two conditions: first, the probability that the next market opportunity is filled by any currently active firm is a non-decreasing function of the size of that firm, and second, the probability that this opportunity is taken up by a new entrant is constant over time. His inclusion of firm births thus makes his model more general than that of Gibrat. His survey of firm "turbulence" relates to the entrance and exit of firms from the firm population and must be distinguished from the size mobility of firms, which relates to movements of surviving firms up and down the size distribution. The emphasis on stochastic growth by Jovanovic (1982) and Sutton (1997) is consistent with Hart and Oulton (1996) and the generation of skew size distributions of firms as the result of multiplicative stochastic shocks.

The evolutionary approach to firms' growth implies that there is some serial correlation in growth: "success breeds success and failure breeds failure". This approach suggests that the growth of successful firms should persist over time: there should be positive serial correlation of growth between consecutive periods, and those older companies should have faster average growth than younger companies (Hart, 2000).

[1] The first implication holds if technology is Cobb-Douglas with decreasing returns to scale. The second implication holds if the distribution of ability in the population is lognormal.

According to Verspagen (2004), those nations (regions or agents) that are growing rapidly accumulate experience and hence learn faster than others. This leads to a better competitive position for those already ahead and enables them to move further ahead. Hence, the crucial tendency here is one of divergence, in which some nations (regions or agents) are able to grow rapidly while others are left behind. This idea contrasts with purely stochastic models of growth, such as Gibrat's (1931) law of proportionate effect, which postulate that the proportionate growth of surviving firms is random and hence independent of previous success.

Nelson and Winter (1982) propose a formal evolutionary model of the growth of firms. The agents or decision makers operate under a scheme of bounded rationality, in which relatively simple and occasionally adaptive behavioural rules (rules of thumb or routines) are used to make decisions. These are not fixed, but can be changed over time, especially so under the influence of feedback from economic performance. Thus, instead of optimising, agents tend to adapt to changes in the market environment using routines which are often specific to the firm. They stem from the skills and experience of the managers and workers in the firm and this "know-how" is passed on to new members of the firm. Thus successful routines which have produced growth in the past, are likely to continue to do so in the future. It is true that circumstances change, but successful firms have successful routines for changing previous methods to meet new market environments. Unlike Jovanovic (1982), Nelson and Winter's model predicts that firm growth initially increases but then decreases with firm size for mature firms. This prediction is based on simulation results of a model for firms 20 years old or older.

Following the evolutionary perspective pointed out by Audretsch (1995) one may assume that new firm start-ups, as well as larger incumbent firms, are likely to their various contributions to the dynamics of different industries. In this connection, a distinction can be drawn between an entrepreneurial regime, more favourable to innovative entry and unfavourable to established firms, and a routinised regime, characterised by opposite conditions. Accordingly, industry-specific characteristics, such as scale economies and the endowment of innovative capabilities, exert a significant impact on entry, exit and the likelihood of survival of new start-ups. For example, in manufacturing industries characterised by higher minimum efficient scale (MES) levels of output, smaller entrants face higher costs that are likely to push them out of the market within a short period after start-up, unless they are able to grow very fast. Conversely, smaller entrants might not be at a disadvantage in certain industries in the services sector, where the industry dynamics may well be different from that in manufacturing.

3. Models and testable hypotheses

Econometric specification of a model of the growth rate of firms is a fundamental step towards a test of our hypotheses. We refer to a general model such as that of Ijiri and Simon (1977). The growth equation for N firms and T time periods, where firms are indexed by *i* and time by *t*, can be formulated as

$$\frac{S_{it}}{S_{it-1}} = aS_{it-1}^{b-1}e_{it} \tag{1}$$

where S_{it} is the firm size for firm i at time t. This model shows that the growth of the firms can be ascribed to three effects. The first effect is a constant growth rate (of the market), a, which is common to all firms. The second effect is a systematic tendency for a firm's growth to be related to its initial size. The effect of initial size on growth is determined by the value of b. A value of b close to unity is taken as evidence that the law is in operation at the time of observation. If $b=1$ the firm size has no effect on firm growth. In other words, the law is satisfied if the log sizes for individual firms are non–stationary and is violated otherwise. For $b>1$ the firm growth is explosive, large firms grow faster than small ones, and vice versa for $b<1$. The latter is termed regression to the mean (mean regression): the tendency for a variate to return to the mean size of the population. The value of b has important implications for the development of market concentration if the distribution of firms is approximately lognormal. The existence of the mean regression $b<1$ is the only factor that counteracts the exploding variance of the random process. Finally, the third effect is a random growth term, e_{it}.

Taking natural logarithms and rewriting the equation above, the growth equation for N firms and T time periods, where firms are indexed by i and time by t, can be formulated as a simplest autoregressive AR(1) model as,

$$\Delta y_{i,t} = a_i + (b-1)y_{i,t-1} + d_t + m_{i,t}; \quad m_{it} = rm_{it-1} + e_{it} \quad i = 1, 2, \ldots, \mathrm{N} \quad t = 2, 3, \ldots, \mathrm{T} \tag{2}$$

where $y_{i,t-1}$ is the natural log of the firm size for firm i in period $t-1$, Δy_{it} is the firm growth rate measured by the difference between y_{it} and y_{it-1}, a_i and d_t are individual and time effects, respectively. The unobserved time-invariant firm specific effects, a_i, allow for heterogeneity across firms. The parameter b determines the relationship between size and growth whilst r captures persistence of chance or serial correlation in m_{it}, the disturbance term of the growth equation. To ascertain whether Gibrat's law is in operation both b and r must be estimated. Serial correlation in proportionate growth rates can be ascribed to persistence of chance factors which make a company grow abnormally fast or abnormally slowly. Chesher (1979) says that, when b is not equal to one, size encourages (or discourages) growth, and that, when there is serial correlation in growth rates, growth encourages (or discourages) growth. Thus, a positive r means that success breeds success. However, a negative r, where initial success leads to hubris is also quite possible (Hart and Oulton, 1998). However, Singh and Whittington (1975) emphasize that the degree of persistence of growth is likely to be greater over shorter time periods and it may disappear altogether if a time span of much more than 6 years is considered. Finally, e_{it}, is a random disturbance, assumed to be normal, independent and identically distributed (IID) with $E(e_{it}) = 0$ and $\mathrm{var}(e_{it}) = s_e^2 > 0$.

For the purposes of panel estimation, (2) can be re-written as follows:

$$\Delta y_{i,t} = a_i + (b-1)y_{i,t-1} + r\Delta y_{it-1} + d_t + h_{i,t}\,. \qquad (3)$$

The analysis of the relationship between growth and size consists of testing the null hypothesis of $H_0 : b - 1 = 0$, which states that the probability distribution of growth rates is the same for all classes of firm, that is, growth is unrelated to size, with the alternative that $H_1 : b - 1 < 0$, firm sizes are mean-reverting. Another factor, which has been tested, is persistence in growth rates[2]. Thus, because our model includes serial correlation in the error term, to test Gibrat's law we should also test the null hypothesis of no serial correlation ($H_0 : r = 0$) under the alternative that $H_1 : r \neq 0$. If $r = 0$ the growth rate of a firm is independent of its past growth history, that is, above or below average growth for any individual firm does not persist from one period to the next. In the evolutionary literature (Nelson and Winter, 1982) firms have "routines" embodied in persons and organizations; routines which are transferred from one period to another.

[2] See for example Singh and Whittington (1975), Chesher (1979), Kumar (1985), Wagner (1992), Dunne and Hughes (1994), Tschoegl (1996), Hart and Oulton (1998), Almus and Nerlinger (2000), Vander Vennet (2001), Goddard et al (2002) and Audretsch et al. (2004).

Thus successful routines which have been producing growth in the past are likely to continue to produce growth in the future. Hence, the evolutionary approach implies that there is some serial correlation in growth. This contrasts with Gibrat’s (1931) law of proportionate growth, which postulates that the proportionate growth of (surviving) firms is random, and accordingly independent of previous success. Empirically, authors like Geroski (2000) have proposed that firms do not display persistent differences in their growth performance. However, it should be pointed out that some empirical studies have shown weak signs of serial correlation in firm performance (Hart, 2000).

The relative importance of systematic and stochastic factors in the growth of companies may be indicated by the degree of serial correlation of growth (Hart, 2000). Systematic factors should be expected to produce persistent company growth and hence a high degree of serial correlation. Hart and Oulton (1998) found that between the two periods 1986–1989 and 1989–92, the serial correlation of growth was 0. 024, compared with 0. 046 between 1989–92 and 1992–95. There appears to be some serial correlation but it is very small. The implication is that stochastic factors are more important than systematic factors in determining company growth. Thus, he concludes that while firm growth is to a large extent stochastic or random there are some systematic factors, such as R&D intensity and investment, both physical and R&D. Hart (2000) states that while firm growth to a large extent is stochastic or random there are some systematic factors involved, such as capital investment and R&D. Thus to allow for these systematic factors we adapted Del Monte and Papagni (2003) and Hall (1987) growths specifications as follow:

$$\Delta y_{i,t} = a_i + (b-1) y_{i,t-1} + r \Delta y_{it-1} + c_1 \left(\frac{R\,\&\,D}{sales} \right)_{it-1} + c_2 \left(\frac{R\,\&\,D}{sales} \right)_{it-2} + d_t + h_{i,t} \quad (4)$$

$$\Delta y_{i,t} = a_i + (b-1) y_{i,t-1} + r \Delta y_{it-1} + q_1 \left(\frac{I_{it-1}}{K_{it-2}} \right) + q_2 \left(\frac{R\,\&\,D_{it-1}}{C_{it-2}} \right) + d_t + h_{i,t}\,. \quad (5)$$

With respect to specification (4) the presence and intensity of R&D, measured by the ratio between R&D expenditure over total sales, constitutes a structural factor which can explain the prospects of growth and can differentiate the firms. We expect that research intensity has a positive effect on the growth rate of firms. Many empirical studies have sought to ascertain the relationship between R&D and the performance of a firm. The works published on this topic can be divided into those which have investigated a relation between the research intensity and the growth of firms and those which have examined the relation between innovation and the growth of firms. Table A.1 in the appendix reports results achieved by various authors. It can be seen that a significant relation between research intensity and firm growth has not always been found. Finally, equation (5) makes it possible to relate the firm growth rates to the level of investment, both physical (I / K) and R&D ($R \& D / C$).

To estimate these dynamic regression models using panels containing many firms and a small number of time periods, we use a system GMM estimator developed by Blundell and Bond (1998). This estimator controls for the presence of unobserved firm-specific effects and for the endogeneity of the current-dated explanatory variables. The system GMM estimator uses equations in first-differences, from which the firm-specific effects are eliminated by the transformation, and for which endogenous variables lagged two or more periods will be valid instruments provided there is no serial correlation in the time-varying component of the error terms. This is tested by examining tests for serial correlation in the first-differenced residuals (see Arellano and Bond, 1991). These differenced equations are combined with equations in levels for which the instruments used must be orthogonal to the firm-specific effects. Obviously the level of the dependent variable must be correlated with the firm-specific effects, and we want to allow for the levels of all the explanatory variables to be potentially correlated with the firm-specific effects, so this rules out using the levels of any variables as instruments for the levels equations. However, Blundell and Bond (1998) show that in autoregressive-distributed lag models, the first-differences of the series can be uncorrelated with the firm-specific effects provided that the series have stationary means. We therefore experimented with lagged differences of the variables as instruments for the levels equations.

The precise instruments that we use are reported in the notes to the Tables below. Essentially we use lags of all the firm level variables in the model. Instrument validity was tested using a Sargan test of over-identifying restrictions. The system GMM estimators reported here generally produced more reasonable estimates of the autoregressive dynamics than the basic first-differenced estimators[3]. This is consistent with the analysis of Blundell and Bond (1998), who show that in autoregressive models

3 This was assessed by comparison with alternative estimators such as OLS levels, which are known to produce biased estimates of autoregressive parameters.

with persistent series, the first-differenced estimator can be subject to serious finite sample biases as a result of weak instruments, and that these biases can be greatly reduced by the inclusion of the levels equations in the system estimator. We report results for a two-step GMM estimator, with standard errors and test statistics that are asymptotically robust to general heteroskedasticity[4].

4. Data and variables

The database we use in this study was constructed by the Portuguese Central Bank. We selected an unbalanced panel of 1248 Portuguese firms with 5709 observations covering the years 1990 to 2001 in the manufacturing industry. Firms were selected according to the criterion of having positive R&D expenses in not less than three consecutive years during the period under consideration.

For the purpose of the present paper cleaning procedures have been followed. Firstly, we removed firms with unknown industry activity from the original sample. Secondly, we excluded observations with either missing or non-positive values for the variables used. The introduction of this restriction was unavoidable. Thirdly, for the empirical part of this paper the data is limited to surviving firms. Finally, given the requirements of the adopted econometric methodology we selected only firms with at least four consecutive periods.

With respect to the variables used, firm size can be measured in a number of ways, with employment, assets, value added and sales being some common measures. According to Heshmati (2001), the results may be sensitive to the definition of firm size. Firm size (*size*) is the natural logarithm of the number of employees. Employment is chosen as a unit of analysis in order to allow comparisons with previous studies, to avoid the effects of inflation and to draw policy conclusions from the employment perspective. Firm growth rate (*growth*) is computed by the difference between $ln(SIZE_{it})$-$ln(SIZE_{it-1})$. R&D intensity (*R&D/SALES*) is the ratio between R&D expenditure and sales. Investment (*I*) is an addition to plant, property and equipment. Capital stock (*K*) is obtained by applying the perpetual inventory procedure described

[4] Although a more efficient two-step GMM estimator is available, the asymptotic standard errors for the two-step estimator can be an unreliable guide for inference in finite samples. The system GMM estimates that we report are computed using DPD for OX (see Doornik, Arellano, and Bond, 2002).

by Bond *et. al.* (1999: 43). Finally, to calculate knowledge capital (*C*) we adopt the "steady state" approximation, as described by Bond *et. al.* (1999: 19) to compute the R&D capital stock.

Table 1 reports means, standard errors and inter-quartile ranges of the most important variables. The firm's mean, median and percentile 75 for employment are less than 250 employees, confirming the relevance of small and medium firms in our sample. According to standard error values R&D is more volatile than physical investment.

Table 1: Summary statistics for the whole sample

Variables	Mean	Std. dev.	Median	Perc. 25th	Perc. 75th
EMPLOY	135.3	216.3	68	33	149
GROWTH RATE	0.022	0.174	0	-0.036	0.075
R&D	229059.6	784117.1	34527	8170	121826
I	1041236	5948618	239829.5	62525	754671
K	4.46e+07	1.72e+08	1.19e+07	4123066	3.43e+07
C	87870.21	299284.3	13263.78	3023.022	48251.07
$R\&D/SALES$	0.0272	0.0657	0.0097	0.0029	0.0278
I/K	0.0474	0.0907	0.0085	0.0535	0.0224
$R\&D/C$	12.614	263.598	3.145	2.718	4.170

5. Empirical results

In the presence of dynamic models the pooled OLS estimator (Tables A.2, A.3 and A.4) is biased upwards and inconsistent. To correct some of the problems in estimating such a relationship we have used the Generalized Method of Moments (GMM) system estimator developed by Blundell and Bond (1998). The results of estimating dynamic growth specifications with serial correlation (equations (4) and (5)) by GMM-SYS estimator for an unbalanced panel of Portuguese manufacturing firms for the period 1990-2001 are reported in Tables 2, 3 and 4.

Table 2 reports GMM-SYS estimates of the parameters of the growth specification with persistence of chance for the whole sample. As we can see, the coefficient of firm size is always negative and significant, which means that small firms grow faster than larger firms. In the tests for persistence of growth r is always positive but non-significant. An interesting question is how the observed serial correlation measured by r can be interpreted. In theory, consistently positive serially correlated growth would imply advantages acquired over time carry over to the next periods. There is consistent evidence with positive serial correlation; those firms with above average growth in one period tend to experience above average growth in the next. However, because the serial correlation is low the success is not prolonged. Most studies of other industrial and financial sectors have found there is no persistence of growth (Acs and Audretsch, 1990; Dunne and Hughes, 1994), or no positive persistence (Chesher, 1979; Kumar, 1985; Wagner, 1992; Tschoegl, 1996). A smaller number of researchers have found evidence of negative persistence of growth (Contini and Revelli, 1989; Almus and Nerlinger, 2000; Goddard et al. 2002). However, to ascertain whether Gibrat's law is in operation both b and r must be rejected. According to the Wald joint significance test, column 1, the null hypothesis that both b and r are equal to zero is rejected at 1% level, which means that Gibrat's law does not hold. The R&D intensity coefficient presents with only 1 and 2 lags because a contemporaneous relation with the growth rate of the firms cannot be easily justified. Research intensity has a positive but small and non-significant effect on firm growth. This means that it does not have an immediate effect on firm growth. Besides, the small and non-significance of coefficient R&D intensity confirms that the Portuguese manufacturing firms have low R&D expenditure. Lastly, the results reported in column (3) confirm that both physical and R&D investment have a positive effect on growth. Unlike Hall's findings (1987), physical investment is a more important predictor of growth than R&D investment. This may be explained because R&D expenditure is not a major factor in the Portuguese economy. The physical investment coefficient is significant at 1% level. For each regression, we report the p-value of the Wald test of joint significance of the regressors.The joint insignificance of the coefficients included in the regression is clearly rejected by the Wald test for the whole sample.

Table 2: GMM-sys results for whole sample

	(1)	(2)	(3)
$size_{it-1}$	-0.0419** (0.019)	-0.0105*** (0.0037)	-0.0487* (0.0257)
$growth_{it-1}$	0.0116 (0.0397)	0.0564 (0.1339)	0.0401 (0.0453)
$(R\&D/sales)_{it-1}$	–	0.0064 (0.0039)	–
$(R\&D/sales)_{it-2}$	–	0.004 (0.0037)	–
I_{it-1}/K_{it-2}	–	–	0.0244*** (0.008)
$R\&D_{it-1}/C_{it-2}$	–	–	0.002 (0.0036)
Constant	0.1432 (0.0885)	0.0228 (0.113)	0.2718* (0.1542)
w_{JS}	16.42 [0.000]	17.09 [0.002]	18.23 [0.001]
Sargan	14.90 [0.602]	35.04 [0.514]	35.24 [0.943]
m_2	0.7876 [0.431]	-1.561 [0.119]	0.2310 [0.817]
Instrument matrix	$size_{it-2}$ $\Delta size_{it-1}$	$size_{it-2}$ $(R\&D/sales)_{it-1}$ $\Delta size_{it-1}$ $\Delta(R\&D/sales)_{it}$	$size_{it-2}$ $(I/K)_{it-1}$ $(R\&D/C)_{it-1}$ $\Delta size_{it-1}$ $\Delta((I/K)_{it}$ $\Delta(R\&D/C)_{it}$

Notes: Asymptotic standard errors robust to general cross-section and time-series heteroskedasticity are reported in parenthesis. W_{JS} is the Wald statistic of joint significance of the independent variables (excluding time dummies and the constant term). Sargan is a test of the overidentifying restrictions, asymptotically distributed as c^2 under the null hypothesis of instrument validity. m_2 is a tests for second-order serial correlation in the first differenced residual, asymptotically distributed as N(0, 1) under the nullity of no serial correlation. The *p*-value of Sargan's test for overidentifying restrictions and m_2 test are reported in square brackets. The underlying sample consists of 1248 manufacturing firms with a total of 4276 observations.

Because the growth process of small companies is quite different from large companies they merit separate treatment (Penrose, 1980). Table 3 reports the GMM-SYS results when we split our sample by size. We partitioned the sample according to the exogenous criterion of size. Using the European Union convention, firms with less than 50 employees were considered micro and small firms and the others medium and large enterprises. In columns (1) and (4), according to the Wald joint test, we find that Gibrat's law is rejected for a sub-sample of micro and small firms at 5% level, whilst it is accepted for medium and large firms. With respect to research intensity, we again get a positive but non-significant coefficient. However, this coefficient is slightly higher for smaller firms. Lastly, the physical investment coefficient is higher for smaller firms than larger firms and is always significant. This confirms that physical investment plays a different role in the growth of smaller and larger firms. If we consider the R&D investment, the estimated coefficient is equal and non-significant for smaller and larger firms. However, if we compare physical with R&D investment we observe that smaller firms "prefer" physical investment.

Table 3: GMM-sys results split sample by firm size

	Micro and small firms ($<$ 50 employees)			**Medium and large firms ($\geq$ 50 employees)**		
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$size_{it-1}$	-0.0595*** (0.0223)	-0.0328*** (0.0158)	-0.0515** (0.019)	-0.007 (0.0265)	-0.0203 (0.0322)	-0.0069 (0.0424)
$growth_{it-1}$	0.024 (0.0485)	0.0281 (0.0428)	0.0254 (0.0406)	0.0161 (0.0794)	0.0154 (0.0492)	0.0199 (0.0562)
$(R\&D/sales)_{it-1}$	–	0.016 (0.0085)	–	–	0.0043 (0.0273)	–
$(R\&D/sales)_{it-2}$	–	0.013 (0.007)	–	–	0.0014 (0.0293)	–
I_{it-1}/K_{it-2}	–	–	0.0241** (0.0119)	–	–	0.019** (0.01)
$R\&D_{it-1}/C_{it-2}$	–	–	0.006 (0.0068)	–	–	0.006 (0.0045)
Constant	0.1706 (0.2721)	-0.0072 (0.1554)	0.0999 (0.2281)	-0.0868 (0.1343)	0.0377 (0.1524)	0.3963* (0.2381)
w_{JS}	6.936 [0.031]	8.564 [0.004]	13.632 [0.000]	0.6207 [0.733]	1.687 [0.793]	8.120 [0.087]
Sargan	15.23 [0.579]	34.19 [0.555]	32.96 [0.568]	23.01 [0.149]	39.73 [0.230]	30.47 [0.987]
m_2	0.6697 [0.503]	-1.479 [0.139]	-1.140 [0.254]	0.3404 [0.734]	-0.8727 [0.383]	0.03592 [0.971]
Instrument matrix	$size_{it-2}$ $\Delta size_{it-1}$	$size_{it-2}$ $(R\&D/sales)_{it-1}$ $\Delta size_{it-1}$ $\Delta(R\&D/sales)_{it}$	$size_{it-2}$ $(I/K)_{it-1}$ $(R\&D/C)_{it-1}$ $\Delta size_{it-1}$ $\Delta((I/K)_{it}$ $\Delta(R\&D/C)_{it}$	$size_{it-2}$ $\Delta size_{it-1}$	$size_{it-2}$ $(R\&D/sales)_{it-1}$ $\Delta size_{it-1}$ $\Delta(R\&D/sales)_{it}$	$size_{it-2}$ $(I/K)_{it-1}$ $(R\&D/C)_{it-1}$ $\Delta size_{it-1}$ $\Delta((I/K)_{it}$ $\Delta(R\&D/C)_{it}$

Notes: as in Table 2. The underlying sample of micro and small firms consists of 561 firms with a total of 1747 observations. The sample of medium and large firms consists of 687 firms with a total of 2529.

Table 4 reports the results for a sample of high-tech firms. High-tech firms include Chemical Products, Machine Products, Office Equipment and Computers, Electrical Machinery, Radio, TV and TLC Equipments, Medical Equipment, Measuring Instruments, Motor Vehicles and Other Transport Equipment. The departures from Gibrat's law are more evident for a sub-sample of high-tech firms which is generally characterised by a fast-growth path. The null hypothesis that b and r are equal to zero is rejected by the Wald joint test, at 1% level. Furthermore, these firms have a positive and higher research intensity coefficient but it still remains non-significant. The estimated coefficient for physical investment is positive and significant at 1% level. In respect to R&D investment, this estimated coefficient is also positive and is now significant, but only at 10% level. It is important to note that these coefficients are higher for high-tech firms. Nevertheless, physical investment continues to play a more important role in the growth of the high-tech firms than R&D investment.

Arellano and Bond (1991) consider specification tests that are applicable after estimating a dynamic model from panel data by the GMM estimators: a direct test on the second-order residual serial correlation coefficient (m_2) and a Sargan test of over-identifying restrictions. In this context the key identifying assumption that there is no serial correlation in the e_{it} disturbances can be tested by testing for no second-order serial correlation in the first-differenced residuals. The consistency of the GMM estimator depends on the absence of second-order serial correlation in the residuals of the growth specifications. Another test of specification is a Sargan test of over-identifying restrictions, which has an asymptotic c^2 distribution under the null hypothesis that these moment conditions are valid. Thus, the validity of the dynamic models depends on a lack of second-order serial correlation (see the m_2 statistics) and the validity of the instrument set measured by the Sargan test. The Sargan and m_2 tests are always accepted, which confirms the validity of the instruments chosen and the consistency of the results obtained.

Table 4: GMM-sys results for high-tech firms

	(1)	(2)	(3)
$size_{it-1}$	-0.0442*** (0.0162)	-0.0457*** (0.0184)	-0.0446*** (0.0141)
$growth_{it-1}$	0.027 (0.0364)	0.0332 (0.027)	0.034 (0.021)
$(R\&D/sales)_{it-1}$	–	0.0312 (0.0345)	–
$(R\&D/sales)_{it-2}$	–	0.0271 (0.0346)	–
I_{it-1}/K_{it-2}	–	–	0.0352*** (0.0145)
$R\&D_{it-1}/C_{it-2}$	–	–	0.0147 (0.0088)
Constant	-0.0162 (0.1791)	0.0061 (0.1365)	0.1694 (0.1417)
w_{JS}	15.64 [0.000]	13.52 [0.000]	19.73 [0.001]
Sargan	13.49 [0.637]	23.72 [0.785]	40.31 [0.671]
m_2	-0.3107 [0.756]	-0.2886 [0.773]	1.178 [0.239]
Instrument matrix	$size_{it-2}$ $\Delta size_{it-1}$	$size_{it-2}$ $(R\&D/sales)_{it-1}$ $\Delta size_{it-1}$ $\Delta(R\&D/sales)_{it}$	$size_{it-2}$ $(I/K)_{it-1}$ $(R\&D/C)_{it-1}$ $\Delta size_{it-1}$ $\Delta((I/K)_{it}$ $\Delta(R\&D/C)_{it}$

Notes: as in Table 2. The underlying sample of high-tech firms consists of 117 firms with a total of 350 observations.

6. Conclusions

In this paper we have taken into account the role of persistence of chance in the growth process. On the other hand, because firm growth is not quite random we consider systematic factors, such as R&D intensity and both physical and R&D investment, which could have some influence on firms' growth. The relative importance of systematic and stochastic factors on the growth of firms may be indicated by the degree of serial correlation of growth. These dynamic growth specifications were estimated by applying dynamic panel data techniques (GMM-SYS estimator).

Our empirical evidence, obtained from an unbalanced panel of 1248 Portuguese manufacturing (surviving) firms, covering a complete size distribution, for the period 1990 to 2001, provides some support for the notion that log firm sizes are mean-reverting. Smaller firms have been growing more quickly than larger firms, thus generating proportionally more jobs, and there is some positive but non-significant persistence in firm growth over the period examined, so success does not persist. The balance of evidence seems to suggest that Gibrat's law should be rejected for Portuguese firms over the period in question. If we consider a size breakdown and a sample of high-tech firms we find that the departures from Gibrat's law are higher for smaller and high-tech firms.

When we consider some systematic factors that may explain the firm growth, the results obtained support the existence of a positive relation between R&D intensity and the growth rate of the firms. Physical and R&D investment have a positive effect on the growth of the firms. However, physical investment is a more important predictor of growth than R&D investment. For smaller and high-tech firms this finding is even more noticeable. The investment in physical capital is more relevant for smaller than larger firms. In addition, we may also find that stochastic factors are more important than systematic factors in determining company growth.

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Appendix

Table A. 1: Econometric studies of the effects of innovation on firm growth

Study	Country	Innovation variable	Sales growth rate	Employment growth rate	Financial variables
Scherer (1965)	US	Patents	+		+
Nolan et al. (1980)	UK	R&D/sales	+	+	
Thwaites (1982)	UK	Product innovations		+	
Hall (1987)	US	R&D/employ		+	+
Singh (1994)	India	R&D/sales	+		
Geroski (1995)	UK	Patents	Unrelated	Unrelated	
Leo and Steiner (1995)	Austria	Patents		Unrelated	
Cosh et al. (1996)	UK	Patents		Unrelated	
Geroski et al (1997)	UK	Patents	Unrelated		Unrelated
Tether and Massini (1998)	UK	Propensity to innovations		+	
Ernest (2001)	Germany	Patents	+		
Del Monte and Papagni (2003)	Italy	R&D/sales	+		

Table A. 2: Pooled OLS results for whole sample

	(1)	(2)	(3)
$size_{it-1}$	-0.0106*** (0.0024)	-0.0077*** (0.0029)	-0.0109** (0.0044)
$growth_{it-1}$	-0.0262 (0.0501)	-0.0332 (0.0584)	0.0114 (0.0541)
$(R\&D/sales)_{it-1}$	–	0.0064 (0.0039)	–
$(R\&D/sales)_{it-2}$	–	0.004 (0.0037)	–
I_{it-1}/K_{it-2}	–	–	0.017*** (0.0043)
$R\&D_{it-1}/C_{it-2}$	–	–	0.0019 (0.0023)
Constant	0.0007 (0.0191)	-0.034 (0.0249)	0.0702 (0.0526)
w_{JS}	20.07 [0.000]	13.71 [0.008]	22.95 [0.000]
m_2	1.601 [0.109]	1.237 [0.216]	0.5385 [0.590]

Table A. 3: Pooled OLS results whole sample split by firm size

	Micro and small firms (< 50 employees)			Medium and large firms (≥ 50 employees)		
	(1)	**(2)**	**(3)**	**(5)**	**(6)**	**(7)**
$size_{it-1}$	-0.014*** (0.0081)	-0.0044 (0.0118)	-0.0301** (0.0144)	-0.0048 (0.0031)	-0.0057* (0.0034)	-0.0071 (0.0046)
$growth_{it-1}$	-0.0725 (0.0811)	-0.0892 (0.096)	0.0229 (0.1048)	0.0284 (0.0361)	0.0263 (0.0432)	0.0111 (0.0587)
$(R\&D/sales)_{it-1}$	–	0.0153* (0.0086)	–	–	0.0018 (0.0037)	–
$(R\&D/sales)_{it-2}$	–	0.0122 (0.0079)	–	–	0.0006 (0.0036)	–
I_{it-1}/K_{it-2}	–	–	0.0226*** (0.0081)	–	–	0.013*** (0.0042)
$R\&D_{it-1}/C_{it-2}$	–	–	0.0026 (0.0031)	–	–	0.0017 (0.0032)
Constant	-0.0062 (0.0384)	-0.0432 (0.0551)	0.1625 (0.1283)	-0.0268 (0.0252)	-0.0562* (0.0305)	0.0324 (0.0446)
w_{JS}	16.248 [0.000]	13.643 [0.016]	10.18 [0.037]	2.698 [0.259]	6.440 [0.169]	14.27 [0.006]
m_2	1.149 [0.251]	1.466 [0.143]	1.126 [0.260]	1.191 [0.234]	-0.3577 [0.721]	0.9484 [0.343]

Table A. 4: Pooled OLS results for high-tech firms

	(1)	(2)	(3)
$size_{it-1}$	-0.047*** (0.0103)	-0.023*** (0.0092)	-0.019* (0.0112)
$growth_{it-1}$	0.0277 (0.0575)	0.0237 (0.0613)	0.068 (0.0902)
$(R\&D/sales)_{it-1}$	–	0.0226* (0.0133)	–
$(R\&D/sales)_{it-2}$	–	0.0183 (0.0123)	–
I_{it-1}/K_{it-2}	–	–	0.039*** (0.0116)
$R\&D_{it-1}/C_{it-2}$	–	–	0.008 (0.0051)
Constant	-0.0159 (0.0568)	-0.0674 (0.0583)	0.1512* (0.0802)
w_{JS}	16.658 [0.000]	17.554 [0.000]	14.41 [0.006]
m_2	0.6848 [0.493]	0.1731 [0.863]	-0.6314 [0.528]

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