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**The Determinants of Growth in the Information and  
Communication Technology (ICT) Industry: A Firm-Level Analysis**

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# The determinants of growth in the information and communication technology (ICT) industry: A firm-level analysis

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**Abstract:** Why do some firms grow faster than others? This question has become the focus of a large number of empirical studies in industrial organization, strategic management, and entrepreneurship since the publications of Gibrat (1931) and Penrose (1959). Using an unbalanced panel data set of 85 U.S. information and communication technology (ICT) firms that survived over the period from 1990 to 2013, we examine the effect of firm size, agency costs, R&D investments, capital structure, profitability, and the Great Recession of 2007-2009 on firm growth. Adopting the two-step, system, generalized-method-of-moments estimator for linear dynamic panel models (Blundell and Bond, 1998), we document that growth in the ICT industry is not stochastic, as predicted by Gibrat (1931), but driven by systematic factors. We find compelling evidence that in the ICT industry: (i) firm growth exhibits positive persistence, which endorses the controversial "success-breeds-success" evolutionary hypothesis; (ii) agency costs and financial leverage exert a negative effect on firm growth; (iii) R&D investment and financial performance generate a positive effect on firm growth; (iv) the Great Recession (2007-2009) produced a negative effect on firm growth; (v) a nonlinear, inverted U-shaped relationship exists between firm size and firm growth; and (vi) Gibrat's law does not hold. Our findings remain robust to transformations using first differences and forward orthogonal deviations as well as principal components reductions. These results are new to the literature, since the dynamics of firm growth has not been documented at the ICT industry level. Noteworthy policy implications emerge because the growth dynamics of the ICT industry move this sector toward more concentration and less competition.

Keywords: ICT industry; Agency costs; Firm growth; Panel data; system-GMM

JEL classification: L16; L25, L86; C23, C26

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## 1. Introduction

What determines firm growth remains the controversial subject of extensive theoretical and empirical research that spans a variety of academic fields, including strategic entrepreneurship (Storey, 2004; Vivarelli, 2007; Davidsson, 1991; Davidsson, Delmar and Wiklund, 2002; and McKelvie and Wiklund, 2010), strategic management (Stam, 2010; Leitner and Guldenberg, 2010; and Parker, Storey and Van Witteloostuijn, 2010), and industrial organization (Evans, 1987a, 1987b; Geroski, 2005; and Coad, 2009). Firm growth is a multi-faceted, multi-dimensional, complex and heterogeneous phenomenon (Delmar, Davidsson, and Gartner, 2003). Firm growth is often portrayed as “the very essence of entrepreneurship” (Sexton and Smilor, 1997) and as evidence of business success (Kiviluoto, 2013). This perspective receives special emphasis in the entrepreneurship and strategy literatures (Davidsson, Steffens and Fritzsimmons, 2009). In the industrial organization literature, in contrast, analysts view firm growth as a necessary condition for firm survival, innovation, and technological change (Aghion, Fally and Scarpetta, 2007; Pagano and Schivardi, 2003; and Yazdanfar, 2013). As Geroski (1995) famously states, “entry is easy, but survival is not”. Firm growth is also viewed as path-dependent and persistent. As Nelson and Winter (1982) describe the evolutionary approach to industrial dynamics, “success breeds success, and failure breeds failure”.

The early contributions of Gibrat (1931) and Penrose (1959) still dominate the field.<sup>1</sup> The Penrose (1959) resource-based theory of growth, which underlines a great deal of the strategic management and entrepreneurship literatures, implies that growth depends primarily on

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<sup>1</sup> The dynamic theory of firm movements traces back to Alfred Marshall. In *Principles of Economics*, Marshall discusses the entry of firms, their growth, and, finally, their decline and exit. This process is captured by his famous analogy of firms in the economy as “trees in the forest.” Firms, like trees in the forest “struggle upwards through the benumbing shade of their older rivals. Many succumb on the way, and a few only survive...One tree will last longer in full vigor and attain a greater size than another; but sooner or later age tells on them all” (Marshall, 1925, 316). The dynamic approach perhaps finds its best association with the work of Joseph Schumpeter on “creative destruction.” This approach sees innovations as the vehicle of growth (Schumpeter, 1934).

idiosyncratic configurations of internal resources. Internal resources and capabilities determine strategic choices and become in the resource-based view of strategic management and entrepreneurship firm-specific, not capable of easy imitation or replication by rivals (Combs and Ketchen, 1999; Barney, 1991; and Barney, Wright and Ketchen, 2001).<sup>2</sup> As such, they generate Ricardian rents that comprise a firm's competitive advantage and imply a sustainable advantage over the longer run.

In contrast to this view from strategy and entrepreneurship, the industrial organization literature sees firm growth as based on stochastic models, where growth follows a random walk process.<sup>3</sup> The classic paper by Gibrat (1931) provides the foundation of this line of research in industrial organization. Gibrat's law, originally formulated in *Les Inégalités économiques* (Gibrat, 1931), provides the benchmark of an extensive literature on firm growth and one of the most conflicting and relentlessly explored issues in the industrial organization literature in economics. According to Gibrat's law, firm growth reflects random shocks (Goddard, McMillan and Wilson, 2006) and firm size and/or firm history do not determine how firms will grow or decline in the future. In a nutshell, Gibrat's law predicts that since firm growth does not depend

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<sup>2</sup> Such resources and capabilities include business models (Cavalcante, Kesting and Ulhoi, 2011), market orientation (Cambra-Fierro, Florin, Perez, and Whitelock, 2011), governance modes (Cantarello, Nosella, Petroni, and Venturini, 2011), management practices and organizational processes (Hotho and Champion, 2010), the dynamic capability of the firm (Goktan and Miles, 2011), the decision making process within the firm (van Riel, Semeijn, Hammedi, and Henseler, 2011), innovative orientation (Rowley, Baregheh and Sambrook, 2011), knowledge and experience of certain employees (Sommer and Haug, 2011), organizational knowledge and management skills (Sitlington and Marshall, 2011), efficient procedure within the firm (Wernerfelt, 1984), firm culture (Barney, 1986; Lee, Lim and Pathak, 2011; and Naranjo-Valencia, Jimenez-Jimenez and Sanz-Valle, 2011), human and social capital (Jansen, Curseu, Vermeulen, Geurts and Gibcus, 2013), social trust (Bergh, Thorgren and Wincent, 2011), and trade contracts (McKelvie and Wiklund, 2010; and Wernerfelt, 1984).

<sup>3</sup> One recent way to explain randomness in the firm growth rate uses the Gambler's Ruin problem, as described in Coad, Frankish, Roberts, and Storey (2013). Firms act like gamblers playing around a table, each of them stocked with individual resources at the start of the game and the outcome of the game (growth of resource stock) follows a purely random process. Players (firms) cannot learn how to actually win the game, since it is a game of chance. When using this framework, the results do confirm that growth paths measured over 4 growth periods closely approximate a random walk. As Coad, Frankish, Roberts, and Storey (2013) suggest, perhaps one point exists, when firms get experience, that they exert more control over their performance.

on firm size and firm history, the logarithm of firm size follows a random walk. Firms are endowed with an initial endowment of resources that determine firm capabilities, technology, and social and financial capital (Helfat and Liberman, 2002) that over time accumulate or deplete by a series of independent random draws from a Gaussian distribution, which generate a composite measure of firm size and firm growth (Coad, Frankish, Roberts and Storey, 2013).

Gibrat (1931) promulgated a large literature<sup>4</sup> which extended the basic stochastic model of firm growth to a multivariate framework. Empirical research using firm-level data identified a large amount of heterogeneity within industries as well as between firms within industries. This heterogeneity in firm growth rates appears in size, profitability, R&D intensity, capital structure, and other firm characteristics, and proves inconsistent with the proposition that growth follows a random and erratic process, as argued by Gibrat's law.<sup>5</sup>

The firm growth research mainly focuses on the manufacturing sector (Hymer and Pashigan, 1962; Hall, 1987; Geroski 1995; Wilson and Morris, 2000; Coad, 2009; Oliveira and Fortunato, 2006; and Fotopoulos and Giotopoulos, 2010), whereas a limited number of studies consider the service sector (Audretsch, Klomp, Santarelli and Thurick, 2004; Fotopoulos and Louri, 2004; Oliveira and Fortunato, 2008; and Giotopoulos and Fotopoulos, 2010), the financial sector (Alhadeff and Alhadeff, 1964; Rhoades and Yeats, 1974; Tschoegl, 1983; Vander Venet,

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<sup>4</sup> Earlier studies (e.g., Hart and Prais, 1956; and Hymer and Pashigian, 1962) as well as more recent ones (e.g., Klette and Griliches, 2000; Geroski and Machin, 1993; Pfaffermayr and Bellak, 2000; Lensink, van Steen and Sterken, 2000; Geroski, Lazarova, Urga and Walters, 2003; and Haltiwanger, Jarmin, and Miranda, 2013) find support for Gibrat's law. By contrast, however, other earlier studies (e.g., Mansfield, 1962; Samuels, 1965; Prais, 1976; Kumar, 1985; and Hall, 1987) and more recent ones (e.g., Dunne, Roberts and Samuelson, 1989; Dunne and Hughes, 1994; Tschoegl, 1996; Reid, 1995; Audretsch, Santarelli and Vivarelli, 1999; Faggio and Konings, 1999; Hart and Oulton, 1996; and Almus and Nerlinger, 2000) find no support for the law. Mixed results appear in the earlier and later literature (Singh and Whittington, 1975; Acs and Armington, 2001; Heshmati, 2001; Delmar, Davidson and Gartner, 2003; Piergiovanni, Santarelli, Klomp and Thurik, 2003).

<sup>5</sup> For recent literature surveys on empirical studies of firm growth, see Sutton (1997), Trau (1996), Caves (1998), Geroski (1999), Santarelli, Klomp and Thurik (2006), and Coad and Hölzl (2012).

2001; Wilson and Williams, 2000; Hardwick and Adams, 2002; and Goddard, Molyneaux and Wilson, 2004), and the real estate industry (An, Cook and Zumpano, 2011).

Understanding how firms grow, especially how small firms grow, is an important issue. Knowledge of the economic determinants of firm growth can provide insights into the dynamics of the competitive process, strategic behavior, the evolution of market structure, and ultimately, about the growth of the aggregate economy (Carpenter and Petersen, 2002). Despite the vast literature, however, little work examines within a rigorous empirical framework the determinants of firm growth in the ICT industry in the United States.<sup>6</sup> This is rather surprising, since many ICT firms have witnessed spectacular growth, and, more specifically, given the crucial role of the ICT sector in the aggregate growth of the United States and world economies (Kraemer and Dedrick, 2001; Schreyer, 2000; Dewan and Kraemer, 2000; Ketteni, 2009; Jorgenson and Stiroh, 2000; and Oliner and Sichel, 2000).<sup>7</sup>

The ICT industry is the largest, most dynamic, most ubiquitous (Andersen and Coffey, 2011), fast-paced, innovative, and productive of all U.S. industries (Fine, 1998, and Mendelson

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<sup>6</sup> Yang and Huang (2005) and Liu, Tsou and Hammitt (1999) document the relationship between R&D, firm size, and growth rates for the electronics industry in Taiwan. Liu, Tsou and Hammitt (1999), using the OLS and fixed-effects models, provide evidence of an inverse relationship between firm growth and size. Yang and Huang (2005), using GMM models, find that an increase in R&D expenditure induces higher growth. Furthermore, they show that, contrary to Gibrat's law, smaller firms grow faster than larger firms, while size does not depend on firm growth in large firms, in support of Gibrat's law. Das (1995) examines the relationship between firm growth and size for the computer hardware sector in India. Using both fixed-effects and random-effects model, Das (1995) finds that both current size and lagged size negatively affect growth. Using difference GMM and system GMM models, Corsino and Gabriele (2011) document that firm growth in the global integrated circuits sector negatively relates to size. Using a strategy approach, Bothner (2005) documents the size-growth link in the global computer industry. De and Dutta (2007) detail the role of organizational capital in the IT software industry in India using system GMM.

<sup>7</sup> Studies in the 1980s found no connection between IT investment and productivity in the U.S. economy, a situation referred to as the "productivity paradox" (Brynjolfsson, 1993; and Dedrick, Gurbaxani and Kraemer, 2003). Since then, a decade of studies at the firm and country level has consistently shown that the effect of IT investment on labor productivity and economic growth is significant and positive. Jorgenson (2003) shows that the growth of IT investment jumped to double-digit levels after 1995 in all the G7 economies -- Canada, France, Germany, Italy, Japan, the United Kingdom, as well as the United States. These economies account for nearly half of world output and a much larger share of world IT investment. The surge of IT investment after 1995 resulted from a sharp acceleration in the rate of decline of prices of IT equipment and software. Jorgenson (2001) traces this outcome to a drastic shortening of the product cycle for semiconductors from three years to two years, beginning in 1995. For a survey of these studies, see Dedrick, Gurbaxani, and Kraemer (2003).

and Pillai, 1998, 1999), and its effects run well beyond the boundaries of the industry itself, if such boundaries even exist (Mendelson and Whang, 2000).<sup>8</sup> The ICT industry experienced unprecedented progress over the last several decades, expanding from plain old telephone service (POTS) to advanced fiber optics, cable, and wireless technologies. Yet, the ICT industry is still not full grown, still retaining significant opportunities for innovation and growth (Andersen and Coffey, 2011). The ongoing development of 5G wireless technologies represents a unique opportunity to radically expand the capacity and flexibility of wireless networks, which will profoundly influence broadband competition and productivity growth.

In 2009, the ICT industry contributed \$1 trillion to U.S. GDP, or 7.1% of GDP, including \$600 billion from the sector itself and \$400 billion in benefits to other sectors that rely on ICT (Shapiro and Mathur, 2011). The ICT sector's direct contributions to GDP have increased 25% since the 1990's, growing from 3.4 percent in 1991-1993 to 4.2 percent in 2005-2009, the highest gains of any industry sector (Shapiro and Mathur, 2011). Over the last two decades, the development and use of IT has accounted for as high as 60 percent of annual U.S. labor productivity gains, and estimates imply that a 1 percent increase in broadband deployment can create as many as 300,000 new jobs. The National Research Council reports that the ICT industry accounted for 25 percent of U.S. economic growth from 1995 to 2007, measured as real change in GDP (President's Council of Advisors on Science and Technology (PCAST), 2007).

The ICT sector is one of the most R&D-intensive sectors its growth significantly depends upon technological innovations. ICT firms operate in an increasingly "knowledge-based"

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<sup>8</sup> Using the North American Industrial Classification System (NAICS), the ICT industry is defined as the sum of ICT manufacturing (NAICS 334: Computers and Electronic Products, including Computer and Peripheral Equipment, Communication Equipment and Semiconductors), and ICT services (NAICS 5112: Software Publishers; NAICS 517: Telecommunications, including Wired and Wireless Telecommunications; NAICS 518: Data Processing, Hosting, and Related services; NAICS 5415: Computer Systems Designs and Related Services; and NAICS 51: Information), excluding traditional paper publishing.

economy, and the survival of ICT firms depends, more than any other firms, on their capacity to innovate. Innovation, in particular, “radical innovation” (Leifer, McDermott, O’Connor, Peters and Veryzer, 2000), proves critical to the growth of ICT firms, since it enables them to remain competitive in an ever-changing landscape of products and services. “Radical innovation”, as opposed to “incremental innovation”, is an important and enduring characteristic of the ICT industry (Leifer, McDermott, O’Connor, Peters, and Veryzer, 2000). In the literature of innovation management, radical innovations transform market structures and reinvent industries, moving them towards a new competitive landscape through a Schumpeterian process of creative destruction. R&D investment is one of the main factors that affects the rate of, and capacity for, innovation.<sup>9</sup> ICT firms operate in an uncertain environment, which mirrors, in varying degrees, the inherent uncertainty of their R&D activity. ICT firms make large, risky investments in inventive activity, where outcomes are unpredictable, idiosyncratic, and long-term in nature (Anderson, Banker and Ravindran, 2000). Moral hazard problems, in particular, may be amplified by the inherent uncertainty of the R&D investment (Guiso, 1998; and Coad and Rao, 2008).

The ICT sector accounts for a large share of R&D expenditures in the United States. The Business R&D and Innovation Survey (BRDIS) reports \$323 billion of R&D performed in 2013,

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<sup>9</sup> Public policies, including monetary policy, tax policy, regulatory policy, and the availability of a skilled technical workforce, are also important in establishing an environment that fosters innovation. Mohnen, and Röller (2005) explores the complementarities between R&D and workers education. ICT sector innovation capabilities depend crucially on its employees' skill levels. Only highly skilled workers, who can keep pace with technological change, can generate innovations in the ICT industry. Thus, a skilled workforce is at the heart of the ICT sector. The debate on the need for a highly skilled workforce in the ICT industry has entered the policy-making domain with industry leaders lobbying the Congress to relax visa restrictions on skilled foreign nationals, who can work in ICT related jobs. See <http://www.npr.org/templates/story/story.php?storyId=88154016>. They argue that these skilled workers are crucial for the United States to maintain its position as a global leader in ICT innovation. Recently, the U.S. Department of Homeland Security relaxed its visa policies for foreign science and engineering graduates so that they can work in the United States for an additional period of 17 months after completing their education in the United States. See [http://www.ice.gov/sevis/updates\\_postcompletion\\_opt.htm#8](http://www.ice.gov/sevis/updates_postcompletion_opt.htm#8). The U.S. government also provided for 20,000 additional work visas to foreign nationals who completed their post-graduate education in the United States. In short, much anecdotal evidence exists suggesting that the ICT sector firms seek highly skilled workers.



where the ICT sector accounted for 41 percent (\$133 billion).<sup>10</sup> In the United States, the ICT manufacturing and the ICT services sectors recorded approximately the same amount of R&D spending, accounting for 20.8 and 20.5 percent, respectively, of total R&D spending in 2013. The R&D activity in the ICT industry in the United States is highly labor-intensive, as reflected in labor costs, which accounted for 76 and 67 percent of R&D expenditures paid for by ICT services and ICT manufacturing industries, respectively, in 2013. Computer system design and related services (NAICS 5415) proves the most labor-intensive in R&D spending, with labor costs accounting for 83 percent of R&D expenditures. In comparison, the aerospace industry and the pharmaceutical and medical industries spend less than 40 percent of their R&D expenditures on labor costs.

This paper contributes to the firm growth literature in three ways. First, to the best of our knowledge, this is the first study of ICT firm growth in a dynamic framework, which fills the gap in the Gibrat's law literature, by examining the size-growth relationship in the ICT industry in the United States. Of all the studies examining Gibrat's law in the United States, none provides an analysis specific to IT firms.

Second, this paper complements the existing literature by broadening the latitude of the analysis on stochastic firm growth. Specifically, we bring together, within the context of Gibrat's law, two different perspectives on firm growth. On the one hand, we rely on the industrial organization literature (Comanor, 1965; Mansfield, 1968; Hall, 1987; Amirkhalkhali and Mukhopadhyay, 1993; and Klette and Griliches, 2000) and, in particular, the newly developed microeconomics of R&D-based endogenous firm growth (Pakes and McGuire, 1994; Ericson and Pakes, 1995; Pakes and Ericson, 1998; Thompson, 2001; Klette and Kortum, 2004; and

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<sup>10</sup> This is 2.5 times the amount spent by the pharmaceutical manufacturing industry, the single largest industry in terms of R&D expenditures.

Laincz, 2005, 2009), which emphasizes the importance of R&D as a mechanism of firm growth. On the other hand, we rely on the corporate finance literature (Jensen and Meckling, 1976; Myers, 1977; Myers and Majluf, 1984; Stein, 2003; Aivazian, Ge and Qiu, 2005; and Khurana, Martin and Pereira, 2006), which suggests that capital structure, corporate debt, and agency costs caused by conflicts of interest and informational asymmetries between corporate insiders, shareholders and debt holders, affect financial decisions, investment decisions, and firm performance, including profitability and growth. The role of agency costs in deterring firm growth has not been previously analyzed in this line of research.

Third, we use an autoregressive dynamic panel model and apply the two-step Blundell-Bond GMM estimator (Blundell and Bond, 1998) to assess the validity of Gibrat's law in the ICT industry and estimate the relationship between firm growth and agency costs, debt and capital structure, R&D investment, and financial performance. We use an unbalanced panel of 85 ICT industry, publicly listed, U.S. surviving firms over the period 1990-2013. The Blundell-Bond two-step GMM estimator avoids the shortcomings of the traditional panel-data approach, such as pooled Ordinary Least Square (OLS) or fixed-effects (FE) estimators, provides a convenient framework for obtaining asymptotically efficient estimates in dynamic panel-data models, and controls for four critical econometric issues, endogeneity, unobserved heterogeneity, heteroskedasticity, and persistence. The estimator uses a stacked system of equations in first differences and equations in levels, and uses lagged first differences as instruments for the equations in levels as well as lagged levels as instruments for the equations in differences. We also control for the effects of the Great Recession (Fort, Haltiwanger, Jarmin, Miranda, 2013; and Perić and Vitezić, 2016).

Our main conclusion notes that growth in the ICT industry is not stochastic, but driven by systematic factors. In particular, our findings reveal that in the ICT industry: (i) firm growth exhibits a positive and significant persistence; (ii) agency costs and financial leverage exert a significantly negative effect on firm growth; (iii) R&D investment and financial performance possess a significantly positive effect on firm growth; (iv) the Great Recession (the 2007-2009 recession) caused a significantly negative effect on firm growth; (v) firm size exerts a significantly positive and, contrary to most findings in the literature, non monotonic, inverted U-shaped effect on firm growth; and, finally, (vi) Gibrat's law does not hold. Our results contain significant policy implications in that they suggest that the growth dynamics of the ICT industry leads to more concentration and less competition.

The rest of the paper is organized as follow. In section 2, we review the literature on stochastic models of firm growth in the tradition of Gibrat's law and outline our main research hypotheses. In section 3, we describe the data and discuss the relevant summary statistics. In section 4, we specify the baseline empirical model and summarize the main aspects of the system GMM methodology. We present and discuss in Section 5 the empirical findings identified by the system GMM estimator. The final section concludes and offers some further remarks.

## **2. Theoretical background and hypotheses development**

This section reviews the relevant literature on the determinants of firm growth, some of which previous studies on stochastic models of firm growth did not consider<sup>11</sup> and develops a series of statistical hypotheses that define the role of systematic firm characteristics in explaining firm growth in the ICT industry within the context of Gibrat's law. The characteristics examined include: (1) agency costs; (2) research and development (R&D) expenditure, (3) firm size; (4)

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<sup>11</sup> See, for example, Coad (2007), Coad and Rao (2008), Hölzl (2009), Colombelli, Haned, and Le Bas (2013); Schimke and Brenner (2011), García-Manjón and Romero-Merino (2012), Oliveira and Fortunato (2006, 2008), and Del Monte and Papagni (2003).

growth persistence; (5) financial leverage; and (6) profitability. In addition, we evaluate the effect of the recent financial crisis and Great Recession (2007-2009) on firm growth.

## 2.1 Agency costs and growth

The corporate finance literature emphasizes the importance of information asymmetry and agency costs in influencing firm growth through the effect on the efficiency of firms' investments (Stein, 2003). Myers and Mailuf (1984) argue that information asymmetry increases the cost of external financing and may, therefore, force firms to forgo potentially profitable investments. As a result, internal resources constrain a firm's growth. Similarly, Myers (1977) identifies a "debt overhang" problem, where managers may forgo positive net present value (NPV) projects in the presence of risky debt. Our measure for agency costs equals the ratio of annual sales to total assets, which measures asset utilization. This ratio was first used in the agency context by Ang, Cole and Lin (2000) and was later adopted by Singh and Davidson (2003), Fleming, Heaning and McCosker (2005), and Florackis and Ozkan (2009). The ratio measures how effectively management deploys the firm's assets. A high asset utilization ratio shows a large amount of sales and ultimately cash flow that a given level of assets generates. A low asset utilization ratio, on the other hand, indicates that management uses assets in non-cash generating activities and asset deployment for unproductive purposes such as value destroying ventures and consumption of perquisites (Singh and Davidson, 2003). Therefore firms with considerable agency conflicts will show lower asset utilization relative to those with less agency conflict. This implies that asset utilization should vary inversely with agency costs. This leads to the following testable hypothesis regarding asset utilization and firm growth in the ICT industry:

*Hypothesis 1. Asset utilization in the ICT industry exerts a positive effect on firm growth (i.e., by proxy, agency costs exert a negative effect on firm growth).*

## 2.2 Research and development (R&D) and growth

The evolutionary perspective argues that innovation drives firm performance and the evolution of industrial structure (Nelson and Winter, 1982). For a firm to survive in a Schumpeterian world, simply producing a given set of outputs, employing a given set of inputs with a given technology is not enough. Successful firms in the long term must develop innovation capabilities (i.e., a stock of technological knowledge) and profit from them (Nelson, 1991). Different endowments of innovation capabilities will eventually lead to persistent differences in the performance and growth of competing firms. While the stock of knowledge and the underlying learning processes through which the stock of knowledge accumulates are unobservable, the amount of R&D expenditure provides an indicator or a signal that these processes occur and can account for the differences in performance and growth across firms. The empirical literature generally finds a positive relationship between R&D expenditure and firm growth (Mansfield, 1962; Hall, 1987; Amirkhalkhali and Mukhopadhyay, 1993; Liu, Tsou and Hammitt, 1999; Yang and Huang, 2005; Del Monte and Papagni, 2003; and Adamou and Sasidharan, 2007). On the other hand, the literature also presents some evidence showing no effect of R&D expenditure on firm growth (Heshmati and Lööf, 2006; and Almus and Nerlinger, 1999). This leads to the following testable hypothesis regarding R&D intensity and firm growth in the ICT industry:

*Hypothesis 2. R&D intensity in the ICT industry produces a positive effect on firm growth.*

## 2.3 Firm size and growth

Firm size forms a building block in many models of firm growth. Most empirical results find a relationship between firm growth and firm size. Such a relationship contradicts Gibrat's law, which states that luck constitutes the main mechanism of firm growth (Scherer, 1970). Hall (1987), Evans (1987a, 1987b), Mata (1994), Cooley and Quadrini (2001), and Becchetti and Trovato (2002) find that firm growth inversely relates to firm size. This negative relationship implies that smaller firms grow faster than larger firms. In contrast, Singh and Whittington (1975) and Hart and Prais (1956) find that growth positively relates to firm size. Kumar (1985), Chen et al (1985) Acs and Audretsch (1990), Wagner (1992) and Fulton, Fulton, Clark, and Parliament (1995) find that firm growth does not relate to firm size, confirming Gibrat's law. Following the previous literature (Mehran, 1995, Fama and French, 2002; Frank and Goyal, 2009; Rahaman, 2011; Coluzzi, Ferrando and Martinez-Carrascal, 2015; and Wu and Yeung, 2012), we measure firm size as the natural logarithm of total assets, and firm growth as the first difference of firm size. Total assets commonly measure firm size and firm growth. By examining the growth of total assets, we capture a broad range of activities undertaken by the firm. As firms grow, they expand not only their physical capital, but also their gross working capital (e.g., inventories, cash and equivalents, and accounts receivable). Growth can also occur through mergers and acquisitions (M&A) and firms can shrink through the divestiture of assets. Total assets are defined as the sum of current assets, net property, plant and equipment, and other noncurrent assets (including intangible assets, deferred items, and investments and advances). We posit two testable hypotheses regarding firm size and firm growth in the ICT industry. The first hypothesis states:

*Hypothesis 3a. Firm size linearly affects firm growth.*

The second hypothesis relies on the work of Hall (1987), Evans (1987a, 1987b), and Dunne and Hughes (1994), who find that a highly nonlinear relationship exists between firm size and firm growth. Thus, the second hypothesis states:

*Hypothesis 3b. Firm size nonlinearly (quadratically) affects firm growth.*

## 2.4 Growth persistence

Does firm growth persist over time? Ijiri and Simon (1967), Singh and Whittington (1975), Kumar (1985), Chesher (1979), Wagner (1992), Geroski et al. (1997), and Bottazzi and Secchi (2003) find positive growth persistence. On the contrary, Oliveira and Fortunato (2006) and Goddard, Wilson, and Blandon (2002) finding evidence of negative persistence, implying a pattern of oscillating growth, in which growth and decline alternate with each other. Finally, Coad and Hölzl (2009), Oliveira and Fortunato (2008), and Goddard, McKillop and Wilson (2002) find no evidence of growth persistence. We measure growth persistence using the first lag of firm growth. We expect that Gibrat's law does not hold and that firm size affects growth, which exhibits persistence.<sup>12</sup> This leads to the following testable hypothesis regarding persistence and firm growth in the ICT industry:

*Hypothesis 4. Firm growth in the ICT industry exhibits persistence.*

## 2.5 Financial leverage and growth

Financial theories (Myers and Majluf, 1984; and Demircuc-Kunt and Maksimovis, 1998) highlight the effect of financial considerations in firm dynamics. Many empirical studies regard the lack of financial resources as an important barrier to firm growth (Audretsch and Elston,

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<sup>12</sup> Hart (2000) argues that the degree of serial correlation of growth may indicate the relative importance of systematic and stochastic factors in firm growth. He suggests that systematic factors should produce persistent firm growth and, hence, a high degree of serial correlation.

2002; Becchetti and Trovato, 2002; Müller and Zimmerman, 2009; and Oliveira and Fortunato, 2006). The financing constraint literature highlights the roles of financial measures, such as profitability and financial leverage, in explaining the dynamics of firm growth (Oliveira and Fortunato, 2006). Leverage affects firm growth through the external financing channel, while profitability affects firm growth through the internal financing channel. Huynh and Petrunia (2010) find a positive and nonlinear relationship between firm growth and leverage; on the other hand, Land, Ofek and Stulz (1996) find a strong negative relationship between leverage and firm growth, as leverage slows down the growth of investment. Both Huynh and Petrunia (2010) and Lang, Ofek and Stulz (1996) define leverage as total debt divided by total assets. They use different datasets, however. Huynh and Petrunia use a dataset (1984-1998) of small private firms, while Lang, Ofek and Stulz (1996) use a data set (1970-1989) of large U.S. public firms. From the agency cost perspective, leverage associates with moral hazard behavior (Jensen and Meckling, 1976; and Stulz, 1990). Thus, lower debt financing associates with less moral hazard and higher firm growth. Myers (1977) argues that leverage exerts a negative effect on investment because of an agency problem between shareholders and bondholders. The theories of Jensen (1986), Stulz (1990), and Grossman and Hart (1982) also suggest a negative relationship between leverage and investment, but their arguments rely on agency conflicts between managers and shareholders. Bryan, Hwang and Lilien (2000) and Yermack (1995) use firm leverage as a proxy for all agency debt problems. Thus, agency theory predicts a negative relationship between leverage and investment and, therefore, a relationship between leverage and firm growth. This leads to the following testable hypothesis regarding financial leverage and firm growth in the ICT industry:



*Hypothesis 5. Financial leverage in the ICT industry causes a negative effect on firm growth.*

## 2.6 Profitability and growth

Profitability generally proxies for financial resources of the firm that boost growth. Profits play a dominant role in the firm's capacity to access resources, since it simultaneously provides a source of internal financing and a direct mechanism to attract external sources of financing (Chen, Babb, and Schrader, 1985). With a few exceptions, some show a negative effect of profits on growth (Markman and Gartner, 2002; Reid, 1995; and Lee, 2014) and others show a rather limited influence of profits on growth (Coad, 2007; Bottazzi, Dosi, Jacoby, Secchi and Tamagni 2010; and Delmar, McKelvie and Wennberg, 2013), most empirical work (Brush, Bromiley and Hendrickx, 2000; Capon, Farley and Hoening, 1990; Cho and Pucik, 2005; Cowling 2004; and Jang and Park, 2011) find that profitability exerts a positive effect on firm growth. This finding proves consistent with Alchian's theory of the firm (Alchian, 1950), the evolutionary view of the firm (Nelson and Winter, 1982), and the resource-based view of the firm (Barney, 1991). The financing constraint theory (Goldratt, 1990) and the pecking order theory (Myers and Majluf, 1984) are also consistent with the finding of a positive effect of profitability on growth. The financing constraint theory argues that non-profitable firms do not possess a buffer, as retained earnings, available for investment, and cannot finance their growth or, at least, their sustainability and will finally disappear. In the pecking order theory, firms take the course of least resistance, obtaining financing from readily available sources, such as retained earnings, before moving on to more difficult to use sources, such as debt. We use return on equity (ROE) to measure profitability, which equals the ratio of net profit to common equity. This leads to the following testable hypothesis regarding firm profitability and firm growth in the ICT industry:

*Hypothesis 6. Profitability (ROE) in the ICT industry generates a positive effect on firm growth.*

## 2.7 The Great Recession and growth

The cyclical dynamics of the economy, in the form of the business cycle, is a contextual factor that can explain firm growth (Oberhofer, 2012; and Fort, Haltiwanger, Jarmin and Miranda 2013). The literature documents that the Great Recession and the global financial crisis produced, in addition to the obvious macroeconomic effects, significant microeconomic repercussions, which resulted in adverse outcomes on production (Liu, 2009), sales (Cowling, Liu, Ledger and Zhang, 2015), investment (Campello, Graham and Harvey, 2010), and performance (Akbar, Rehman and Ormrod, 2013; Perić and Vitezić, 2016). All these repercussions, in turn, exert a negative effect on firm growth.<sup>13</sup> This leads to the following testable hypothesis regarding the Great Recession and firm growth in the ICT industry:

*Hypothesis 7. The 2007-2009 Great Recession produced a negative effect on firm growth in the ICT industry.*

## 3. Data and descriptive analysis

We use firm-level annual data from 85 ICT firms that managed to survive over the period 1990-2013. We obtain our sample from the Standard and Poor's COMPUSTAT Annual North America database (Economic Sector Code: 8000). We do not isolate outliers, such as firms with very high growth rates, as this procedure associates with the risk of excluding firms with truly high growth

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<sup>13</sup> Claessens, Djankov and Xu (2000) studied corporate performance in the East-Asian financial crisis on a sample of more than 850 publicly listed firms in the four crisis countries (Indonesia, Malaysia, the Republic of Korea, and Thailand) and two comparators (Hong Kong and Singapore). They compared the growth and financing patterns of East-Asian corporations in the years before the crisis with those in other countries and found little microeconomic evidence that corporate growth weakened. They found some support, however, for the argument that many firms possessed a weak financial structure that left them vulnerable to an economic downturn. They claim that firm-specific weaknesses that already existed before the crisis were important factors in the deteriorating performance of the corporate sector.

rates. We also do not put any restrictions on a minimum amount of sales as this procedure associates with the risk of excluding firms that are nascent. The data constitute an unbalanced panel, and comprise seven sectors of the ICT industry: 1) Telecommunication Equipment (8030); 2) System Software (8140) and Application Software (8130); 3) Semiconductors (8230) and Semiconductor Equipment (8220); 4) Computer Hardware (8050) and Computer Storage and Peripherals (8052); 5) Electronic Manufacturing Services (8200) and Consulting Services (8120); 6) Electronic Equipment and Instruments (8150); 7) Technology Distributors (8210). The COMPUSTAT industry sector codes appear in parentheses.

Table 1 provides the ICT industry distribution of the sample. Semiconductors and Semiconductor Equipment, the largest category, comprises 22% of the sample. Electronic Equipment and Instruments and Electronic Manufacturing Services and Consulting Services comprise 21% and 18% of the sample, respectively. The smallest industry category, Technology Distributors, comprises 4% of the sample.

Table 2 reports summary statistics of the relevant variables over the entire sample period (1990-2013). They include the mean, the standard deviation, and the minimum and maximum values. We compute firm growth (GROWTH) as the first difference in the logarithm of total assets (COMPUSTAT number 6). The minimum and maximum values of the firm growth are -105% (Electronic Equipment and Instruments) and 172% (Telecommunication Equipment), with an average of 9.7%. We compute return on equity (ROE) as income before extraordinary items (COMPUSTAT item no. 18) divided by common equity (COMPUSTAT item no. 60). ROE has a minimum of -492% (Electronic Equipment and Instruments) and a maximum of 261% (Technology Distributors) with an average of 6.6%. We compute total assets (TOTAL ASSETS) (COMPUSTAT number 6) as the sum of current assets, net property, plant and equipment, and

other noncurrent assets (including intangible assets, deferred items, and investments and advances). Total assets (in millions of dollars) has a minimum of \$1.36 (Electronic Manufacturing Services and IT Consulting Services) and a maximum of \$114,288 (Electronic Equipment and Instruments). Net sales (in millions of dollars) (COMPUSTAT item no. 12) equals the amount of sales after the deduction of returns, allowances for damaged or missing goods, and any discounts allowed. Net sales has a minimum of \$0.42 (Electronic Equipment and Instruments) and a maximum of \$127,245 million (Computer Hardware and Computer Storage and Peripherals). The natural logarithm of total assets equals firm size (SIZE). We compute asset utilization (ASSET UTILIZATION) equals net sales (COMPUSTAT item no. 12) divided by total assets (COMPUSTAT item no. 6). The asset utilization ratio has a minimum of 1.3% (Electronic Equipment and Instruments) and maximum of 378% (Electronic Manufacturing Services and IT Consulting Services) with a mean of 110%. We compute leverage (LEVERAGE) equals the sum of long-term debt (COMPUSTAT item no. 9) and short-term debt (COMPUSTAT item no. 12) divided by total assets (COMPUSTAT item number 6). The leverage ratio has a minimum of 0% (Computer Hardware and Computer Storage and Peripherals; Electronic Manufacturing Services and IT Consulting Services; Electronic Equipment and Instruments) and a maximum of 92.3% (Technology Distributors) with an average of 56%. We compute R&D intensity (R&D INTENSITY) equals R&D expenditure (COMPUSTAT item no. 46) divided by net sales (COMPUSTAT item no. 12). R&D intensity has a minimum of 0% for one or more firms (in all industries except Telecommunication Equipment, and Semiconductors and Semiconductor Equipment) and a maximum of 277% for one firm (Electronic Equipment and Instruments) with an average of 9.4% across all firms. The

large range of maximum and minimum values for all variables shows that the sample covers both large and small firms.

Sector-specific comparisons reveal that the average growth rate is highest in the System Software and Application Software sector (15.35%) and lowest in the Electronic Equipment and Instruments sector (5.62%). The average ROE is highest in the System Software sector (15.55%) and lowest in the Electronic Equipment and Instrument sector (0.00%). The average asset utilization ratio is highest in the Technology Distributors sector (252.81%), and lowest in the System Software and Application Software sector (84.63%). The average debt-to-asset ratio (leverage) is highest in the Computer Hardware and Computer Storage and Peripherals (50.23) and lowest in the Semiconductors and Semiconductor Equipment sector (30.02%). R&D intensity is highest in the Semiconductors and Semiconductor Equipment sector (14.9%), and lowest in the Technology Distributor sector (0.31%).

#### **4. Empirical methodology**

We consider an autoregressive dynamic panel model of order one of the type:

$$y_{i,t} = \alpha y_{i,t-1} + X_{i,t}\beta + \gamma_t + \mu_i + \varepsilon_{i,t}, \quad (1)$$

where the subscripts  $i$  and  $t$  denote firm and year, respectively,  $y_{i,t}$  is firm growth,  $y_{i,t-1}$  is one-period lagged firm growth,  $X_{i,t}$  is a matrix of explanatory variables,  $\gamma_t$  and  $\mu_i$  are, respectively, a time-specific and firm-specific effect. The most commonly used firm-specific effect is a fixed (within-group) effect, because a random effect assumes an independent distribution of the explanatory variables from the individual effects, an assumption that is violated between  $y_{i,t-1}$  and  $\gamma_t$ . The time-specific effect (common to all firms and specific to each time period) is a row vector of year dummy variables. The last term in equation (1),  $\varepsilon_{i,t}$ , is the idiosyncratic random

disturbance, assumed independent and identically distributed with mean 0 and variance  $\sigma_\varepsilon^2$  both over time and across firms. Autoregressive dynamic panel models such as equation (1) have become increasingly popular in the last two decades due, in part, to the increased availability of micro level data (e.g., data for individuals, households, or firms). The identification of economic relationships at the disaggregate level possess numerous advantages, including avoiding the serious problem of aggregation bias (Lippi and Forni, 1990).

Despite its growing importance, several econometric issues exist that relate to the dynamic panel model of equation (1) (Greene, 2012). Pooled Ordinary Least Squares estimation (OLS) fails to account for the time-series dimensions of the data and creates two major shortcomings: (i) it fails to account for the unobserved firm-specific (fixed) effects, which causes an omitted-variable bias (Nickell, 1981) that enters the error term; (ii) it fails to control for the potential endogeneity problem. Fixed Effects (FE) estimation controls for the unobserved time-invariant effects by first-differencing equation (1), which eliminates the time-invariant firm-specific effects  $\eta_i$  and its associated omitted-variable bias:

$$\Delta y_{i,t} = \alpha \Delta y_{i,t-1} + \Delta X_{i,t} \beta + \Delta \varepsilon_{i,t} \quad (2)$$

The differenced error term  $\Delta \varepsilon_{i,t}$  (i.e.,  $\varepsilon_{i,t} - \varepsilon_{i,t-1}$ ), however, which is now by construction an MA(1), is correlated with  $\Delta y_{i,t-1}$  (i.e.,  $y_{i,t-1} - y_{i,t-2}$ ), since they both include  $\varepsilon_{i,t-1}$ . Thus, FE (as well as OLS) on the first differences in a dynamic panel produces inconsistent parameter estimates because  $E(\Delta y_{i,t-1} \Delta \varepsilon_{i,t}) \neq 0$ . Moreover, the FE estimator does not address the endogeneity problem either.

The most widely used alternatives to the pooled OLS and FE estimation are the dynamic panel GMM estimators, which are specifically designed to capture the joint endogeneity of the

lagged dependent variable and other explanatory variables by creating a matrix of internal instruments. The dynamic panel GMM estimators generalize the Anderson and Hsiao (1992) IV estimator that uses  $y_{i,t-2}$  as an instrument for  $\Delta y_{i,t-1}$ . This is a valid approach because  $y_{i,t-2}$  is correlated with  $\Delta y_{i,t-1}$ , but not with  $\Delta \varepsilon_{i,t}$ , i.e.,  $E(y_{i,t-2} \Delta \varepsilon_{i,t}) = 0$ , but is not efficient, since it does not use all the available instruments.

The GMM method for dynamic panel data (Arellano and Bond, 1991; Arellano and Bover, 1995; and Blundell and Bond, 1998) provides an adequate and more convenient framework for obtaining asymptotically efficient results in this context. This methodology handles important modeling concerns, in particular, unobserved heterogeneity and endogeneity of regressors, while avoiding the dynamic panel bias (Nickell, 1981). Moreover, it accommodates unbalanced panels and multiple endogenous variables.

Two types of GMM estimators for dynamic panels exist: 1) the difference GMM estimator, developed by Arellano and Bond (1991), and 2) the system GMM estimator, developed by Blundell and Bond (1998).<sup>14</sup>

The difference GMM estimator uses lagged values in levels as instruments of the variables in differences and requires that the error term does not have second-order autocorrelation. Specifically,

$$E[y_{i,t-s}(\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \text{ for } s \geq 2 \text{ and } t = 3, \dots, T \quad (3)$$

and

$$E[X_{i,t-s}(\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \text{ for } s \geq 2 \text{ and } t = 3, \dots, T \quad (4)$$

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<sup>14</sup> Each estimator, in turn, has two versions: the one-step version, which corresponds to the homoskedastic case, and the two-step version, in which the standard covariance matrix remains robust to panel-specific autocorrelation and heteroskedasticity. The two-step system GMM estimator, however, produces downward biased standard errors. Windmeijer (2005), however, proposes corrected standard errors using a finite-sample correction.

A well-known problem, however, with the difference GMM estimation is that it suffers from the "weakness" of its instruments, resulting in poor finite sample properties in terms of bias and consistency. Specifically, the lagged values of the explanatory variables provide "weak" instruments for the equation in first differences (Arellano and Bover, 1995). Additionally, differencing may reduce the power of the tests by reducing the variation in the explanatory variables (Beck, Levine and Loayza, 2000), and exacerbate the effect of measurement errors on the dependent variable (Griliches and Hausman, 1986). Arellano and Bover (1995) argue that the absence of information concerning the parameters in the variables in levels causes substantial loss of efficiency in models estimated in first differences using instruments in levels. Arellano and Bover (1995) and Blundell and Bond (1998) argue that we can mitigate these shortcomings by including the equation in levels in the estimation procedure. Blundell and Bond (1998) further document that for short sample periods and persistent data, the difference GMM performs poorly and propose the system GMM estimator, which combines the equation in differences (equation 2) with the equation in levels (equation 1). The instruments for the equation in differences are the same as in the difference GMM (i.e., the lags in levels starting from lag 2 and beyond). For the equation in levels, which contains the fixed effects, the instruments are the lags in differences, which makes them exogenous to the fixed effects. Thus the system GMM estimator involves the estimation of a system containing both differenced and level equations, where lagged values in levels are used as instruments of the variables in differences, and lagged differenced values are used as instruments for variable in levels. The additional moment conditions requires that the unobserved firm-specific effects do not correlate with the explanatory variables in differences. That is,

$$E[(y_{i,t-1} - y_{i,t-2})(\mu_i + \varepsilon_{i,t})] = 0 \text{ for } s \geq 2 \text{ and } t = 3, \dots, T \quad (5)$$



and

$$E[(X_{i,t-1} - X_{i,t-2})(\mu_i + \varepsilon_{i,t})] = 0 \text{ for } s \geq 2 \text{ and } t = 3, \dots, T \quad (6)$$

The system GMM estimator, however, leads to the proliferation of instruments: the number of instruments grows quadratically with  $T$  and system GMM becomes inconsistent as the number of instruments becomes too large. Too many instruments leads to overfitting the model (Roodman, 2009b) and weakens the power of the tests. No guidance, however, exists in the econometric literature to determine when the instruments are "too many." Roodman (2009b) recommends as a rule of thumb that the number of instruments should not exceed the number of individuals (in our case, 85 firms). Two techniques exist to reduce the instrument count: one "collapses" the instrument set; the other limits (truncates) the lag depth. Both solutions make the instrument count linear in  $T$ . The "collapsing" solution consists of creating different instruments for each lag, but not each time period; the "limiting" solution consists of including as instruments only a few lags instead of all the available ones (Blundell, Bond and Windmeijer, 2000).<sup>15</sup>

## 5. Empirical results

We report the findings of the system GMM estimation for two dynamic panel models. The first model enters firm size into the regression in a linear fashion (Model 1), while the second model enters firm size in a quadratic form (Model 2). All the regressions use firm growth as the dependent variable, computed as the first difference of firm size. The explanatory variables in Model 1 include (a) the one-period lagged firm growth; (b) the one-period lagged SIZE; (c) the

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<sup>15</sup> Recently, a new approach to the problem of "too many" instruments in system GMM suggests the application of stochastic transformations rather than deterministic ones, more precisely the application of principal component analysis (PCA) to the set of GMM instruments (Mehrhoff, 2009; Kapetanios and Marcellino, 2010; and Bai and Ng, 2010). Principal components analysis (PCA) of the GMM instruments extracts the largest eigenvalues of the estimated covariance matrix of the GMM instruments (Doran and Schmidt, 2006) and assembles the corresponding principal components (eigenvectors) with the largest variance (eigenvalues). From an initial set of uncorrelated instruments, PCA creates a set of uncorrelated components, where each component is a linear weighted combination of the initial instruments. This technique reduces the number of instruments to a smaller set that reflects the original instruments without any loss of information.

one-period lagged R & D INTENSITY; (d) the one-period lagged ASSET UTILIZATION; (e) the one-period lagged LEVERAGE ; and (f) the one-period lagged PERFORMANCE , measured as return on equity (ROE). All explanatory variables enter with a lag because a contemporaneous relation with firm growth is difficult to justify. The one-period lag is also introduced to avoid any spurious correlation. We also include the dummy variable GREAT RECESSION that takes on value of 1 during the years of the Great Recession (2007-2009) and 0 otherwise. We use a set of year dummies to control for any macroeconomic shock other than the Great Recession and, thus, capture any unobserved heterogeneity across time and common to all firms.<sup>16</sup> In Model 2, the set of explanatory variables also includes the square of SIZE to capture possible non-linearity.

For each model, we estimate various specifications concerning the endogeneity of the explanatory variables, but report only the results of two specifications. The first specification posits that all explanatory variables, except firm size (Model 1A in the linear case) or firm size and firm size squared (Model 2A in the quadratic case), are endogenous and are internally instrumented. The second specification posits, instead, that all variables are endogenous, including firm size (Model 1B in the linear case) or firm size and firm size squared (Model 2B in the quadratic case), and are instrumented accordingly. We implement both the one-step and two-step system GMM estimators, but report only the results of the two-step system GMM estimator, which is generally more efficient than the one-step estimator, especially for system GMM. The robust standard errors (robust to heteroskedasticity and any arbitrary pattern of autocorrelation within firms) are reported in parentheses using the Windmeijer (2005) finite-sample correction. In all cases, to reduce the number of instruments and to avoid the dangers of instrument

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<sup>16</sup> The inclusion of a set of year dummies is a prudent step in GMM models, because the estimates of the coefficients' standard errors assume no correlation across firms in the idiosyncratic errors. Year dummies make this assumption more likely to hold.

proliferation, we use levels dated  $t-3$  and  $t-4$  in the equation in differences, and differences dated  $t-1$  and  $t-2$  in the equation in level, and “collapse” (Roodman, 2009a) the instrument set.

Table 3 and 4 report the main findings of system GMM estimation. Each table contains four columns corresponding to four different ways to deal with the data. We report in columns (1) and (3) the estimates using the first difference (FD) transformation, while we report in columns (2) and (4) the estimates based on the forward orthogonal deviation (FOD) transformation suggested by Arellano and Bover (1995).<sup>17</sup> The validity of system GMM hinges on statistical diagnostics. We include in each table five sets of diagnostic statistics. First, we report the Sargan and Hansen tests of overidentification. The system GMM estimator uses multiple lags as instruments. This means that our model is overidentified, which provides the opportunity to conduct a test of overidentification to see if the instruments are exogenous. We report both tests since the Sargan test, whilst not robust to heteroskedasticity, is not weakened by increasing numbers of instruments, whereas the Hansen test is robust to heteroskedasticity, but is weakened by using many instruments. Both tests yield a statistic that has a chi-square distribution under the null hypothesis that the instrument are orthogonal to the error term. A second set of statistics is the Arellano and Bond (1991) tests for first- and second-order serial correlation. The tests are applied to the residuals in differences. First-order serial correlation is expected in a dynamic panel, since the residuals in first differences should correlate by construction. The AR(2) test evaluates second-order serial correlation in differences, since

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<sup>17</sup> One drawback of the FD transformation is that in unbalanced panels it, magnifies the gaps. If an observation in a panel is missing, then in the first difference data, the first difference at  $t$  and  $t+1$  are also missing, since they cannot be computed. In contrast to the FD transformation, which subtracts the previous value from the current value, the FOD transformation subtracts the average of all available future observations from the current value. While the FD transformation drops the first observation on each individual in the panel, the FOD transformation drops the last observation for each individual in the panel, but can be computed even in the presence of gaps in the panel. Hayakawa (2009) compares the performances of the GMM estimator of dynamic panel model wherein individual effects are removed by the forward orthogonal deviations or the first differences. The simulation results indicate that the GMM estimator of the model transformed by the forward orthogonal deviations tends to work better than that transformed by the first differences.

second-order serial correlation in differences indicates first-order serial correlation in levels. A third set of statistics is the Wald test of the hypothesis that the coefficient estimates of firm size and firm persistence are jointly not significantly different from zero. Chesher (1979) and Tschoegl (1983) note that the validity of Gibrat's law requires two conditions. First, firm growth is independent of firm size and, second, firm growth does not persist, avoiding any autocorrelation structure. A fourth set of statistics is the difference-in-Hansen tests, which examine the validity of instrument subsets in the level and the difference equation separately. The difference-in-Hansen test statistics are distributed as a chi-square with degrees of freedom equal to the subset of instruments.

## **5.1 Linearity in size**

Tables 3 report the estimates of Model 1, which posits linearity of the firm size. In columns (1) and (2), we treat all explanatory variables as endogenous, except firm size (Model 1A), while in columns (3) and (4), we treat all explanatory variables, including firm size, as endogenous (Model 1B). We report in columns (1) and (3) the estimates using the first differences (FD) transformation and report in columns (2) and (4) the estimates based on the forward orthogonal deviations (FOD) transformation suggested by Arellano and Bover (1995).

The results do not appear to suffer from the problem of proliferation of instruments. The number of instruments is fairly low, and much less than the number of firms (85), which mitigates the problem of too many instruments. If we did not truncate the lag length and collapse the instruments or did not apply principal components, the estimation would include over 1000 instruments. The results are robust across FD and FOD transformations, and lend support to the hypotheses that firm-specific characteristics reflect the hypothesized influence on firm growth.

The results provide strong evidence that asset utilization positively affects firm growth ( $p < 0.01$ ) in all four cases. This implies that agency costs, which are inversely related to asset utilization, exert a negative effect on firm growth. Thus, this finding confirms the link between agency costs and firm growth, as predicted by Hypothesis 1. Strong evidence of a positive nexus between R&D intensity and firm growth ( $p < 0.01$ ) exists in all cases. Firms that invest in R&D grow more than firms that do not. This result confirms Hypothesis 2. The findings provide strong evidence that firm size affects firm growth ( $p < 0.01$  in three cases and  $p < 0.05$  in one case). The positive coefficient of size implies that large firms grow larger, contrary to most findings in the firm growth literature, than small firms. Lagged growth is positively related to current growth and firm size is positively related to current growth ( $p < 0.01$  in all cases). The positive, but less than one, coefficient for lagged growth implies that growth is persistent, but not explosive. This means that in our sample of ICT firms, growth encourages growth, or, in the evolutionary perspective, "success breeds success" (Nelson and Winter, 1982). Growth generates a positive "self-reinforcing" effect, meaning that firms that grew faster in any one year are more likely to repeat this performance in the following year. Our results support those obtained by Bottazzi and Secchi (2003) for U.S. manufacturing companies. These results confirm Hypotheses 3 and 4. The results provide strong evidence of an inverse relationship between firm growth and leverage. Leverage is negatively related to firm growth ( $p < 0.01$  in all four cases), suggesting that firms with high leverage do not take advantage of growth opportunities. This result is similar to the findings in the capital structure literature (Myers, 1977; Auerbach, 1985; Lang, Ofek and Stulz, 1996) that shows that increased leverage reduces the firm's ability to raise additional funds to invest. Thus, we confirm Hypothesis 5. Profitability exerts a positive effect on firm growth ( $p < 0.01$  in three cases and  $p < 0.05$  in one case). Firms with internal financing resources can capture

growth opportunities and grow more than firms that experience internal financing constraints. Profitable firms grow, which is consistent with the evolutionary perspective (Nelson and Winter, 1982), Alchian's theory of the firm (Alchian, 1950), and the resource-based view of strategic management and entrepreneurship. Thus we confirm the link between firm growth and profitability as predicted by Hypothesis 6. Finally, firm growth is negatively related to the Great Recession ( $p < .01$  in all four cases), indicating that this extreme macroeconomic event significantly slowed the growth of the ICT industry. This in turn confirms Hypothesis 7. The Wald test rejects ( $p < 0.01$  in all four cases) the null that the coefficients on firm size and lagged firm growth are jointly equal to zero, which implies that our sample of ICT firms do not support Gibrat's law. This is in addition to the t-tests that reject Hypotheses 3 and 4 individually.

Both Model 1A and Model 2A perform reasonably well in terms of diagnostics. The reliability of our econometric methodology depends crucially on the validity of the instruments. The Sargan and Hansen statistics confirm the validity of the instruments and the difference-in-Hansen tests, which check the validity of the instruments in the level equation and the difference equation separately, further substantiate it. This is important because it confirms that the outcome of the Hansen tests is not a type II error arising from pooling valid and invalid instruments. The consistency of the estimates also depends on the serial correlation in the error term. The Arellano-Bond test for AR(1) confirms the presence of serial correlation of order one, which is expected, and the Arellano-Bond test for AR(2) provides no indication that the instruments are correlated with the error term. We cannot reject the null hypothesis of no second-order serial correlation in all regressions. That we do not find second-order serial correlation provides additional evidence that our use of lags is valid, and we do not need to use deeper lags as instruments.

To complete our analysis of Model 1, we implement two robustness checks that examine the sensitivity of the findings to alternative estimation methods and variables. First, we estimate all four versions of Model 1 using principal component analysis (PCA) with the instrument matrix restricted and collapsed as in the specifications of Table 3. The parameter estimates and test statistics are very close in magnitude and significance to the corresponding values in the four versions of Table 3. The explained variance from PCA captures most of the variation of the instruments, and the Kaiser-Meyer-Olkin measure of sampling adequacy confirms that PCA performs reasonably well. Second, we assess the robustness of our findings to the choice of the measure of profitability. We employed two additional measures of profitability and replaced return on equity (ROE) by return on assets (ROA) and return on investment (ROI), which are more stringent measures of profitability. The findings using ROA or ROI do not lead to the rejection of the hypothesis that profitability exerts a positive effect on growth. The size and significance of the parameter estimates do not materially change, and all the diagnostic tests support the validity of the instruments. For the sake of brevity, the detailed results are not reported, but are available from the corresponding author upon request.

## 5.2 Nonlinearity in size

The previous analysis assumes that the relationship between firm growth and firm size is linear. We test this hypothesis by estimating a nonlinear model that adds a quadratic term  $SIZE_{i,t-1}^2$  to Model 1 to capture possible non-linearities. Then, we test the null hypothesis of linearity in size by testing the null hypothesis that the coefficient on the quadratic term does not differ significantly from zero. If we reject this hypothesis, we can affirm the existence of non-linearity nexus between firm size and firm growth. Letting  $\beta_1$  be the estimate of size and  $\beta_2$  the estimate of size squared, the marginal effect of firm size on firm growth is  $\beta_1 + 2\beta_2 SIZE_{i,t-1}$ , which is

positive when  $\beta_1 > 0$  and  $\beta_2 > 0$ , and negative when  $\beta_1 < 0$  and  $\beta_2 < 0$ . If  $\beta_1 > 0$  and  $\beta_2 < 0$ , however, the effect can turn from positive to negative. Similarly, if  $\beta_1 < 0$  and  $\beta_2 > 0$ , the effect can turn from negative to positive. So, the quadratic specification introduces the possibility that the relationship between size and growth may be non-monotonic and may switch sign at some level of size. Firm size will exert a negative effect on growth when  $\beta_2 < 0$  and  $SIZE_{i,t-1} > -\frac{\beta_1}{2\beta_2}$ , which comes from setting the marginal effect  $\beta_1 + 2\beta_2 SIZE_{i,t-1} = 0$ .

We present the results in Table 4. The Table follows the same basic structure as Table 3. In columns (1) and (2), we treat all explanatory variables as endogenous, except firm size and firm size squared (Model 2A), while in columns (3) and (4), we treat all explanatory variables, including firm size and firm size squared, as endogenous (Model 2B). We report in columns (1) and (3) the estimates using the first differences (FD) transformation and report in columns (2) and (4) the estimates based on the forward orthogonal deviations (FOD) transformation suggested by Arellano and Bover (1995). In all cases, we maintain the same instrument matrix employed in the estimates in Table 3. The coefficients on one-period lagged growth are positive and significant ( $p < 0.01$ ) in all four cases and close in magnitude to the coefficients displayed in Table 3. Growth persists in both the linear and quadratic specification of size. For profitability (ROE), we find a positive relationship with firm growth and all coefficients are significant ( $p < 0.05$  in two cases and  $p < 0.01$  in the other two cases). The addition of the quadratic term does not appear to change the magnitude of these estimates. Agency costs are negatively related to firm growth, since the coefficients on asset utilization are positive and significant ( $p < 0.01$ ). The comparison with the coefficients on asset utilization in Table 3 does not reveal any material difference. Financial leverage negatively affects firm growth ( $p < 0.01$ ), but the size of the



coefficients is lower. R&D intensity maintains a positive effect on firm growth, but the significance of the coefficients is lower ( $p < 0.05$  in three cases and  $p < 0.01$  in one case). Thus, all hypotheses, except the hypothesis concerning size, that are accepted in the linear case are also accepted in the nonlinear case with minor, if any, modifications in the magnitude and significance of the coefficients across the four specifications. For the level and square of size, however, the results vary across the four specifications. Size and size squared affect firm growth in Model 2A ( $p < 0.01$ ). When size and size squared are assumed endogenous, the coefficient on size remains significant ( $p < 0.01$ ) only in the FD case. In all cases, however, the estimated coefficient on size is consistently positive, and the estimated coefficient on size squared is consistently negative. This leads to a non-linear inverted-U shaped relationship between firm growth and size. This result suggests that firms in the ICT industry do not enjoy unlimited economies of scale. They do enjoy economies of scale, but only up to a certain point. Above that threshold, size acts as a drag on growth and triggers a negative effect. This supports the arguments of Hall (1987), Evans (1987a, 1987b), and Dunne and Hughes (1994). Thus, size initially engenders a positive effect, but this influence turns negative as the firm size increases. We display the estimates of this threshold (SIZE\*) along with the “delta-method”<sup>18</sup> standard errors and the 95% “delta method” confidence intervals. This threshold indicates that the marginal effect becomes negative for values of the logarithm of total assets in the range 7.95-10.09. This implies a range in the value of total assets between \$2,852 million and \$57,526 million. The lower value occurs in the 95% confidence intervals of the 71-74 percentiles of the distribution of total assets, while the upper value occurs in the 95% confidence intervals of the 95-96 percentiles. The vast majority of the firms in our sample do not reach the threshold, and in

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<sup>18</sup> The delta method approximates the moments of nonlinear combinations of random variables by relying on a truncated Taylor series expansion.

their case, size continues to exert a positive effect on growth. Still, contrary to most of the extant literature, large firms grow larger than small firms. An important difference between Model 2A and Model 2B is the significance of the diagnostic tests, in particular the Hansen and the difference-in-Hansen tests. The significance of these tests increases by more than twice in Model 2A compared to Model 2B, which suggests more confidence in the specification and instruments of Model 2A.

To complete our analysis of Model 2, we implemented the same robustness checks that we employed in Model 1. First, we estimated all four versions of Model 2 using principal component analysis (PCA) with the instrument matrix restricted and collapsed as in the specifications of Model 1. The parameter estimates and test statistics for the two versions (FD and FOD) of Model 2A are close in magnitude and significance to the corresponding versions of Model 1A. The explained variance from PCA captures most of the variation of the instruments, and the Kaiser-Meyer-Olkin measure of sampling adequacy confirms that PCA performs reasonably well. Conversely, the two versions (FD and FOD) of Model 2B exhibit a few shortcomings. The Hansen test statistic for the FD version rejects the validity of the instruments ( $p < .05$ ) while the FOD version yields estimates for size and size squared that are not significantly different from zero. Second, we checked if the findings are robust when we replaced return on equity (ROE) by return on assets (ROA) and return on investment (ROI). The findings using ROA or ROI do not lead to the rejection of the hypothesis that profitability exerts a positive effect on growth. The size and significance of the parameter estimates do not materially change, and the diagnostic tests vary again across the two specifications. These results are not reported for economy of space, but are available from the corresponding author.

## **6. Concluding remarks**

This paper provides a unified framework to assess the debate on Gibrat's law in the ICT industry and to examine the main factors that determine growth using a sample of ICT firms that are publicly traded in the United States. We perform the analysis in a dynamic framework using data pertaining to 85 ICT firms for the period 1990-2013. We employ the two-step system GMM approach that allows for non-normality, unobservable heterogeneity, and most importantly, endogeneity in variables. We implement two main models: Model 1 assumes that growth is linear in size, while Model 2 assumes that growth is quadratic in size. Each model, in turn, has a dual specification, depending upon the treatment of size or size and size squared. In the first specification of Model 1 (Model 1A), we treat all the explanatory variables as endogenous, except size, which we treat as exogenous; in the second specification of Model 1 (Model 1B), we also treat size as endogenous. Similarly, in the first specification of Model 2 (Model 2A), we treat all the explanatory variables as endogenous, except size and size squared, which we treated as exogenous; in the second specification of Model 2 (Model 2B), we also treat size and size squared as endogenous. Our findings are robust to alternative transformations of the data and are new to the literature, since the dynamics of firm growth has not been documented at the ICT industry level in the United States.

The role played by size is important to assess the validity of Gibrat's law, and our results show that, in the linear or quadratic form, firm size significantly affects firm growth, especially in the exogenous specification. Thus, our findings invalidate Gibrat's law. Growth in the ICT industry is not random. In Model 1, firm size affects growth in a positive manner; in Model 2 firm, size affects growth in a positive fashion also, but only up to a certain point, beyond which the effect turns negative and size acts as a constraint to growth. We find that for, at most, about 20 percent of the firms in our ICT sample are size-constrained. We find that the quadratic effect

resembles an inverted-U shaped pattern. The fact that after a certain point, the effect of size on firm growth turns negative, does not imply that small firms will grow faster than large firms. Large firms still grow faster, and small firms are still left behind.

Profound implications emerge from this finding. Most importantly, the industry may evolve in the direction of more concentration and less competition, and may eventually require regulatory intervention. Another important implication relates to macroeconomics. Current research on income inequality (see, for instance, Autor, 2014 and Acemoglu and Autor, 2011) finds that the “skill premium” (i.e., the wage difference between low skill and high skill workers) is increasing and one of the factors that drives income inequality. Mueller, Ouimet, and Simintzi (2015) find that the “skill premium” is larger in larger firms. Economies of scale allow workers at larger firms to be more productive than those at smaller firms. That, in turn, allows larger firms to pay higher wages. This suggests that income inequality may relate to firm size and firm growth. Increasing inequality requires firms whose size increases over time, although not unbounded, and the ICT industry provides some evidence of this outcome.

Our results show the importance of agency costs and research and development investment. Agency costs, through the asset utilization proxy, negatively affect growth. A key implication of this finding is that ICT firms, if they want to grow, should examine the effectiveness of their own corporate governance mechanisms and devices, such as corporate ownership structure, managerial compensation structure, and the structure of the Board of Directors in mitigating managerial problems arising from agency conflicts. Research and development (R&D) investment affects growth in a positive way. Firms that invest in R&D grow and ultimately survive. A key policy implication is that policies designed to stimulate more R&D effort enables them to achieve superior performance in terms of firm growth. The puzzle,

however, is that R&D policies designed to help small firms may end up mainly helping large firms, because small firms remain small. Financial performance and leverage also affect growth. Growth and profitability are positively related, while growth and leverage are negatively related. Finally, we show that growth persists, which endorses the controversial evolutionary perspective inaugurated by Nelson and Winter (1982) that “success breeds success.”

Much scope exists for further research. For example, it would be important to understand what factors account for the empirical value of the threshold, and it would be interesting to establish the extent to which the inverted-U shape between growth and size is detected in other industries.

## References

- Acemoglu, D., and Autor, D., 2011. Skills, tasks and technologies: implications for employment and earnings, in O. Ashenfelter and D. Card (eds.), *Handbook of Labor Economics*, 4, 1043-1171. North-Holland: Amsterdam.
- Acs, Z. J., and Armington, C., 2001. Gibrat's Law reconsidered: the relationship between firm growth, establishment age, establishment size and firm size. Working Paper, Regional Entrepreneurship Catalyst Kauffman Center for Entrepreneurial Leadership, Kansas City, MO.
- Acs, Z. J., and Audretsch, D. B., 1990. *Innovation and Small Firms*. MIT Press: Cambridge, MA.
- Adamou, A., and Sasidharan, S., 2007. The impact of R&D and FDI on firm growth in emerging-developing countries: evidence from Indian manufacturing industries, Working Paper 37/2008, Madras School of Economics.
- Aghion, P., Fally, T., and Scarpetta, S., 2007. Credit constraints as a barrier to the entry and post-entry growth of firms. *Economic Policy* 22, 731-79.
- Akbar, S., Rehman, S., and Ormrod, P., 2013. The impact of recent financial shocks on the financing and investment policies of UK private firms. *International Review of Financial Analysis* 26, 59- 70.
- Aivazian, V., Ge, Y., and Qiu, J., 2005. The impact of leverage on firm investment: Canadian evidence. *Journal of Corporate Finance* 11, 277-291.

- Alchian, A. A., 1950. Uncertainty, evolution, and economic theory. *Journal of Political Economy* 58, 211-21.
- Alhadeff, D. A., and Alhadeff, C. P., 1964. Growth of large banks, 1930-1960. *Review of Economics and Statistics* 46, 356-363.
- Almus M., and Nerlinger, E. A., 2000. Testing Gibrat's Law for young firms. Empirical results for West Germany', *Small Business Economics* 15, 1-12.
- Amirkhalkhali, S., and Mukhopadhyay, A. K., 1993. The influence of size and R&D on the growth of firms in the U.S. *Eastern Economic Journal* 19, 223-233.
- An, H., Cook, D., and Zumpano, L., 2011. Corporate transparency and firm growth: Evidence from real estate investment trusts. *Journal of Real Estate Economics* 39, 429- 454.
- Andersen, J. C. and Coffey, D., 2011. U.S. ICT R&D Policy Report: The United States: ICT Leader or Laggard? Telecommunications Industry Association (TIA) Innovation White Paper;  
<http://www.tiaonline.org/sites/default/files/pages/TIA%20U%20S%20%20ICT%20RD%20Policy%20Report.pdf>
- Anderson, M., Banker, R., and Ravindran, S., 2000. Executive compensation in the information technology industry. *Management Science* 46, 530-547.
- Anderson, T. W., and Hsiao, C., 1982. Formulation and estimation of dynamic models using panel data. *Journal of Econometrics* 18, 47-82
- Ang J. S., Cole, R. A., and Lin, J. W., 2000. Agency costs and ownership structure. *Journal of Finance* 55, 81-106.
- Arellano M., and Bond S., 1991. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies* 58, 277-297.
- Arellano, M., and Bover, O., 1995. Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics* 68 29-51.
- Auerbach, A. J., 1985. Real determinants of corporate leverage, in B. M. Friedman (ed.) *Corporate capital structures in the United States*. University of Chicago Press: Chicago.
- Audretsch D. B., Santarelli, E., and Vivarelli, M., 1999. Start-up size and industrial dynamics: Some evidence from Italian manufacturing. *International Journal of Industrial Organization* 17, 965-983.
- Audretsch, D., Klomp, L., Santarelli, E., and Thurik, A., 2004. Gibrat's law: Are the services different? *Review of Industrial Organization* 24, 301-324.

- Audretsch, D., and Elston, J., 2002. Does firm size matter? Evidence on the impact of liquidity constraints on firm investment behaviour in Germany. *International Journal of Industrial Organization* 20, 1-17.
- Autor, D., 2014. Skills, education, and the rise of earnings inequality among the “other 99 percent. *Science* 344, 843-851.
- Bai, J., and Ng, S., 2010. Instrumental variables estimation in a data rich environment. *Econometric Theory* 26, 1577-1606.
- Barney, J., 1991. Firm resources and sustained competitive advantage. *Journal of Management* 17, 99-120.
- Barney, J., Wright, M., and Ketchen, D. J., 2001. The resource-based view of the firm: Ten years after 1991. *Journal of Management* 27, 625-641.
- Becchetti, L., and Trovato, G., 2002. The determinants of growth for small and medium sized firms. The role of the availability of external finance. *Small Business Economics* 19, 291-300.
- Beck, T., Levine, R., and Loayza, N., 2000. Finance and the sources of growth. *Journal of Financial Economics* 58, 261-300.
- Bergh, P., Thorgren, S., and Wincent, J., 2011. Entrepreneurs learning together - The importance of building trust for learning and exploiting business opportunities. *International Entrepreneurship and Management Journal* 7, 17-37.
- Blundell, R., and Bond, S., 1998. Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics* 87, 115-143.
- Blundell, R. W., Bond, S. R., and Windmeijer, F., 2000. Estimation in dynamic panel data models: improving on the performance of the standard GMM estimator, in B. Baltagi (ed.), *Advances in Econometrics*, vol. 15, *Nonstationary panels, panel cointegration, and dynamic panels*. Elsevier: Amsterdam.
- Bothner, M. S., 2005. Relative size and firm growth in the global computer industry. *Industrial and Corporate Change* 14, 617-638.
- Bottazzi, G., and Secchi, A., 2003. Common properties and sectoral specificities in the dynamics of U.S. manufacturing companies. *Review of Industrial Organization* 23, 217-232.
- Bottazzi, G., Dosi, G., Jacoby, N., Secchi, A., and Tamagni, F., 2010. Corporate performances and market selection: some comparative evidence. *Industrial and Corporate Change* 19, 1953-1996.

- Brush, C. G., Bromiley, P., and Hendrickx, M., 2000. The free cash flow hypothesis for sales growth and firm performance. *Strategic Management Journal* 21, 455-472.
- Bryan, S., Hwang, L., and Lilien, S., 2000. CEO stock-based compensation: an empirical analysis of incentive-intensity, relative mix, and economic determinants. *Journal of Business* 73: 661-693
- Brynjolfsson, E., 1993. The productivity paradox of information technology. *Communications of the ACM* 36, 67-77.
- Cambra-Fierro, J., Florin, J., Perez, L., and Whitelock, J., 2011. Inter-firm market orientation as 90 antecedent of knowledge transfer, innovation and value creation in networks. *Management Decision* 49, 444-467.
- Campello, M., Graham, J., and Harvey, C., 2010. The real effects of financial constraints: Evidence from a financial crisis. *Journal of Financial Economics* 97, 470-487.
- Cantarello, S., Nosella, A., Petroni, G. and Venturini, K., 2011. External technology sourcing: evidence from design-driven innovation. *Management Decision* 49, 962-983.
- Capon, N., Farley, J.U., and Hoenig, S., 1990. Determinants of financial performance: a meta-analysis. *Management Science* 36, 1143-1159
- Carpenter, R. E., and Petersen, B. C., 2002. Capital market imperfections, high-tech investment, and new equity financing. *The Economic Journal* 112, F54-F72.
- Cavalcante, S. A., Kesting, P. and Ulhøi, J. P., 2011. Business model dynamics and innovation: (re)establishing the missing linkages. *Management Decision* 49, 1327-1342.
- Caves, R. E., 1998. Industrial organization and new findings on the turnover and mobility of firms. *Journal of Economic Literature* 36, 1947-1982.
- Chen, K.-S., Babb, E.M., and Schrader, L.F., 1985. Growth of large cooperative and proprietary firms in the U.S. food sector. *Agribusiness* 1, 201-210.
- Chesher, A., 1979. Testing the law of proportionate effect. *Journal of Industrial Economics* 27, 403-411.
- Cho, H., and Pucik, V., 2005. Relationship between innovativeness, quality, growth, profitability, and market value. *Strategic Management Journal* 26, 555-575.
- Claessens, S., Djankov, S., and Xu, L.C., 2000. Corporate performance in the East Asian financial crisis. *World Bank Research Observer* 15, 23-46
- Coad, A., 2007. Testing the principle of 'growth of the fitter': the relationship between profits and firm growth. *Structural Change and Economic Dynamics* 18, 370-386.



- Coad, A., 2009. *The growth of firms: A survey of theories and empirical evidence*. Edward Elgar: Cheltenham, UK.
- Coad, A., Frankish, J. S., Roberts, R. G., and Storey, D. J., 2013. Growth paths and survival chances: An application of Gambler's Ruin theory. *Journal of Business Venturing* 28, 615–632.
- Coad, A., and Hözl, W., 2009. On the autocorrelation of growth rates. *Journal of Industry, Competition and Trade* 9, 139-166.
- Coad, A., and Hözl, W., 2012. Firms growth: empirical analysis, in M. Dietrich and J. Krafft (eds), *Handbook on the economics and theory of the firm*. Edward Elgar: Cheltenham, UK.
- Coad, A., and Rao, R., 2008. Innovation and firm growth in high tech sectors: A quantile regression approach. *Research Policy* 37, 633–648.
- Colombelli, A., Haned, N., and Le Bas, C., 2013. On firm growth and innovation. Some new empirical perspectives using French CIS (1992-2004). *Structural Change and Economic Dynamics* 26, 14-26.
- Coluzzi, C., Ferrando, A., and Martinez-Carrascal, C., 2015. Financing obstacles and growth: An analysis for euro area non-financial firms. *The European Journal of Finance* 21, 773-790.
- Comanor, W. S., 1965. Research and technical change in the pharmaceutical industry. *Review of Economics and Statistics* 47, 182–190.
- Combs, J. G., and Ketchen, D. J., 1999. Explaining inter-firm cooperation and performance: Toward a reconciliation of predictions from the resource-based view and organizational economics. *Strategic Management Journal* 20, 867–888.
- Cooley, T. F., and Quadrini, V., 2001. Financial markets and firm dynamics. *American Economic Review* 91, 1286-1310.
- Corsino, M. and Gabriele, R., 2011. Product innovation and firm growth: evidence from the integrated circuit industry. *Industrial and corporate change* 20, 29-56.
- Cowling, M., 2004. The growth-profit nexus. *Small Business Economics* 22, 1-9.
- Cowling, M., Liu, W., Ledger, A., and Zhang, N., 2015. What really happens to small and medium-sized enterprises in a global economic recession? UK evidence on sales and job dynamics. *International Small Business Journal* 33, 488-513.
- Das, S., 1995. Size, age and firm growth in an infant industry: the computer hardware industry in India. *International Journal of Industrial Organization* 13, 111-126.

- Davidsson, P., 1991. Continued entrepreneurship: Ability, need, and opportunity as determinants of small firm growth. *Journal of Business Venturing* 6, 405-429.
- Davidsson, P., Delmar, F., and Wiklund, J., 2002. Entrepreneurship as growth; growth as entrepreneurship. In M. A. Hitt & R. D. Ireland and S. M. Camp & D. L. Sexton (Eds.), *Strategic Entrepreneurship: Creating a New Mindset*, 328-342. Blackwell: Oxford, UK.
- Davidsson, P., Steffens, P., and Fitzsimmons, J., 2009. Growing profitable or growing from profits: Putting the horse in front of the cart? *Journal of Business Venturing* 24, 388-406.
- De, S., and Dutta, D., 2007. Impact of intangible capital on productivity and growth: Lessons from the Indian information technology software industry. *Economic Record* 83, S73-S86.
- Dedrick, J., Gurbaxani, V., and Kraemer, K. L., 2003. Information technology and economic performance: A critical review and empirical evidence. Working Paper. Center for Research on Information Technology and Organizations, University of California at Irvine.
- Delmar, F., Davidsson, P., and Gartner, W., 2003. Arriving at the high-growth firm. *Journal of Business Venturing* 18, 189-216.
- Delmar, F., McKelvie, A., and Wennberg, K., 2013. Untangling the relationships among growth, profitability and survival in new firms. *Technovation* 33, 276-291.
- Del Monte, A., and Papagni, E., 2003. R&D and the growth of firms: empirical analysis of a panel of Italian firms. *Research Policy* 32, 1003-1014
- Demirguc-Kunt, A., and Maksimovic, V., 1998. Law, finance and firm growth. *Journal of Finance* 53, 2107-2137.
- Dewan, S., and Kraemer, K., 2000. Information technology and productivity: Evidence from country-level-data. *Management Science* 46, 548-562.
- Doran, H. E., and Schmidt, P., 2006. GMM estimators with improved finite sample properties using principal components of the weighting matrix, with an application to the dynamic panel data model. *Journal of Econometrics* 133, 387-409.
- Dunne T., Roberts, M.J., and Samuelson, L., 1988. Patterns of Firm Entry and Exit in US Manufacturing Industries. *Rand Journal of Economics* 19, 495-515.
- Dunne P., and Hughes, A., 1994. Age, size, growth and survival: UK comparisons in the 1980s. *Journal of Industrial Economics* 42, 115-139.
- Ericson, R. E., and Pakes, A., 1995. Markov-perfect industry dynamics: A framework for empirical work. *Review of Economic Studies* 62, 53-82.

- Evans, D. S., 1987a. Tests of alternative theories of firm growth. *Journal of Political Economy* 95, 657-674.
- Evans, D. S., 1987b. The relationship between firm growth, size and age: Estimates for 100 manufacturing industries. *Journal of Industrial Economics* 35, 567–581.
- Faggio, G., and Konings, J., 2003. Job creation, job destruction and employment growth in transition countries in the 90s. *Economic Systems* 27, 129–154.
- Fama, E. F., and French K. R., 2002. Testing trade-off and pecking order predictions about dividends and debt. *Review of Financial Studies* 15, 1-33.
- Fine, C. H., 1998. *Clockspeed – Winning Industry Control in the Age of Temporary Advantage*. Perseus Books: Reading, MA.
- Fleming, G., Heaney, R., and McCosker, R., 2005. Agency costs and ownership structure in Australia. *Pacific-Basin Finance Journal* 13, 29-52.
- Florackis, C., and Ozkan, A., 2009. The impact of managerial entrenchment on agency costs: An empirical investigation using UK panel data. *European Financial Management* 15, 497-528.
- Fort, T., Haltiwanger, J., Jarmin, R. S., and Miranda, J., 2013. How firms respond to business cycles: The role of the firm age and firm size. *IMF Economic Review* 61 520-559.
- Fotopoulos, G., and Giotopoulos, I., 2010. Gibrat’s law and persistence of growth in Greek manufacturing. *Small Business Economics* 35, 191-202.
- Fotopoulos, G., and Louri, H., 2004. Corporate growth and FDI: Are multinationals stimulating local industrial development? *Journal of Industry, Competition and Trade* 4, 163-189.
- Frank, M. Z., and Goyal, V. K., 2009. Capital structure decisions: Which factors are reliably important? *Financial Management* 38, 1–37.
- Fulton, M., Fulton, J., Clark, S., and Parliament, C., 1995. Cooperative growth: Is it constrained? *Agribusiness* 11, 245-261.
- García-Manjón, J. V., and Romero-Merino, M. E., 2012. Research, development, and firm growth. Empirical evidence from European top R&D spending firms. *Research Policy* 41, 1084-1092.
- Geroski, P. A., 1995. What do we know about entry? *International Journal of Industrial Organization* 13, 421-440.

- Geroski, P.A., 1999. The growth of firms in theory and in practice, In N. Foss and V. Mahnke (eds.), *Competence, Governance, and Entrepreneurship*. Oxford University Press: Oxford, UK.
- Geroski, P. A., 2005. Understanding the implications of empirical work on corporate growth rates. *Managerial and Decision Economics* 26, 129-138.
- Geroski, P.A., and Machin, S., 1993. Innovation, profitability and growth over the business cycle. *Empirica* 20, 35–50.
- Geroski, P. A., Machin, S. J., and Walters, C. F., 1997. Corporate growth and profitability. *The Journal of Industrial Economics* 45, 171-189.
- Geroski, P. A., Lazarova, S., Urga, G., and Walters, C. F., 2003. Are differences in firm size transitory or permanent? *Journal of Applied Econometrics* 18, 47-59.
- Gibrat, R., 1931. *Les inégalités économiques*. Sirey: Paris, France.
- Giotopoulos, I., and Fotopoulos, G., 2010. Intra-industry growth dynamics in the Greek services sector: Firm-level estimates for ICT-producing, ICT-using, and Non-ICT industries. *Review of Industrial Organization* 36 59-74.
- Goddard, J., McMillan, D. G., and Wilson, J. O. S., 2006. Dividend smoothing vs dividend signalling: Evidence from UK firms. *Managerial Finance* 32, 493–504.
- Goddard, J., Wilson, J. O. S., and Blandon, P., 2002. Panel tests of Gibrat's Law for Japanese manufacturing. *International Journal of Industrial Organization* 20, 415-433.
- Goddard, J. A., Molyneux, P., and Wilson, J. O. S., 2004. Dynamics of growth and profitability in banking. *Journal of Money, Credit, and Banking* 36, 1069-1090.
- Goddard, J. A., McKillop, D. G., and Wilson J. O. S., 2002. The growth of US credit unions. *Journal of Banking and Finance* 26, 2327-2356.
- Goktan, A. B., and Miles, G., 2011. Innovation speed and radicalness: Are they inversely related? *Management Decision* 49, 533–547.
- Greene, W. H., 2012. *Econometric Analysis*. Prentice Hall: Upper Saddle River, NJ.
- Griliches, Z., and Hausman, J. A., 1986. Errors in variables in panel data. *Journal of Econometrics* 32, 93-118.
- Grossman, S. J., and Hart, O., 1982. Corporate financial structure and managerial incentives. In J. McCall (ed.), *The economics of information and uncertainty*. University of Chicago Press: Chicago, IL.

- Guiso, L., 1998. High-tech firms and credit rationing. *Journal of Economic Behavior and Organization* 35, 39-59.
- Hall, B., 1987. The relationship between firm size and firm growth in the US manufacturing sector. *Journal of Industrial Economics* 35, 583-606.
- Hall, G., 1995. *Surviving and Prospering in the Small Firm Sector*. Rutledge: London, UK.
- Haltiwanger, J., Jarmin, R., and Miranda, J., 2013. Who creates jobs? Small vs large vs young. *Review of Economics and Statistics* 95, 347–361.
- Hardwick, P., and Adams, M., 2002. Firm size and growth in the United Kingdom life insurance industry. *The Journal of Risk and Insurance* 69, 577-593.
- Hart, P. E., 2000. Theories of firms' growth and the generation of jobs. *Review of Industrial Organization* 17, 229-248.
- Hart, P. E. and Oulton, N., 1996. Growth and size of firms. *Economic Journal* 106, 1242-1252.
- Hart, P. E., and Prais, S. J., 1956. The analysis of business concentration: a statistical approach. *Journal of the Royal Statistical Society, Series A* 119, 150-91.
- Hart, P. E., and Oulton, N., 1996. The growth and size of firms. *Economic Journal* 106, 1242-1252.
- Hayakawa, K., 2009. First difference or forward orthogonal deviation- which transformation should be used in dynamic panel data models? A simulation study. *Economics Bulletin* 29, 2008-2017.
- Helfat, C. E., and Lieberman, M. B., 2002. The birth of capabilities: Market entry and the importance of pre-history. *Industrial and Corporate Change* 11, 725-760.
- Heshmati, A., 2001. On the growth of micro and small firms: Evidence from Sweden. *Small Business Economics* 17, 213–228.
- Heshmati, A., and Löf, H., 2006. On the relation between innovation and performance: A sensitivity analysis. *Economics of Innovation and New Technology* 15, 317–344.
- Hölzl, W., 2009. Is the R&D behaviour of fast-growing SMEs different? Evidence from CIS III data for 16 countries. *Small Business Economics* 33, 59-75.
- Hotho, S., and Champion, K., 2010. We are always after that balance: managing innovation in the new digital media industry. *Journal of Technology Management and Innovation* 5, 36-50.

- Hymer, S. and Pashigian, P., 1962. Firm size and rate of growth. *The Journal of Political Economy* 70, 556-569.
- Huynh, K. P., and Petrunia, R. J., 2010. Age effects, leverage and firm growth. *Journal of Economic Dynamics and Control* 34, 1003-1013.
- Ijiri, Y., and Simon, H. A., 1967. A model of business firm growth. *Econometrica* 35, 348–355.
- Jang, S., and Park, K., 2011. Inter-relationship between firm growth and profitability. *International Journal of Hospitality Management* 30, 1027-1035.
- Jansen, R. J. G., Curseu, P. L., Vermeulen, P. A. M., Geurts, J. L. A., and Gibcus, P., 2013. Information processing and strategic decision-making in small and medium sized enterprises: The role of human and social capital in attaining decision effectiveness. *International Small Business Journal* 31, 192–216.
- Jensen, M., 1986. Agency cost of free cash flow, corporate finance and takeovers. *American Economic Review Papers and Proceedings* 76, 323-329.
- Jensen, M., and Meckling, W., 1976. Theory of the firm: managerial behavior, agency costs and ownership structure. *Journal of Financial Economics* 3, 305-360.
- Jorgenson, D. W., 2001. Information technology and the U.S. economy. *American Economic Review* 91, 1-32.
- Jorgenson, D. W., 2003. Information technology and the G7 economies. *World Economics* 4, 139-170.
- Jorgenson, D. W., and Stiroh, K. J., 2000. Raising the speed limit: U.S. economic growth in the information age. *Brookings Papers on Economic Activity* 31, 125-236.
- Kapetanios, G., and Marcellino, M., 2010. Factor-GMM estimation with large sets of possibly weak instruments. *Computational Statistics and Data Analysis* 54, 2655-2675.
- Ketteni, E., 2009. Information technology and economic performance in U.S. industries. *Canadian Journal of Economics/Revue Canadienne d'économie* 42, 844-865.
- Klette, J., and Griliches, Z., 2000. Empirical patterns of firm growth and R&D investment: A quality ladder model interpretation. *Economic Journal* 110, 363-87.
- Klette, J., and Kortum, S., 2004. Innovating firms and aggregate innovation. *Journal of Political Economy* 112, 986-1018.
- Kiviluoto, N., 2013. Growth as evidence of firm success: myth or reality? *Entrepreneurship & Regional Development* 25, 569-586.

- Kraemer, K. L., and Dedrick, J., 2001. Information technology and productivity: results and policy implications of cross-country studies. In: Pohjola, M. (Ed.), *Information Technology, Productivity, and Economic Growth*. Oxford University Press: Oxford, UK.
- Kumar, M., 1985. Growth, acquisition activity and firm size: evidence from the United Kingdom. *Journal of Industrial Economics* 33 327-338.
- Khurana, I. K., Martin, X., and Pereira, R., 2006. Financial development and the cash flow sensitivity of cash. *Journal of Financial and Quantitative Analysis* 41, 787-806.
- Laincz, C. A., 2009. R&D subsidies in a model of growth with dynamic market structure. *Journal of Evolutionary Economics* 19, 643-673.
- Laincz, C. A., 2005. Market structure and endogenous productivity growth: How do R&D subsidies affect market structure? *Journal of Economic Dynamics and Control* 29, 187-223.
- Lang, L., Ofek, E., and Stulz, R. M., 1996. Leverage, investment and firm growth. *Journal of Financial Economics* 40, 3-29.
- Lee, S., 2014. The relationship between growth and profit: Evidence from firm-level panel data. *Structural Change and Economic Dynamics* 28, 1-11
- Lee, S. M., Lim, S. B., and Pathak, R. D., 2011. Culture and entrepreneurial orientation: a multicountry study. *International Entrepreneurship and Management Journal* 7, 1-15.
- Leifer, R., McDermott, C. M., O'Connor, G. C., Peters, L. S., Rice, M. P., and Veryzer, R. W., 2000. *Radical Innovation: How mature companies can outsmart upstarts*. Boston, MA: Harvard Business School Press.
- Leitner, K.-H., and Güldenbergs S., 2010. Generic strategies and firm performance in SMEs: a longitudinal study of Austrian SMEs. *Small Business Economics* 35, 169-189.
- Lensink, R., Van Steen, P., and Sterken, E. 2000. Is size important for the investment uncertainty relationship? An empirical analysis for Dutch firms. University of Groningen, Research Institute: Research Report No. 00E03.
- Lippi, M., and Forni M., 1990. On the dynamic specification of aggregated models, in T. Barker T. and M. H. Pesaran (eds), *Disaggregation in econometric modelling*, 150-170. Routledge: London, UK.
- Liu, L., 2009. Impact of the global financial crisis on China: Empirical evidence and policy implications. *China & World Economy* 17, 1-23.
- Liu, J.-T., Tsou, M.-W., and Hammitt, J., 1999. Export activity and productivity: Evidence from the Taiwan electronics industry. *Review of World Economics* 135, 675-691.

- Mansfield, E., 1968. *The Economics of Technical Change*. Norton: New York.
- Mansfield, E., 1962. Entry, Gibrat's law, innovation, and the growth of firms. *American Economic Review* 52, 1023–1051.
- Markman, G. D., & Gartner, W. B. 2002. Is extraordinary growth Profitable? A study of Inc. 500 high-growth companies. *Entrepreneurship Theory and Practice* 27, 65-75.
- Marshall, A., 1925. *Principles of Economics*, 5<sup>th</sup> ed. Macmillan: London.
- Mata, J., 1994. Firm growth during infancy. *Small Business Economics* 6, 27-39.
- McKelvie, A., and Wiklund, J., 2010. Advancing firm growth research: a focus on growth mode instead of growth rate. *Entrepreneurship Theory and Practice* 34, 261-288.
- Mehrhoff, J., 2009. A solution to the problem of too many instruments in dynamic panel data GMM. Discussion Paper n. 1/2009, Deutsche Bundesbank.
- Mehran, H., 1995, Executive compensation structure, ownership, and firm performance. *Journal of Financial Economics* 38, 163-184.
- Mendelson, H., and Pillai, R., 1999. Information age organizations, dynamics and performance. *Journal of Economic Behavior & Organization*. 38: 253-281.
- Mendelson, H., and Pillai, R. 1998. Clockspeed and informational response: Evidence from the information technology industry. *Information Systems Research* 9, 415-433.
- Mendelson, H., and Whang, S., 2000. Introduction to the special issue on the information technology industry. *Management Science* 46, i-iii.
- Mohnen, P., and Röller, L.-H., 2005. Complementarities in innovation policy. *European Economic Review* 49, 1431-1450.
- Mueller, H., Ouimet, P., and Simintzi, E., 2015. Wage inequality and firm growth. CEPR Discussion Paper 10365.
- Müller, E., and Zimmerman, V., 2009. The importance of equity finance for R&D. *Small Business Economics* 33, 303-318.
- Myers, S. C., 1977. Determinants of corporate borrowing. *Journal of Finance* 5, 147-176.
- Myers, S. C., and Majluf, N., 1984. Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics* 13, 187–221.



- Naranjo-Valencia, J. C., Jiménez-Jiménez, D., and Sanz-Valle, R., 2011. Innovation or imitation? The role of organizational culture. *Management Decision* 49, 55-72.
- Nickell, S., 1981. Biases in dynamic models with fixed effects. *Econometrica* 49, 1417-26.
- Nelson, R. R., 1991. Why do firms differ, and how does it matter? *Strategic Management Journal* 12, 61-74
- Nelson, R. R., and Winter, S. G., 1982. *An Evolutionary Theory of Economic Change*. Belknap Press/Harvard University Press: Cambridge, MA.
- Oberhofer, H., 2012. Firm growth, European industry dynamics and domestic business cycles. *Scottish Journal of Political Economy* 59, 316-337.
- Oliner, S. D., and Sichel, D. E., 2000. The resurgence of growth in the late 1990s: Is information technology the story? *Journal of Economic Perspectives* 14, 3-22.
- Oliveira, B., and Fortunato, A., 2006. Testing Gibrat's law: Empirical evidence from a panel of Portuguese manufacturing firms. *International Journal of the Economics of Business* 13, 65-81.
- Oliveira, B., and Fortunato, A., 2008. The dynamics of the growth of firms: Evidence from the services sector. *Empirica* 35, 293-313.
- Pagano, P., and Schivardi, F., 2003. Firm size, distribution and growth. *The Scandinavian Journal of Economics* 105, 255-274.
- Pakes, A., and Ericson, R., 1998. Empirical implications of alternative models of firm dynamics. *Journal of Economic Theory* 79, 1-45.
- Pakes, A., and McGuire, P., 1994. Computing Markov-perfect Nash equilibria: Numerical implications of a dynamic differentiated product model. *Rand Journal of Economics* 25, 555-89.
- Parker, S. C., Storey, D. J., and Van Witteloostuijn, A., 2010. What happens to gazelles? The importance of dynamic management strategy. *Small Business Economics* 35, 203-226.
- Penrose, E., 1959. *The Theory of the Growth of the Firm*. Oxford University Press: Oxford, UK.
- Perić, M., and Vitezić, V., 2016. Impact of global economic crisis on firm growth. *Small Business Economics* 46, 1-12.
- Pfaffermayr, M., and Bellak, C., 2000. Why foreign-owned firms are different? A conceptual framework and empirical evidence for Austria. Hamburg Institute of International Economics, Discussion Paper No. 115

- Piergiovanni, R., Santarelli, E., Klomp, L., and Thurik, A. R., 2003. Gibrat's law and the firm size/firm growth relationship in Italian services. *Revue d'Economie Industrielle* 102, 69-82.
- Prais S.J., 1976. *The Evolution of Giant Firms in Britain*. Cambridge University Press: London, UK.
- President's Council of Advisors on Science and Technology (PCAST), 2007, Leadership Under Challenge: Information Technology R&D in a Competitive World, 22 (August). <http://cpsvo.org/node/207>.
- Rahaman, M. M., 2011. Access to financing and firm growth. *Journal of Banking and Finance*, 35, 709-723.
- Reid, G., 1995. 'Early Life-Cycle Behaviour of Micro-Firms in Scotland. *Small Business Economics* 7, 89-95.
- Rhoades, S. A., and Yeats, A. J., 1974. Growth, consolidation and mergers in banking, *Journal of Finance*, 29, 1397-1405.
- Roodman D., 2009a. How to do xtabond2: an introduction to difference and system GMM in Stata. *The Stata Journal* 9, 86-136.
- Roodman D., 2009b. A note on the Theme of Too Many Instruments. *Oxford Bulletin of Economics and Statistics* 71, 135-158
- Rowley, J., Baregheh, A., and Sambrook, S., 2011. Towards an innovation-type mapping tool. *Management Decision* 49, 73-86.
- Samuels, J. M., 1965. Size and growth of firms, *Review of Economic Studies* 32, 105-112.
- Santarelli, E., Klomp, L., and Thurik, A.R., 2006. Gibrat's Law: An overview of the empirical literature. In E. Santarelli (ed.), *Entrepreneurship, Growth, and Innovation: the Dynamics of Firms and Industries*, Springer, New York, 41-73
- Sexton, D. L., and Smilor, R. S., 1997. *Entrepreneurship 2000*. Upstart Publishing Company: Chicago, IL.
- Scherer, F. M., 1970. *Industrial Market Structure and Economic Performance*. Rand McNally: Chicago, IL.
- Schumpeter, J., 1934. *The Theory of Economic Development*. Harvard University Press: Cambridge, MA.
- Schreyer, P., 2000. The contribution of ICTs to output growth: A study of the G7 countries. STI Working Paper 2000/2, OECD, Paris.

- Singh, A., and Whittington, G., 1975. The size and growth of firms. *Review of Economic Studies* 42, 15-26.
- Singh, M., and Davidson, W. N., 2003. Agency costs, ownership structure and corporate governance mechanisms. *Journal of Banking and Finance* 27, 793-816.
- Sitlington, H., and Marshall, V., 2011. Do downsizing decisions affect organizational knowledge and performance? *Management Decision* 49, 116-129.
- Shapiro, R. J., and Mathur, A., 2011. The contributions of information and communication technologies to American growth, productivity, jobs and prosperity. Sonecon: Washington, DC:
- Schimke, A., and Brenner, T., 2011. Temporal structure of firm growth and the impact of R&D. Working Paper. University of the State of Baden-Wuerttemberg and National Laboratory of the Helmholtz Association.
- Sommer, L., and Haug, M., 2011. Intention as a cognitive antecedent to international entrepreneurship—understanding the moderating roles of knowledge and experience. *International Entrepreneurship and Management Journal* 7, 111-142.
- Stam, E., 2010. Growth beyond Gibrat: Firm growth processes and strategies. *Small Business Economics* 35, 129-135.
- Stein, J., 2003, Agency, information and corporate investment. In *Handbook of the Economics of Finance*, edited by G. Constantinides, Milton Harris and Rene Stulz, Elsevier, 111-165.
- Storey, D. J., 2004. Explaining the links among small firms between management training and firm performance: A Comparison between the UK and other OECD countries. *International Journal of Human Resource Management* 15, 112-130.
- Stultz, R. M., 1990. Managerial discretion and optimal financing policies. *Journal of Financial Economics* 26, 3-27.
- Sutton, J., 1997. Gibrat's Legacy. *Journal of Economic Literature* 35, 40–59.
- Thompson, P., 2001. The microeconomics of an R&D-based model of endogenous growth, *Journal of Economic Growth* 6, 263-283.
- Tschoegl, A. E., 1983. Size, growth and transnationality among the world's largest banks, *Journal of Business* 56, 187-201.
- Trau, F., 1996. *Why do firms grow?* Working Paper 26, ESRC Centre for Business Research, University of Cambridge.

- Tschoegl, A., 1996. Managerial Dis(economies) of Scale: The Case of Regional Banks in Japan. Reginald H. Jones Center for Management and Policy, Strategy and Organization, The Wharton School of the University of Pennsylvania, Working Paper 96-04.
- Vivarelli, M., 2007. *Entry and Post-Entry Performance of Newborn Firms*. Routledge: London, UK.
- van Riel, A. C., Semeijn, J., Hammedi, W., and Henseler, J., 2011. Technology based service proposal screening and decision-making effectiveness. *Management Decision* 49, 762-783.
- Vander Venet, R., 2001. The Law of proportionate effect and OECD bank sectors. *Applied Economics* 33, 539-546.
- Wagner, J., 1992. Firm size, firm growth, and persistence of chance: Testing Gibrat's law with establishment data from Lower Saxony, 1978-1989. *Small Business Economics* 4, 125-131.
- Wernerfelt, B., 1984. A resource-based view of the firm. *Strategic Management Journal* 5, 171-180.
- Wilson, J.O.S., and Morris, J.E., 2000. The size and growth of UK manufacturing and service firms. *The Service Industries Journal* 20, 25-38.
- Wilson, J.O.S., and Williams, J., 2000. The size and growth of banks: evidence from four European countries. *Applied Economics* 32, 1101-1109.
- Windmeijer, F., 2005. A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics* 26, 25-51.
- Wu, X., and Yeung, C. K., 2012. Firm growth type and capital structure persistence. *Journal of Banking and Finance* 36, 3427-3443.
- Yang, C.-H., and Huang, C.-H., 2005. R&D, size and firm growth in Taiwan's electronics industry. *Small Business Economics* 25, 477-487.
- Yazdanfar, D., 2013. Profitability determinants among micro firms: evidence from Swedish data. *International Journal of Managerial Finance* 9, 150-160.
- Yermack, D., 1995. Do corporations award CEO stock options effectively? *Journal of Financial Economics* 39: 237-269.

**Table 1. Sector distribution of the ICT sample**

This table presents the COMPUSTAT distribution of the ICT sample into seven sectors : 1) Telecommunication Equipment (8030); 2) System Software (8140) and Application Software (8130); 3) Semiconductors (8230) and Semiconductor Equipment (8220); 4) Computer Hardware (8050) and Computer Storage and Peripherals (8052); 5) Electronic Manufacturing Services (8200) and Consulting Services (8120); 6) Electronic Equipment and Instruments (8150); 7) Technology Distributors (8210). The industry sector code is in parentheses. The total number of firms is 85. The data are annual and comprise the period 1990-2013.

Sector	No. of firms
Telecommunication Equipment (8030)	10
System Software (8140) and Application Software (8130)	10
Semiconductors (8230) and Semiconductor Equipment (8220)	19
Computer Hardware (8050) and Computer Storage and Peripherals (8052)	8
Electronic Manufacturing Services (8200) and Consulting Services (8120)	16
Electronic Equipment and Instruments (8150);	18
Technology Distributors (8210)	4

**Table 2. Descriptive statistics**

This table presents a few descriptive statistics (mean, standard deviation, maximum and minimum) of the relevant variables. The data are from COMPUSTAT and the sample contains 85 US firms that belong to the COMPUSTAT Economic Sector 8000. The time period is 1990-2013. GROWTH is the first difference of SIZE; SIZE is the natural logarithm of total assets; ROE is the ratio of income before extraordinary items to common equity; ASSET UTILIZATION is the ratio of net sales to total assets ; LEVERAGE is the ratio of the sum of long-term debt and short-term debt to total assets; SALES is net sales; R&D INTENSITY is the ratio of R&D expenditures divided by net sales . SALES and TOTAL ASSETS are in millions of US dollars.

Variable	Obs.	Mean	St. Dev.	Min	Max
GROWTH	1955	9.75%	23.42%	-105.38%	172.93%
ROE	2040	6.60%	27.62%	-492.51%	261.98%
TOTAL ASSETS	2040	8,215.87	2,0261.34	1.36	142,431.00
SIZE	2040	6.19	2.72	0.31	11.86
SALES	2040	7,010.16	1,7786.97	0.42	127,245.00
ASSET UTILIZATION	2040	110.88%	72.89%	1.37%	622.57%
LEVERAGE	2040	38.05%	19.91%	0.00%	92.26%
R&D INTENSITY	2033	9.37%	11.58%	0.00%	277.98%

**Table 3. Two-step system GMM estimates of ICT growth: Model 1**

The table presents estimates of Model 1 using the two-step system GMM in the xtabond2 package for Stata (Roodman, 2009a). The data are from COMPUSTAT and the sample contains 85 US firms that belong to the COMPUSTAT Economic Sector 8000. The time period is 1990-2013. The dependent variable is GROWTH, calculated as the first difference of SIZE; SIZE is the natural logarithm of total assets; ROE is the ratio of income before extraordinary items profits to common equity; ASSET UTILIZATION is the ratio of sales to total assets; LEVERAGE is the ratio of the sum of long-term debt and short-term debt to total assets; SALES is net sales; R&D INTENSITY is the ratio of R&D expenditures divided by sales; GREAT RECESSION is a dummy variable that takes on value 1 if year = 2007, 2008, and 2009, and zero otherwise. Statistical significance is reported at 1, 5 and 10% (\*\*\*, \*\*, \* respectively). Figures in parentheses are the robust Windmeijer (2005) finite-sample corrected standard errors. The Wald test is a test of the null hypothesis that the parameters of lagged GROWTH and lagged SIZE are jointly zero. Rejection of the null hypothesis is equivalent to the rejection of the Gibrat's law. Year dummies are included but not reported. In MODEL 1 all explanatory variables are endogenous, except for firm size, and are instrumented. In MODEL 2 all explanatory variables are endogenous, including firm size, and are instrumented. FD is the first difference transformation; FOD is the forward orthogonal deviations transformation. For the equation in FD or FOD differences, levels dated t-3 and t-4 are used as instruments, whereas for the equation in levels, FD or FOD differences dated t-1 and t-2 are used. Arellano-Bond test for AR (1) is the test for first order autocorrelation in the differenced residuals and is distributed as N(0,1) under the null hypothesis of no first-order autocorrelation; Arellano-Bond test for AR (2) is the test for second order autocorrelation in the differenced residuals and is distributed as N(0,1) under the null hypothesis of no second-order autocorrelation. The Sargan test and the Hansen test are tests of overidentifying restrictions, i.e., tests of the validity of the instruments. The Sargan test is not robust but is not weakened by a large numbers of instruments. The Hansen test is robust, but is weakened by a large number of instruments. The Wald, Sargan, Hansen and difference-in-Hansen tests are chi-square distributed. The corresponding degrees of freedom are reported in bold in parentheses next to the test statistics

	MODEL 1A		MODEL 1B	
	FD (1)	FOD (2)	FD (3)	FOD (4)
GROWTH <sub>i,t-1</sub>	.152*** (.029)	.197*** (.031)	.170*** (.028)	.214*** (.031)
ROE <sub>i,t-1</sub>	.137*** (.043)	.090** (.044)	.129*** (.045)	.103*** (.048)
SIZE <sub>i,t-1</sub>	.023*** (.005)	.023*** (.004)	.045*** (.012)	.029** (.010)
ASSET UTILIZATION <sub>i,t-1</sub>	.141*** (.031)	.165*** (.032)	.157*** (.037)	.167*** (.032)
LEVERAGE <sub>i,t-1</sub>	-.259*** (.089)	-.267*** (.068)	-.362*** (.077)	-.238*** (.057)
R & D INTENSITY <sub>i,t-1</sub>	.143*** (.048)	.098*** (.034)	.157*** (.043)	.117*** (.034)
GREAT RECESSION <sub>t</sub>	-.209 (.057)	-.223*** (.053)	-.433*** (.103)	-.372*** (.091)
Arellano-Bond test for AR (1) (p-value)	-4.83 (.000)	-4.82 (.000)	-4.78 (.000)	-4.87 (.000)
Arellano-Bond test for AR (2) (p-value)	.99 (.321)	1.15 (.251)	1.02 (.309)	1.23 (.217)

**Table 3. Two-step system GMM estimates of ICT growth: Model 1 (Continued)**

	MODEL 1A		MODEL 1B	
	FD (1)	FOD (2)	FD (3)	FOD (4)
Wald test	46.91 (2)	62.79 (2)	47.10 (2)	53.09 (2)
(p-value)	(.000)	(.000)	(.000)	(.000)
Sargan test	15.26 (12)	18.17 (12)	18.33 (15)	22.27 (15)
(p-value)	(.229)	(.111)	(.246)	(.101)
Hansen test	17.35 (12)	14.76 (12)	19.66 (15)	17.32 (15)
(p-value)	(.137)	(.255)	(.185)	(.300)
Difference-in-Hansen tests				
Hansen test excluding groups (eq. diff.)	2.08 (2)	1.97 (2)	2.44 (3)	2.41 (3)
(p-value)	(.354)	(.374)	(.486)	(.492)
Difference (null H: exogenous)	15.28 (10)	12.79 (10)	17.22 (12)	14.91 (12)
(p-value)	(.122)	(.236)	(.142)	(.246)
Hansen test excluding groups (eq. level)	4.15 (2)	.83 (2)	5.51 (3)	.81 (3)
(p-value)	(.125)	(.661)	(.138)	(.848)
Difference (null H: exogenous)	13.20 (10)	13.93 (10)	14.15 (12)	16.51 (12)
(p-value)	(.213)	(.176)	(.292)	(.169)
No. Obs.	1865	1865	1865	1865
No. Firms	85	85	85	85
No. Instruments	43	43	46	46



**Table 4. Two-step system GMM estimates of ICT growth: Model 2**

The table presents estimates of Model 2 using the two-step SYSTEM GMM in the xtabond2 package for Stata (Roodman, 2009a). The data are from COMPUSTAT and the sample contains 85 US firms that belong to the COMPUSTAT Economic Sector 8000. The time period is 1990-2013. The dependent variable in all four specification is GROWTH, calculated as the first difference of SIZE; SIZE is the natural logarithm of total assets; ROE is the ratio of income before extraordinary items profits to common equity; ASSET UTILIZATION is the ratio of net sales to total assets; LEVERAGE is the ratio of the sum of long-term debt and short-term debt to total assets; SALES is total net sales; R&D INTENSITY is the ratio of R&D expenditures divided by net sales; GREAT RECESSION is a dummy variable that takes on value 1 if year = 2007, 2008, and 2009, and zero otherwise. SIZE\* is the level of firm size at which the effect of size on growth switches from positive to negative. Statistical significance is reported at 1, 5 and 10% (\*\*\*, \*\*, \* respectively). Figures in parentheses are the robust Windmeijer (2005) finite-sample corrected standard errors. The Wald test is a test of the null hypothesis that the parameters of lagged GROWTH, lagged SIZE and lagged SIZE SQUARE are jointly zero. Rejection of the null hypothesis is equivalent to the rejection of the Gibrat's law. Year dummies are included. In columns (1) and (2) all explanatory variables are endogenous (except the year dummies, firm size and the GREAT RECESSION dummy) and are instrumented. In columns (3) and (4) all explanatory variables are endogenous (except the year dummies and the GREAT RECESSION dummy) and are instrumented. FD is the first difference transformation; FOD is the forward orthogonal deviations transformation. For the equation in FD or FOD differences, levels dated t-3 and t-4 are used as instruments, whereas for the equation in levels, FD or FOD differences dated t-1 and t-2 are used. Arellano-Bond test for AR (1) is the test for first order autocorrelation in the differenced residuals and is distributed as N(0,1) under the null hypothesis of no first-order autocorrelation; Arellano-Bond test for AR (2) is the test for second order autocorrelation in the differenced residuals and is distributed as N(0,1) under the null hypothesis of no first-order autocorrelation. The Sargan test and the Hansen test are tests of overidentifying restrictions, i.e., tests of the validity of the instruments. The Sargan test is not robust, but is not weakened by a large numbers of instruments. The Hansen test is robust, but is weakened by a large number of instruments. The Wald, Sargan, Hansen and difference-in-Hansen tests are chi-square distributed. The corresponding degrees of freedom are reported in parentheses next to the test statistics.

	MODEL 2A		MODEL 2B	
	FD (1)	FOD (2)	FD (3)	FOD (4)
GROWTH <sub>i,t-1</sub>	.157*** (.029)	.188*** (.030)	.163*** (.029)	.206*** (.031)
ROE <sub>i,t-1</sub>	.136*** (.041)	.082** (.042)	.132*** (.046)	.102** (.048)
SIZE <sub>i,t-1</sub>	.073*** (.015)	.067*** (.012)	.096*** (.029)	.040* (.024)
SIZE <sub>i,t-1</sub> <sup>2</sup>	-.004*** (.001)	-.003*** (.001)	-.006*** (.002)	-.002 (.002)
ASSET UTILIZATION <sub>i,t-1</sub>	.159*** (.038)	.169*** (.031)	.164*** (.038)	.158*** (.034)
LEVERAGE <sub>i,t-1</sub>	-.261*** (.083)	-.269*** (.063)	-.256*** (.082)	-.203*** (.068)
R & D INTENSITY <sub>i,t-1</sub>	.143** (.061)	.085** (.037)	.127** (.059)	.098*** (.036)
GREAT RECESSION <sub>t</sub>	-.361*** (.085)	-.347*** (.061)	-.518*** (.118)	-.231*** (.107)

**Table 4. Two-step system GMM estimates of ICT growth: Model 2 (Continued)**

	MODEL 2A		MODEL 2B	
	FD (1)	FOD (2)	FD (3)	FOD (4)
SIZE*	9.697*** (.995)	10.096*** (1.010)	7.956*** (.877)	8.583*** (2.374)
95% Confidence Interval	[7.74 11.64]	[8.11 12.07]	[6.23 9.67]	[3.92 13.23]
Arellano-Bond test for AR (1)	-4.84	-4.81	-4.78	-4.85
(p-value)	(.000)	(.000)	(.000)	(.000)
Arellano-Bond test for AR (2)	1.00	1.09	1.00	1.22
(p-value)	(.318)	(.277)	(.317)	(.221)
Wald test	63.01 (3)	102.12 (3)	52.90 (3)	52.21 (3)
(p-value)	(.000)	(.000)	(.000)	(.000)
Sargan test	15.12 (12)	18.22 (12)	22.13 (18)	25.60 (18)
(p-value)	(.235)	(.109)	(.226)	(.109)
Hansen test	14.15 (12)	10.82 (12)	25.52 (18)	25.48 (18)
(p-value)	(.291)	(.544)	(.111)	(.112)
Difference-in-Hansen tests				
Hansen test excluding groups (eq. diff.)	2.01 (2)	1.92 (2)	6.67 (4)	6.82 (4)
(p-value)	(.366)	(.384)	(.154)	(.146)
Difference (null H: exogenous)	12.14 (10)	8.90 (10)	18.85 (14)	18.66 (14)
(p-value)	(.276)	(.541)	(.171)	(.178)
Hansen test excluding groups (eq. level)	4.13 (2)	0.67 (2)	5.03 (4)	.85 (4)
(p-value)	(.127)	(.714)	(.284)	(.932)
Difference (null H: exogenous)	10.02 (10)	10.15 (10)	20.49 (14)	24.63 (14)
(p-value)	(.439)	(.428)	(.115)	(.038)
No. Obs.	1865	1865	1865	1865
No. Firms	85	85	85	85
No. Instruments	44	44	50	50