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Testing Gibrat's Law: Empirical Evidence from a Panel of Portuguese Manufacturing Firms

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Abstract

The purpose of this paper is to use Dynamic Panel Data (DPD) models to see if Gibrat's law holds and to analyse the empirical determinants of firm growth. This paper makes significant contributions to the empirical literature on the dynamics of firm growth, since it updates the work carried out by previous researchers in this field using micro panel data and GMM estimators. To conduct this study we use an unbalanced panel of Portuguese manufacturing firms over the period from 1990 to 1999. The main implication of our findings is that firm growth is not quite random since there are some determinants which exert influence on firm growth.

JEL classification: L11, C23.

Keywords: Firm growth; Gibrat's law; Panel data; GMM estimators.

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1. Introduction

The growth of the firm is central to any explanation of the growth of any economy and it is not surprising that so many reasons have been suggested to explain firm growth. Superimposed upon all the systematic forces is a large stochastic factor: storms and floods, earthquakes, wars, terrorism, change of government, Stock Exchange bubbles, health scares and a multitude of other random effects influence a firm's growth. These stochastic shocks outweigh the systematic forces in so many cases that the resulting skew size distribution of firms by output appears to be generated by a multiplicative stochastic process.

Gibrat (1931) was the first to investigate the implications of a stochastic multiplicative growth process of this kind and to present the first formal model of the dynamics of firm size and industry structure. Gibrat's law states that firm growth in one period should be independent of growth in the previous period. Gibrat's law or the Law of Proportionate Effect (LPE) in its strict version implies that, over a period of time, all firms have equal chances for the same amount of proportionate growth, regardless of their size at the beginning of the period[1]. The assumptions of LPE are violated if growth rates or their variance are correlated with firm size.

The firm growth literature has a long history of contributions. A rich body of empirical evidence has been produced on firm dynamics and industry evolution, spanning numerous countries and time periods. Work has been carried out in a number of countries, including: in the USA, (Evans (1987), Hall (1987), Dunne et al. (1988, 1989) and Audretsch (1995)); the United Kingdom, ((Dunne and Hughes (1994)); Portugal, (Mata (1994)); Germany, (Wagner (1992) and Almus and Nerlinger (1999, 2000)); Austria, (Weiss (1998)); Italy, (Audretsch, Santarelli and Vivarelli (1999)); Japan, (Goddard, Wilson and Blandon (2002)), and Greece, (Fotopoulos and Louri (2002)). All of these studies were applied to the manufacturing sector, except that by Weiss (1998), which tested Gibrat's law in the farm sector. More recently, the relationship between firm size and firm growth has also been tested in high–tech firms

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[1] A formal definition for Gibrat's law is: a variate subject to a process of change is said to obey the law of proportionate effect if the change in the variate at any step of the process is a random proportion of the previous value of the variate. LPE postulates that firm size has no systematic effect on the rate of growth of firms, implying that although the actual rate of growth of a firm is stochastic, the expected growth rate is the same across all size classes of firms.

(Almus and Nerlinger (1999, 2000)) and services industries (Audretsch, Klomp and Thurik (2002)).

Accumulated evidence seems to reject randomness. However, when differentiating firms by size, one may observe that deviations from the law become smaller with increasing firm size (Evans (1987) and Hall (1987)). Analysing quoted firms or largest firms, some studies (Hall (1987)) cannot reject the law. Hymer and Pashighian (1962), Prais (1974) and Singh and Wittington (1975) found that firm size and firm growth are roughly independent[2], but Mansfield (1962) reported conflicting results. He found a negative relationship between firm size and firm growth, which, however, failed to hold for firms of a certain dimension upwards. He suggested that the fact that small firms are more prone to die could have biased the results, in favour of the negative relationship found between size and growth. Evans (1987), Hall (1987) and Weiss (1998) addressed this issue and found that although the probability of survival is positively related to firm size, the negative relationship between size and growth still holds after this effect is taken into account.

The purpose of this paper is to test a dynamic panel data model on an unbalanced panel of Portuguese manufacturing firms. This type of model has been found to explain a lot of the key aspects of firm size and growth in many other empirical studies. This model assumes that firm growth is determined by random factors that are independent of firm size. Because most of the empirical evidence seems to reject the randomness, we set out to identify other determinants of firm growth. Early studies on firm growth concentrated mainly on the influence of size and age (Jovanovic (1982), Evans (1987), Hall (1987), Dunne et al. (1989)). However, recent contributions to the explanation of firm growth include the roles of share of foreign participation (Markusen and Venables (1999)), sunk costs (Cabral (1995)) and financial structure (Lang et al. (1996), Nickell et al. (1992, 1999)).

This research makes significant contributions to the empirical literature on the dynamics of firm growth. We have made the following advances relative to previous studies. Firstly, our study updates work carried out by previous researchers on the relationship between firm size and growth. We focus on the estimation of autoregressive-distributed lag models from panels with a large number of cross-section units, each observed for a small number of time periods. This situation is typical of

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[2] For references to earlier studies see Hay and Morris (1991), p. 537 – 541.

micro panel data. In the presence of dynamic models the OLS estimator is inconsistent. To correct some of the problems in estimating such a relationship we used Generalized Method of Moments (GMM) estimators. Unlike OLS results, the GMM estimators yield consistent estimates in the presence of both endogenous regressors and firm specific effects. As far as we know there is no evidence on this issue using micro panel data and GMM estimators. Secondly, our study sample also included some very small firms. Finally, because the firms' growth is not fully random we included other variables that may explain a firm's growth.

The paper proceeds as follows. In Section 2, various important studies within the considerable literature on firm growth are reviewed and the key results are highlighted, paving the way for the empirical investigation to follow. In Section 3 the sample of companies is described and the descriptive statistics and methodology used is presented, whilst in Section 4 the empirical findings yielded by the OLS and GMM-SYS estimator are displayed and discussed. The final section contains the conclusions drawn and some further remarks.

2. Firm Growth Literature Review

Since 1931, when it was first formulated, Gibrat's law has been a useful theoretical benchmark for theoretical and empirical research on firm growth. Sutton (1997) provides an excellent survey of the theoretical and empirical literature on the dynamics of firm growth.

Theoretical contributions to firm growth may be divided into stochastic and deterministic approaches. The stochastic approach holds that, in a world with no *ex ante* differences in profits, size and power market across firms, all changes in size are due to chance. The contrary, the deterministic approach assumes that differences in the rates of growth across firms depend on a set of observable industry and firm specific characteristics.

Early studies (Hart and Prais (1956); Hart (1962)), using UK data from 1850s to 1950s, provide evidence in support of the operation of Gibrat's law. Hart (1962) makes the point that "there is a large stochastic component in the forces determining the growth of firms, which makes it difficult to adopt a deterministic explanation". Simon and Bonini (1958) assume that Gibrat's law holds for firms above the minimum efficient size level. These authors studied the growth rates of the 500 largest firms in the

US from 1954-1956 and found that there is difference in the growth rates of firms above a certain critical value. Lucas' (1967) model of capital adjustment implies that the time series of firm employment, capital and output obey Gibrat's law. Lucas' (1978) influential model of the size distribution of firms assumes Gibrat's law in order to prove the existence and uniqueness of an equilibrium. Jovanovic (1982) develops special cases of his model of firm learning in which Gibrat's law holds for the limit for mature firms, or for firms that entered the industry at the same time.

Mansfield (1962) studied a sample of firms of different sizes in three specific industries (steel, petroleum and tires) over different time periods. This author pointed out that Gibrat's law may be interpreted in different ways, depending on the way we treat firms "disappearing" from the sample, whether by exiting or otherwise. Mansfield concludes that "Gibrat's law does not seem to hold up very well empirically", but he nevertheless left open the possibility that Gibrat's law might still be true in another form: Consider the distribution of growth rates of firms that would have resulted if none had left the industry; interpret Gibrat's law as saying that this distribution is independent of firm size and then it is possible that the measured growth–size relations could still exhibit the qualitative features observed in Mansfield's data. This depends on the growth rates that would have been achieved by exiting firms. Now suppose that small firms with low growth rates are more likely to exit. Then the proportional rate of growth, conditional on survival, will be smaller for large firms. Whether resorting to this sample-censoring effect could rescue some underlying version of Gibrat's law was one of the main questions posed in the literature of the 1980s.

The new generation of models differs from the older stochastic growth models in that the random growth process has been replaced by one in which firms that differ in various attributes make different profit maximizing choices. The models remain stochastic but the source of randomness has either been pushed backward, into a description of firms' intrinsic efficiency differences, or forward into random outcomes emanating from R&D programs.

The new literature developed in the 1980s raised two main issues. The first concerns about econometric problems as sample-censoring, the specification of an appropriate functional relationship, and heteroskedasticity. A central question was whether a failure of Gibart's law could be attributed to any of these effects. The second issue is uneasiness with the models of the 1950s and 60s. It seems to have been widely felt that these models might fit well, but were only stochastic.

Hall (1987), Evans (1987) and Weiss (1998) addressed specifically the sample selection involved in the analysis of the relationship between firm size and firm growth. Evans (1987) and Dunne, Roberts and Samuelson (1989) covered a full range of firm sizes and ages. Evans's work was based on a large dataset for the US manufacturing industry. Apart from the econometric issues noted above, a major focus of interest in Evans (1987) and Dunne, Roberts and Samuelson (1989) is the roles played by firm age and firm size as determinants of growth. Hall (1987) and Evans (1987) found that the tendency for proportional growth rates decreases with firm size after corrections for sample selection effects.

Evans (1987) and Dunne, Roberts and Samuelson (1989) considered age and size effects as determinant of firm growth. These authors suggest two statistical regularities: the probability of survival increases with firm size and the proportional rate of growth of a firm conditional on survival is decreasing in size; for any given size of firm, the proportional rate of growth is smaller according to the firm is older, but its probability of survival is greater. These results indicate that there are two effects on the size–growth relationship: large firms have lower growth rates, but are more likely to survive.

These findings prompted new interest in theoretical models of firm growth. Another example is the Jovanovic's learning model. Jovanovic (1982) assumed a homogeneous–goods industry; a series of firms enters the market and introduces a learning mechanism which gradually reveals firm-specific efficiency differences as the industry evolves. Each firm has some level of efficiency (its unit cost of production), but it does not know what its relative efficiency is prior to entering. Over time, the profits it achieves provide information on its relative efficiency. More efficient firms grow and survive. Less efficient firms learn from their relative inefficiency, and some choose to exit. This model provides a qualitative description of a process of excess entry followed by some exiting.

Many empirical investigations have sought to determine whether firm growth rates are independent of firm size, the former using cross-section data and the latter using panel data. Goddard *et al.* (2002) present a summary of some of the classical and more recent studies. The studies differ widely in terms of the samples and methods used. The overall impression, however, is that Gibrat's law is not valid and that growth rates tend to decrease with firm size.

Chesher (1979) presented a new methodology to test the relationship between firm growth and firm size using cross-section regression and took into account the existence of serial correlation which induces dependence between variable dependent lag and error term. Serial correlation in proportionate growth rates can be ascribed to the persistence of chance factors which make a company grow abnormally fast or abnormally slowly. To conduct this study Chesher use a sample of 183 firms drawn from the population of UK quoted companies classified as "Commercial and Industrial" in the Stock Exchange Official Yearbook. Only companies in existence in 1960 and 1969 are included in the population. The null hypothesis is rejected at better than the 5% level, i.e the law of proportionate effect does not hold during the sample period.

Wagner (1992) tested the validity of Gibrat's law of proportionate growth using cross-section data for some 7000 manufacturing establishments from Lower Saxony between 1978 and 1989. This author found that the law is only valid for very few groups of firms in some of the periods covered. However, he did not find that small firms grew systematically faster or slower than larger firms, or vice versa. On the other hand, he found "persistence of chance" in the sense that a firm grows faster if it happened to grow faster in the past.

Hart and Oulton (1996), using a sample of independent UK firms, also investigate the relationship between firm size and growth. For a sample as a whole, a Galton – Markov model of regression towards the mean shows that growth is negatively related to initial size. However, when the sample is grouped by size these authors find that Gibrat's model is unsuited to explain the growth of the smallest firms, those with less than 8 employees.

Based on theoretical models of firm growth Almus and Nerlinger (1999) explain the variations in the growth between new technology–based firms and non–innovative firm. In particular, they shed more light on the growth determinants of innovative firms founded between 1989 and 1996 in West Germany. The results indicate strong correlations between the growth rates on the one hand and firm-specific, founder-specific and external factors on the other. These factors influence the growth rates of innovative and non-innovative young firms in different ways. Based on the results of multivariate regressions, which take into account potential selection biases, new technology-based firms achieve on average higher growth rates than non-innovative young firms. For example, Audretsch (1995) and Almus et al. (1999) find that firms in technology-intensive branches have an above average potential growth. Agarwal (1998) finds evidence that small firms which operate in a high–tech environment clearly have higher survival rates. This might indicate that such firms are also more likely to grow quickly (Almus (2002)).

Recently, empirical research in industrial organization has been enriched by the availability of a wealth of new sources of data: cross-sections of individuals observed over the time. Panel data econometrics uses both time series and cross-sectional data sets that contain repeated observations over time for the same individuals (individuals can be households, firms, industries, regions or countries). Panel data play an important role in empirical economics. With panel data one can answer questions about dynamic microeconomic behaviour that could not be answered with cross-sectional data. However, there are some problems associated with panel data regressions, such as sample-censoring, sample selection and heteroskedasticity.

Hall (1987), using a panel data on the publicly traded firms in the US manufacturing sector, studied the relationship between firm size and firm growth. The study performed by Hall (1987) is really about the relationship of growth and size across firms that have already reached a certain minimum size, large enough to require outside capitalization. Gibrat's law is weakly rejected for the smaller firms and accepted for the larger firms. This finding is unchanged when the selection (attrition) effect is controlled.

Evans (1987) examines the relationships between firm growth, size and age for a sample of manufacturing firms between 1976 and 1982. Firm growth is found to decrease with firm size and firm age. The inverse growth–age relationship is consistent with the theory of firm learning proposed by Jovanovic (1982) while the inverse growth–size relationship is inconsistent with a number of theories that assume or imply Gibrat's law. Evans' works addressed three econometric questions that previous studies had largely ignored. The first question concerns the shape of the firm growth–firm size relationship. Previous studies assumed a linear relationship. Evans found that the relationship is highly non-linear so that the growth–size relationship varies over the size distribution of firms. The second question concerns the effect of sample selection on the growth–size relationship. Mansfield (1962) conjectured that the inverse relationship between growth and size was an artefact of the exit of slow-growing firms from the sample. Evans (1987) finds that the inverse relationship is robust to this kind of sample censoring. The last question concerns the effect of heteroskedasticity.

Mata (1994) studies survival and growth of a panel of young firms, which started their operations in 1983, in the Portuguese manufacturing sector, and seeks to discover what happens to entrants in the first years of their lives. To study the relationship between size and growth he uses a sample of firms of the same age but excluded firms with less than 9 employees. This methodology considerably reduces the heterogeneity among individual firms, allows concentration to focus on the size issue. Mata found not only that newer firms are smaller, more prone to die, and that survivors grow faster than their older counterparts, but also that this picture holds at least for the first four years of firms' lives. The results obtained suggest that firms are considerably more likely to die in the first year of their lives, and that smaller firms are more prone to die than their larger counterparts. He also concludes that firm growth varies negatively with firm size, at least during its infancy. Mata's (1994) results strongly contradict the validity of the law. Instead, he seems to confirm some other studies (for example, Chesher (1979) and Wagner (1992)) that have found a phenomenon of persistence of growth. One of the possibilities that has been raised in the literature (Mansfield (1962)) is that Gibrat's law would only hold for firms of a certain size upwards.

Dunne and Hughes (1994) provide an empirical investigation into the links between corporate size, age, growth and death and of the persistence of growth over time for a large sample of all quoted companies and the larger unquoted companies in UK for the period 1975–1985. They show that smaller companies grew faster than larger companies, that Gibrat's Law does not hold amongst smaller firms, that age is negatively related to growth, and these results are not an artefact of sample selection bias.

Weiss (1998) studied the evolution of the size distribution of a panel of more than 40000 farms in the Upper Austrian farm sector over the period 1980–1990. Using Gibrat's law as point of departure, this author found that growth rates are not independent of initial firm size, as assumed by Gibrat's law. In particular, smaller farms grow much faster towards some minimum efficient scale of production than farms at or above this threshold size, which is not an artefact of sample selection bias.

Audretsch, Santarelli and Vivarelli (1999) shed some light on industry dynamics in Italy. For this purpose they use a large and comprehensive longitudinal data base, identifying the start–up of new manufacturing firms and their subsequent post–entry performance. This enables them to link the survival and growth of firms in each manufacturing industry specifically to their start–up size. Using a Tobit regression they find no evidence to link the start–up size with survival; the growth rates are negatively and significantly correlated with initial size. As in previous studies dealing with other countries, this evidence suggests that Gibrat's law fails to hold, at least for small, new–born manufacturing firms.

Almus and Nerlinger (2000) test if the Gibrat's law is applicable to firms founded between 1989 and 1994 within the West German manufacturing sector. These authors find that firm size follows an approximately lognormal distribution. Using a longitudinal dataset, Gibrat's law is rejected both for the group of young firms belonging to technology intensive branches and for those operating in non–technology intensive branches, in all periods examined, although no significant differences between the two firm groups can be observed. Almus (2002) seeks to empirically identify factors that influence the probability of being a fast-growing firm in Eastern and Western Germany. According to Storey (1994) three categories of factors exist which influence the probability of a firm becoming a fast-growing one. These can be summarized as entrepreneurial characteristics, strategic factors and firm characteristics.

Goddard, Wilson and Blandon (2002) compared the properties of the standard cross-sectional test of the LPE with those of three alternative panel unit root tests using Monte Carlo methods for a sample of 443 Japanese manufacturing firms with data of the period 1980–1996. In general, stronger evidence against the LPE is obtained from the panel than from the cross-sectional tests.

Becchetti and Trovato (2002) present an empirical analysis of the determinants of growth for a sample of small and medium sized Italian firms. They show that, for a sample which includes firms with between 10 and 50 employees and a set of variables larger than those usually considered in the literature, growth turns out to be significantly affected not only by size and age, but also by state subsidies, export capacity and credit rationing. Their results suggest that the hypothesis of firm growth being independent of initial size and other factors is not rejected for large firms, whereas it does not hold for small and medium sized firms under financial constraints in a "bank-oriented" financial system in which access to external finance is difficult.

3. Sample and Methodology

The source used to construct the panel data consists of the annual accounts of quoted and unquoted Portuguese manufacturing firms which are legally bound to file their annual accounts at the Central Balance Sheet Office for the period 1990–1999. The firms are classified according to the sector of their main activity (NACE–Rev. 2). This database has one feature that makes it a very good source for the study of market dynamics. Unlike the database used by Mata (1994), which came from the Portuguese Ministry of Employment and was primarily designed to collect data on the labour market, the *Central de Balanços* of the *Banco de Portugal* contains extensive information about the firm's income statement and balance sheet variables.

The final dataset is an unbalanced panel that includes 9000 manufacturing firms that survived across the period 1990–1999. The focus is on panels where a large number of firms are observed for a small number of time periods, typical of applications with microeconomic data or industrial organization. By unbalanced panel data we mean a sample in which consecutive observations on individual units are available, but the number of time periods available may vary from unit to unit, as may the historical points to which the observations correspond.

Table 1 gives the descriptive statistics of the main variables used in the empirical analysis. The average number of employees is about 58, whereas the median, a measure that is less susceptible to outliers, is 19 employees. The median and percentile 90 confirm the findings of other studies, which fall within the usual definition of small and medium sized business adopted by the European Union[3]. It is known that large numbers of jobs are created in small and medium-sized firms (SMEs), it should also be recognized that many jobs are lost by the closure of smaller firms (Davis, Haltiwanger and Schuh (1996) and Caves (1998)). Casual inspection of the data on firm sizes suggests that the size distribution is skewed, with a few large firms, rather more medium–sized firms and large tail of small firms. Such a size distribution is approximated with a lognormal distribution. This form arises if each firm faces the same distribution of growth possibilities, and each firm's actual growth is determined by a random sampling from that distribution. On average the firm age is 18 years old, whereas the median is 14 years old, which means that most of the firms are young. In terms of share of foreign ownership we have found that, on average, for the manufacturing firms it is 11.56%, and only a very small number of firms have a high share of foreign ownership (95.1%). In relation to financial variables most of the firms exhibit high leverage and liquidity ratios.

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[3] Official Journal of European Communities Nº L 107/04 de 30.4.96.

Table 1 – Sample summary statistics

Variable	**Percentile**		**Mean**	**Std. dev**
	50th	**90th**		
SIZE	19	120	58.25	173.29
AGE	14	36	17.94	15.46
FOWN	7	29.5	11.56	13.83
LEVERAGE	80.49	107.13	84.69	44.17
LIQUIDITY	28.01	57.86	31.20	19.05

Variables

Based on the firm growth literature discussed above, the early studies concentrated mainly on the influence of size and age. Firm size ($size_{it}$) can be measured in a number of ways, with employment, assets, and sales being some common measures. However, each of these has its limitations[4]. We might in principle expect systematic differences between the several measures. To measure the firm size, we use the average number of persons working in a given year. The age for firm *i* at the end of period *t* (age_{it}) is measured by the difference between the end of period *t* (31/12/year *t*) and the date of beginning activity.

To explain the corporate growth we added industry-specific and firm-specific variables, such as percentage of foreign ownership and financial structure, respectively. At the industry level, $fown_{s,t}$ measures the extent of foreign ownership for industry *s* (NACE – three digits) in a period *t*, and is essentially a percentage of foreign participation. The information on $fown$ comes from the *Departamento de Estatística do Trabalho, Emprego e Formação Profissional* (*Ministério da Segurança Social e do Trabalho*). At the firm level, $leverage_{i,t}$ is defined by the ratio of book values of total liabilities to total assets[5] and $liquidity_{i,t}$ is taken as current assets minus inventories over total assets. All variables have been subjected to logarithmic transformation (natural log).

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[4] See, for example, Hart and Oulton (1996).

[5] Unfortunately, since only a small number of our firms are quoted in the Lisbon Stock Exchange, it has not been feasible to calculate Tobin's q, as an index of a firm's known growth opportunities.

Methodology

Gibrat's original formulation and typical textbook presentations of the LPE (e.g. Hay and Morris, 1991, p. 537) emphasize the long term implications of the LPE for changes in industry concentration over time. It therefore seems anomalous, though understandable in view of the limited availability of firm-level data over time, that cross-sectional methods have been used predominantly in the empirical literature.

There have been many attempts to determine whether company size obeys the LPE. The cross-section regression has been by far the most commonly used methodology in this area, in which the logarithmic growth of each firm over a period of duration T is regressed against log size at the start of the period. The cross-sectional procedure produces biased parameter estimates and the test suffers from a loss of power if there are heterogeneous individual firm effects. Suitably designed panel data avoid these difficulties. Its advantage over cross-section data in this context is obvious: we cannot estimate dynamic models from observations at a single point in time, and it is rare for cross-section surveys to provide sufficient information about earlier time periods for dynamic relationships to be investigated. Its advantages over aggregate time series data include the possibility that underlying microeconomic dynamics may be obscured by aggregation biases, and the scope that panel data offers for investigating heterogeneity in adjustment dynamics between different types of firms. This facilitates the construction and testing of more realistic behavioral models that could not be identified using only a cross-section or a single time series data set, controlling for aggregate effects and individual heterogeneity. Panel data can answer questions about microeconomic dynamic behaviour that could not be answered with cross-sectional data.

Recent advances in methods for testing panel data have created opportunities for the incorporation of a short panel data into empirical tests of the LPE. Methodologically, Goddard, Wilson and Blandon (2002) have contributed to the embryonic literature on the analysis of panel data sets with a large cross-sectional and a small time series dimension (large N and small T).

The shift from cross-sectional to panel methods is more than purely technical. This is because it creates the possibility of testing a null hypothesis under which log firm size is non-stationary and therefore complies with the LPE, against a wider range of alternative hypotheses under which log firm sizes are stationary and mean-reverting.

The econometric approaches to deal with these issues in the context of panel data models have developed in several stages in the literature over the past decade. For reasons of clarity in the discussion that follows, a brief outline is given below of the regression model, the estimation problems, and the generalized method of moments (GMM) estimator we have chosen to use. It offers a reasonably robust solution for the problems of possible misspecification.

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,

$$y_{i,t} = \beta y_{i,t-1} + \alpha_t + \mu_{i,t} \qquad i = 1, 2, \ldots, \mathrm{N} \quad t = 2, 3, \ldots, \mathrm{T}. \qquad (1)$$

where $y_{i,t}$ is the natural log of the firm size and $y_{i,t-1}$ is the lagged dependent variable. The parameter β determines the relationship between log size and annual log growth. Dynamic panel models such as those in equations (1) and (2) are characterized by the presence of a lagged dependent variable. We have adopted the terminology conventionally employed by dynamic panel data studies: GMM-SYS estimator.

One remarkable fact about the model (1) is its lack of economics. Some authors have tried to add economics to this model, particularly by exploring the implications of the assumptions that managers are heterogeneous (Lucas (1978) and Jovanovic (1982)), and considering the fact that capacity and technology choices involve some degree of sunkness (Cabral (1995)). These models point to a number of socio-economic variables influencing firm performance and, moreover, provide a theoretical explanation for a relation between size and growth, and can be written in the form

$$y_{i,t} = \beta y_{i,t-1} + \sum_{j=1}^{k} \gamma_j x_{j,i,t} + \alpha_t + \mu_{i,t} \qquad i = 1, 2, \ldots, \mathrm{N} \quad t = 2, 3, \ldots, \mathrm{T}. \; (2)$$

where $x_{j,i,t}$ contains a set of explanatory variables (*k* additional regressors)[6], and α_t (time effect) to control for macroeconomic or other influences on growth common to all firms and specific to each time period. The errors $\mu_{i,t}$ are decomposed into unobserved time-invariant firm specific effects which allow for heterogeneity in the

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[6] Although the RHS variable: y_{it} is endogenous by definition in the sense that is correlated with μ_{it} and earlier shocks, but is uncorrelated with μ_{it+1} and subsequent shocks $\left[E\left(y_{it}\mu_{is}\right) \neq 0 \quad \mathrm{s} \leq \mathrm{t}\right]$; and x_{it} predetermined in the sense that x_{it} and μ_{it} are uncorrelated, but x_{it} may still correlated with μ_{it-1} and earlier shocks $\left[E\left(x_{it}\mu_{is}\right) \neq 0 \quad \mathrm{s} < \mathrm{t}\right]$.

means of the y_{it} series across individuals, μ_i (firm effect), and $\varepsilon_{i,t}$ a random noise, assumed to be normal, independent and identically distributed (IID) with $E(\varepsilon_{it}) = 0$ and $\mathrm{var}(\varepsilon_{it}) = \sigma_\varepsilon^2 > 0$. Thus, the errors $\mu_{i,t}$ can be written as

$$\mu_{i,t} = \mu_i + \varepsilon_{i,t}. \qquad (3)$$

This model formulation shows that the presence of firm specific effects in the growth model ($\mathrm{var}(\mu_i) > 0$) leads to a correlation between a regressor $(y_{i,t-1})$ and the error term. This is why we argue that the OLS estimator is biased and inconsistent. The GMM estimators[7] provide a convenient framework for obtaining asymptotically efficient estimators in this context. These estimators are linear and estimation software is freely available[8]. The solution lies in removing the firm specific effects by the first-differencing transformation of the data in order to obtain valid moment conditions, whereby equation (2) becomes

$$y_{i,t} - y_{i,t-1} = \beta(y_{i,t-1} - y_{i,t-2}) + \sum_{j=1}^{k'} \gamma_j (x_{j,i,t} - x_{j,i,t-1}) + (\alpha_t - \alpha_{t-1}) + \varepsilon_{i,t} - \varepsilon_{i,t-1}. \qquad (4)$$

In the model given by equation (4), the regressors are clearly correlated with the error term under the above assumptions; $y_{i,t-1}$ is correlated with $\varepsilon_{i,t-1}$ and $x_{j,i,t}$ may be correlated with $\varepsilon_{i,t-1}$. The problem is solved by using lagged observations of the regressors as instruments. Specifically, under the assumption that $x_{j,i,t}$ is predetermined, $x_{j,i,t-1}$ is a valid instrument and $x_{j,i,t-2}$ is valid if $x_{j,i,t}$ is endogenous.

The moment restriction for the GMM-DIF can be expressed as

$$E(y_{it-s}\Delta\varepsilon_{it}) = 0 \text{ for } t = 3, \ldots, T \text{ and } s \geq 2. \quad (5)$$

Bond et al. (2001) highlight a problem in using the first-differenced GMM panel data estimator to estimate empirical growth models. When the time series are persistent, the GMM-DIF can be poorly behaved, since lagged levels of the series provide only weak instruments for subsequent first differences. Furthermore, Bond et al. (2001) suggest using a more efficient GMM estimator that exploits stationarity restrictions

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[7] The first-differences GMM (GMM-DIF) proposed by Arellano and Bond (1991) and system GMM (GMM-SYS) proposed by Arellano and Bover (1995) and Blundell and Bond (1998).

[8] All GMM results are obtained using the DPD package for OX, see Doornik et al. (1999). http://www.nuff.ox.ac.uk.

(GMM-SYS), and this approach is shown to give more reasonable results than the GMM-DIF when estimating an empirical growth model.

The system GMM may have superior finite sample properties. Hence, to obtain a linear GMM estimator better suited to estimating autoregressive models with persistent data, Blundell and Bond (1998) consider the additional assumption that

$$E(\mu_i \Delta y_{i2}) = 0 \text{ for } i = 1, \ldots, \text{N}. \quad (6)$$

The assumption (6) requires a stationarity restriction on the initial conditions y_{i1}. Combined with the AR(1) model set out in equation (1), this assumption yields T – 2 further linear moment conditions

$$E(\varepsilon_{i,t} \Delta y_{it-1}) = 0 \text{ for i = 1, …, N and t = 3, 4, …, T.} \quad (7)$$

These conditions allow the use of lagged first-differences of the series as instruments for equations in levels, as suggested by Arellano and Bover (1995).

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 ε_{it} disturbances can be tested by testing for no second-order serial correlation in the first-differenced residuals. The GMM estimator is consistent if there is no second-order serial correlation in the error term of the first-differenced equation $[E(\Delta\varepsilon_{it}\Delta\varepsilon_{it-2}) = 0]$. The m_1 statistics, on the same line as m_2, tests for lack of first-order serial correlation in the differenced residuals. Another test of specification is a Sargan test of over-identifying restrictions which has an asymptotic χ^2 distribution under the null hypothesis that these moment conditions are valid.

4. Empirical Results

In this paper we extend the range of econometric methods used to test the LPE by applying dynamic panel data techniques. The model estimated is a first-order autoregressive specification with year specific intercepts (α_t) included to account for common cyclical or trend components in these growth rates.

Before we run any estimation we calculate the correlation matrix among the variables used in this study. Table 2 presents a correlation matrix for the variables which we think may have significant effects on firm growth. This matrix confirms the existence of some significant correlations among potential regressors. Some of the correlation coefficients are above 0.10: the positive ones fall between size and age, size and share of foreign participation and the negative ones between size and leverage, age and leverage[9].

Table 2 – Correlation matrix among variables

	SIZE	AGE	FOWN	LEVERAGE	LIQUIDITY
SIZE	1.00				
AGE	0.351	1.00			
FOWN	0.144	0.045	1.00		
LEVERAGE	-0.158	-0.137	-0.019	1.00	
LIQUIDITY	0.015	0.026	0.02	-0.17	1.00

The results of estimating growth specification (see equation (2)) by different methods for an unbalanced panel of Portuguese manufacturing firms for the period 1990-1999 are reported in Tables 3 and 4. The Table 3 reports the OLS estimates together with heteroskedasticity consistent estimates of the asymptotic standard errors. In the context of dynamic panel data models, the OLS estimates suggest that there is an upward bias on the lagged dependent variable, which in turn suggests the presence of firm-specific effects and inconsistency. To solve this problem, we therefore proceed to apply an estimator that is consistent in the presence of endogenous regressors and firm specific effects. In Table 4 the GMM-SYS results are presented. All the reported GMM estimates correspond to two-step estimates with asymptotic standard errors robust to heteroskedasticity. A different instrument set is used in each column.

First, we estimate a simple stochastic model (see column [1], Tables 3 – 4). The analysis of the relationship between growth and size consists of testing the null hypothesis $\left(H_0 : \beta = 1\right)$ embodied in the LPE which states that the probability distribution of growth rates is the same for all classes of firm. If the law holds we would expect to find no differences in the mean and variance of growth rates across size classes of firm and no serial correlation in growth rates. When β is not equal to one,

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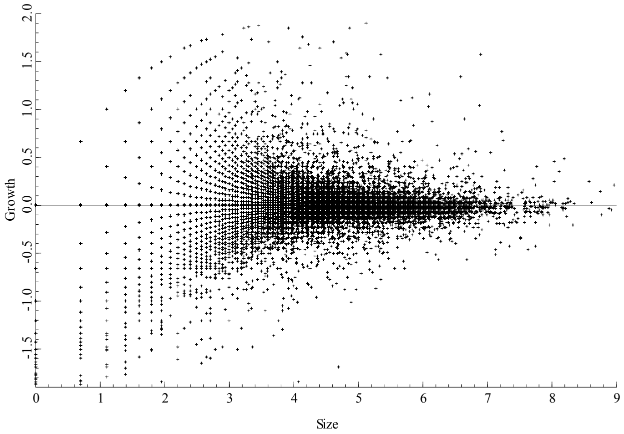
[9] Bechetti and Trovato (2002) drew the same conclusions.

firm sizes regress towards or away from their mean in the Galtonian sense. If the parameter $\beta > 1$ then company growth path is explosive: firms tend to grow faster as they get larger (large firms grow faster than small ones). Such a pattern is conceivable for a limited time, but presumably could not continue indefinitely. The variance of the cross-sectional firm size distribution and the level of concentration both increase over time. If the parameter $\beta < 1$, firm sizes are mean-reverting, which corresponds to the tendency for a variate return to the mean size. It is often the case that the variance of growth rates decreases with increases in the size of firm. In this case μ_i can be considered as being IID with $E(\mu_i) = 0$ and $\mathrm{var}(\mu_i) = \sigma_\mu^2 \geq 0$. If $\sigma_\mu^2 = 0$ the individual effects are homogeneous (all firms tend to revert towards the same mean size) and if $\sigma_\mu^2 > 0$ they are heterogeneous (the mean sizes are firm-specific). In practice, with values of β just below unity, we should expect the size distribution of firms to be approximately lognormal (Hart and Oulton (1996)). The fact that the firm size distribution is approximately lognormal is consistent with the hypothesis that a firm's size is heavily influenced by multiplicative stochastic shocks and that the stochastic process of growth is summarized by equation (2). The results of the tests based on this kind of model have been mixed, with several early studies finding either no relationship or a positive relationship between size and growth. Earlier studies found that Gibrat's law holds, at least as a first approximation, but most of them are based on samples of the largest firms in the economy or quoted firms. Others, including more recent studies, identify an inverse relationship and therefore reject the LPE (Hall, 1987; Evans, 1987; Dunne and Hughes, 1994; Hart and Oulton, 1996; Goddard, Wilson and Blandon, 2002).

Figure 2 plots firm growth against logarithmic size distributions, and the results suggest that the variance of growth rates is size related. Therefore, we can conclude that growth rates of small firms would be concentrated in very high values, which may induce a bias in favour of the negative relationship between growth and size.

Figure 2 – Firm growth and firm size.



This is confirmed by the OLS and GMM-SYS estimations reported in Tables 3 – 4. In column [1] we have ignored any other non-stochastic determinants of firm growth and concentrated on the relationship between size and growth. This study finds that firm growth decreases with firm size, which is inconsistent with theories that assume or imply Gibrat's law. The OLS and GMM results suggest that β is significantly below unity[10], indicating that small firms are growing faster than larger ones during the period. Since one of the size measures used is employment it follows that smaller firms generated more jobs, in proportion to their size, than did the larger firms. One possible explanation, in economic terms, is that there is a minimum efficient scale of firm and until this size is reached, the firm experiences decreasing average costs and can enjoy rapid growth. After this point, its average cost curve flattens out and it enters the world of constant average and marginal costs experienced by firms operating at above minimum efficient scale.

However, it is quite reasonable to admit that a firm's specific factors may play an important role in its growth. If a firm's growth depends on characteristics other than size, the specification presented in column [1] will suffer from misspecification due to omitted variables. For this reason we include other variables in the model that seem to be relevant for firms' growth. One possible explanation for the negative relationship between size and growth found is related to the age of firms. In column [2], we consider

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[10] This result confirms the stability condition $\left(\left|\hat{\beta}\right| < 1\right)$.

the impact of age together with size as a factor affecting growth[11]. Jovanovic (1982) developed a theoretical model that could account for the deviations from LPE uncovered by empirical research. His model of noise selection predicts a negative relationship between firm size and growth, and firm age and growth. The model assumes that firms are heterogeneous with respect to their true efficiencies, and consequently, cost levels. The first years in the life of firms can be thought of a process in which firms learn about their true efficiency. Most firms would be born small, with imperfect knowledge about their true efficiency levels, and the earliest period in the market would then be crucial to updating their expectations. Firms which markets reveal to be inefficient would leave the market, while those which are indicated to be more efficient than average would survive and grow. The negative relationship between firm age and growth has been exposed in a number of empirical studies and in different countries: (Evans (1987) and Dunne et al. (1989) for US, and Dunne and Hughes (1994) for UK). In this study, looking at column [2] Table 3, the estimated coefficients (size and age) show a highly significant influence on the firm growth. With respect to the influence of size, this correlation once again confirms the sub-optimal size of firm, which has to reach a size that enables it to exist in the market – the so-called minimum efficient size. Small firms must grow faster in relative terms to reach the MES of production in their industry that enables them to survive (Sutton (1997)). The negative relationship between firm size and firm age suggests that younger firms grow faster than older ones.

Apart from size and age, industry-specific characteristics have an influence on growth rates. As predicted by the literature on foreign direct investment the coefficient for *fown* is positive. In column [3] the results suggest that sectors with higher foreign participation (*fown*) appear to growing faster. Such an effect may account for the positive spillovers stemming from foreign firms and benefiting all firms in the same industry.

Finally, we allow firm-specific characteristic related to financial structure (columns [4] and [5]). In recent years a growing literature on the role of financial

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[11] See for example Jovanovic (1982), Evans (1987), Dunne, Roberts and Samuelson (1989), Dunne and Hughes (1994), Almus and Nerlinger (1999).

constraints on firm performance has emerged (Lang et al. (1996), Nickell et al. (1992), and Nickell and Nicolitsas (1999). A central issue is whether leverage affects a firm's investment decision, and ultimately its growth, given its investment opportunities. Lang et al. (1996) examine the relation between leverage and firm growth using a sample of large industrial firms. The significantly negative coefficient estimated lends additional weight to the effect of leverage on firm growth, as this could be expected to be weaker for the large firms used in the analysis, which have access to stock markets. Low leverage might be signaling management's private information about the firm's structural growth prospects. Nickell et al. (1992) and Nickell and Nicolitsas (1999) have also examined the issue of financial pressure and its effect on corporate behaviour. Higher leverage increases the threat of bankruptcy and hence forces managers to improve efficiency, possibly through cutting back on organizational slack. Thus, a positive effect on productivity and productivity growth is estimated, with further positive repercussions on overall firm performance. In terms of capital structure, our results suggest that *leverage* plays a negative role in firm growth, whereas *liquidity* appears to have a positive effect.

Table 3 – Pooled OLS estimations

	[1]	**[2]**	**[3]**	**[4]**	**[5]**
SIZE(-1)	0.981 (21.32)	0.987 (13.66)	0.988 (10.28)	0.987 (11.05)	0.987 (10.97)
AGE	–	-0.032 (-19.4)	-0.031 (-15.1)	-0.033 (-16.0)	-0.033 (-16.0)
FOWN	–	–	0.003 (3.40)	0.003 (3.38)	0.003 (3.33)
LEVERAGE	–	–	–	-0.042 (-7.69)	-0.04 (-7.24)
LIQUIDITY	–	–	–	–	0.004 (2.5)
Constant	0.084 (15.5)	0.147 (22.5)	0.137 (11.2)	0.326 (11.7)	0.304 (10.4)
R^2	0.9649	0.9652	0.9633	0.9634	0.9634

Note: Heteroskedasticity consistent t–values are reported in parenthesis.

Table 4 presents the results for the GMM-SYS estimator which uses additional moment conditions that typically require stronger assumptions on the initial conditions, but which can be highly informative in cases where identification using the first-differenced equations alone becomes weak. As with the pooled ordinary least squares results, the GMM estimates confirm the expected signal for all coefficients.

The validity of the dynamic models depends upon a lack of second-order serial correlation (see the m_2 statistics) and the validity of the instrument set measured by the Sargan test. Results of these tests are reported in Table 4. The test of second-order serial correlation is only accepted in column [5], Table 4, which means that growth equation does not exhibit second-order serial correlation in this case, and the Sargan test is not always rejected.

Table 4 – GMM-SYS

	[1]	**[2]**	**[3]**	**[4]**	**[5]**
Size (-1)	0.956 (3.5)	0.963 (3.12)	0.971 (3.09)	0.979 (3.01)	0.982 (2.98)
Age	–	-0.033 (-3.34)	-0.041 (-2.0)	-0.055 (-3.48)	-0.041 (-2.08)
Fown	–	–	0.011 (2.41)	0.002 (1.31)	0.010 (2.33)
Leverage	–	–	–	-0.091 (-2.52)	-0.041 (-4.90)
Liquidity	–	–	–	–	0.003 (1.65)
W_{JS}:	0.000	0.000	0.000	0.000	0.000
W_{TD}:	0.000	0.000	0.000	0.000	0.000
Sargan test:	0.196	0.157	0.172	0.365	0.118
m_1:	0.000	0.000	0.000	0.000	0.000
m_2:	0.003	0.000	0.041	0.000	0.015

Notes:

1. Time dummies are included in all specifications.
2. Heteroskedasticity consistent t–values are reported in parenthesis.
3. W_{JS} is the Wald statistic of joint significance of the independent variables (excluding time dummies and the constant term) and W_{TD} is the Wald statistic of joint significance of the time dummies. Both statistics are asymptotically distributed as a χ^2 and robust to heteroskedasticity.
4. Sargan is a test of the over-identifying restrictions, asymptotically distributed as χ^2 under the null of instrument validity. The *p*-value of Sargan's test for overidentifying restrictionsis reported.
5. m_1 and m_2 are tests for first-order and second–order serial correlation in the first differenced residual, asymptotically distributed as N(0, 1) under the null of no serial correlation.

5. Conclusions and further remarks

In this paper we have analyzed dynamic firm growth an unbalanced Portuguese manufacturing sector for the period 1990-1999. The results show that the initial or actual number of employees should not be ignored in the explanation of future firm size or employment growth. The main implication of our results is that random influences are, in most cases, not the only reason why firms grow, since there is also a deterministic component. Economics literature provides new determinants that may explain a firm's growth. Recent contributions to the explanation of firm growth include financial structure and the role of foreign participation.

Using a GMM estimator to estimate dynamic panel data, our results confirm other empirical studies, indicating that large and mature firms have smaller growth rates than small and young firms. If we allow for the role of foreign participation we find that firms in industries with higher foreign participation appear to grow faster then the others. In the context of capital structure, our results suggest that *leverage* plays a negative role in firm growth, whereas *liquidity* appears to have a positive effect on it.

There are still various unsolved problems that should be taken into account in future analysis. Such analysis should also be extended to other sectors of the economy because the patterns of growth may vary substantially between manufacturing and the services. Finally, the GMM results are greatly affected by whether the data is trend stationary (exhibit regression to individual firm means) or difference stationary (evolve as a random walk). The presence of a unit root or nonstationarity will invalidate the commonly used GMM specification. For this reason is very important to carry out the panel data unit root tests.

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