



Firm Dynamics: The Size and Growth Distribution of Firms

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Abstract

This thesis is about firm dynamics, and relates to the size and growth-rate distribution of firms. As such, it consists of an introductory and four separate chapters. The first chapter concerns the size distribution of firms, the two subsequent chapters deal more specifically with high-growth firms (HGFs), and the last chapter covers a related topic in distributional estimation theory. The first three chapters are empirically oriented, whereas the fourth chapter develops a statistical concept.

Data in the empirical section of the thesis come from two sources. First, PAR, a Swedish consulting firm that gathers information from the Swedish Patent and registration office on all Swedish limited liability firms. Second, the IFDB-database, which comes from the Swedish Agency for Growth Policy Analysis and comprises a selection of longitudinal register data from Statistics Sweden and contains business-related information on firms and establishments operating in Sweden, irrespective of their legal status.

The first chapter addresses the size distribution of firms, outlining a method that can be used to test a number of economic hypotheses of what determines the shape of the firm size distribution. Using the PAR-dataset, firm size distributions (at the 3-digit NACE industry level) are found to exhibit significant heterogeneity, both over time and across industries. Furthermore, the results suggest that easier access to financial capital has a positive effect on the number of large firms in the industry, hence thickening the tail of the firm size distribution. The second chapter problematizes the view of HGFs as a target of economic policy. It applies regression analysis and transition probabilities to the IFDB-dataset of firms to demonstrate that the presence of individual HGFs is not persistent over time, rather high growth is likely followed by a period of lower or negative growth. The third chapter considers the basic definition of HGFs, examining whether the statistical properties of the firm growth-rate distribution can be used to distinguish HGFs from other firms in a more systematic fashion. Using the PAR-dataset, this paper suggests that HGFs can be thought of as firms with growth rates that follow a power law in the growth-rate distribution. Applied to the 2-digit NACE industry level this definition suggests that HGFs might be even rarer than previously thought. The last chapter addresses a statistical property of many growth-rate distributions, known as geometric stability, and develops an estimator for the family of skewed geometric stable distributions.

In all, this thesis provides valuable contributions to firm dynamics and furthers our knowledge in areas of empirical findings, empirical methodology, economic policy and statistical estimation theory.

Keywords: Firm size distribution · High-growth firms · Gazelles · Firm growth-rate distribution · Zipf's law · Gibrat's law · Power law · Laplace distribution · Persistence · Autocorrelation · Transition Probabilities · Geometric stable distribution · Estimation · Fractional lower order moments · Logarithmic moments · Economics

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Firm Dynamics: The Size and Growth Distribution of Firms

Daniel Halvarsson*

1 Introduction

In the last couple of years the discovery that just a few rapidly growing firms stand for most of the net creation of jobs has sparked interest among researchers and policy maker for so called High-Growth Firms (HGFs) or Gazelles. Their contribution to the net creation of jobs far surpasses that of other categories of firms, e.g. small or large firms (Henrekson and Johansson, 2010). The scientific literature on HGFs is however just a small part of a larger, more encompassing literature on firm dynamics.

This thesis addresses related topics in firm dynamics. It consists of an introductory chapter and four separate chapters, each of which contributes to the literature on the distribution of firm size and growth, of which HGFs are an integral part. The first three chapters are empirically oriented, whereas the fourth chapter is purely statistical in character. The chapters in the thesis focus primarily on individual firm growth and the state and development of the dynamic process as a whole, here interpreted as the cross-sectional size and growth-rate distributions of firms.¹

Firm dynamics is a multifaceted topic in economics, its history stretching back to at least the early 20th century. The word “dynamic,” according to the New Oxford English Dictionary, describes a system or process *characterized by constant change, activity, or progress*. The antonym of “dynamic” is “static.”

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¹The aspects of entry and exit (although they are undoubtedly important aspects of firm dynamics) are only addressed indirectly and often implicitly in the following chapters.

Therefore, firm dynamics concerns the aspects of firms that change over time. These qualities include firm entry, growth, and exit. Together, these elements comprise a process that serves as the backbone of every modern market economy.

In theory, firms grow by making good investments that allow them to earn a profit by satisfying tastes and demands of consumers better than their competitors. The individual states included in the dynamic process are the size of each firm, which, in turn, reflects the accumulation of earlier growth episodes and previous profits. In a sense, large firms are large because they have accumulated more growth than smaller firms. However, the size or growth of individual firms do not directly provide information about the state and development of the dynamic process as a whole.

To better understand the governing properties of firm dynamics, researchers have traditionally looked beyond statistical averages and focused on the complete size distribution of firms. Theory suggests that in the search for new profits, an individual firm will constantly change in size as a result of competitive pressure. Yet the economic climate seems to have little lingering effect on the size distribution of firms in a developed economy, which remains approximately static (Axtell, 2001). Different measures of firm size, such as amount of sales or number of employees, do not seem to alter this stylized fact.² The size distribution can be described by a simple mathematical function, often a lognormal or Pareto distribution.

Thus, if individual firms are dynamic in every sense of the word, then in the event that one firm grows, its position in the size distribution should quickly be assumed by another firm. A mechanism of this type was long considered to be the main property of firm growth. In fact, until quite recently (Stanley et al, 1996), individual firms were usually considered to grow at random based on Gaussian models of the growth-rate distribution.

However, research now shows that firm growth is in fact much more complex, and hence inconsistent with the Gaussian framework (Reichstein et al, 2010). Growth rates are characterized by a distinct tent-shaped distribution, which reflect more extreme fluctuations. At the same time, the current stage of research indicates that most firms do not grow at all. For the average firm, sales levels and number of employees remain relatively constant, at least in the short term. Viewed together, the shape of firm size and growth-rate distributions seem to suggest that firms are not purely dynamic. On a year-to-year basis, most firms

²See Section 5.5 for a discussion of different measures of firm size.

remain in roughly the same place in the size distribution, whereas only a few more rapidly growing/declining firms experience notable fluctuations, leaping it up and down.

Research on firm dynamics has yielded a large body of literature, especially regarding the distribution of firm size. Most of the literature on the size distribution falls into one of two categories. On the one hand, there is a strand of more statistical research that focuses on the distributional properties of firm size. On the other hand, more recent research has integrated the size distribution of firms into standard economic theory. However, the dearth of empirical research persists.

In the last few years, the advent of HGF-research has made it popular to bethink heavy tails in the growth-rate distribution. Yet the literature on HGFs is still developing, and many pressing questions remain.

In addressing various topics related to firm dynamics, this thesis contributes to several areas within this field. Contributions are made to empirical findings, empirical methodology, public policy and statistical estimation theory. The first chapter addresses the size distribution of firms, noting the lack of previous empirical research, and outlining a method that can be used to test a number of economic hypotheses of the shape of this distribution. The next two chapters concern HGFs, and address distinct but related issues. The second chapter problematizes a premature adoption of HGFs in economic policy, applying regression analysis and transition probabilities to demonstrate that the presence of HGFs is not persistent over time. The third chapter considers the basic definition of HGFs, examining whether the statistical properties of the growth-rate distribution of all firms can be used to distinguish HGFs from other firms in a more systematic fashion. The last chapter addresses a statistical property of many growth-rate distributions, known as geometric stability, and develops an estimator for the family of skewed geometric stable distributions. This is, in essence, the outline of this thesis.

First however, I will take the opportunity to delve a bit deeper into firm dynamics and related areas, letting the rest of the introductory chapter serve as a background to later chapters. The remainder of this introductory is therefore organized as follows. Section 2 gives a brief overview of influential theoretical concepts and research on firm dynamics that relate to the size and growth-rate distribution of firms. Section 3 presents some more narrow concepts and statistical models that are frequently used in the literature. Section 4 then gives a brief summary of the empirical literature relating to the size and growth-rate

distribution of firms. Section 5 is a presentation of the data employed in the chapters, along with a discussion about measuring firm size and growth, while Section 6 gives more extensive summaries of the four chapters included in this thesis. Finally, a discussion of geometric stability is provided in Appendix A.1.

2 Firm dynamics

At an earlier time, innovators were mostly self-employed laborers, but today, most innovation occurs within the boundaries of the firm. The context in which firms operate is continuously changing and uncertain. In the face of competition, firms must overcome a type of Knightian uncertainty regarding the consequences of new inventions and technological regimes (Dosi and Nelson, 2010).

The theory of the dynamic aspects of firms can be traced back to Alfred Marshall (1920). In his *Principles of Economics*, Marshall discusses the entry of firms, their growth, and finally, their decline and exit. This process is well captured by his famous metaphor, in which firms, like trees in the forest, “struggle upwards through the benumbing shade of their older rivals” (IV.XIII.4). However, as they grow old and become large, they eventually lose their former vigor and have to give way for “younger and smaller rivals” (IV.XIII.5).

The dynamic approach is perhaps best associated with Joseph A. Schumpeter. Like Marshall, Schumpeter emphasized the role of innovations and experiments in the workings of the dynamic economy (Metcalf, 2010). He believed that the innovative force of firm entry, along with new designs and better products, is what transforms the market system from within. It does so by destroying the previously established structure in a process that Schumpeter later called “creative destruction” (Schumpeter, 1942).

In Schumpeter’s view, creative destruction is intimately connected with technology. If the onset of structural change coincides with a technological shift, the resulting destruction will increase. Writing in the early 20th century, Schumpeter (1911) focused on the role of new entry and entrepreneurial small firms as drivers of innovation and economic progress. Later however, with the rise of large business in the interwar period, he came to revise his theory, emphasizing larger firms, which are more routinized and benefit from increasing returns, as the driving force behind new innovations.³

Coupled with ideas from biological selection, later research on evolutionary

³These two views later become known as Schumpeter’s Mark I and Mark II.

economics has followed in Schumpeter's footsteps (e.g. Alchian, 1950; Nelson and Winter, 1982), sharing Marshall's belief that economic activity is not compatible with a stationary state. Rather, firms are constantly searching for new profits by looking for new technology, alternative behavior and better organizational structures that will allow them to outcompete their peers. In the face of competition, successful firms survive and thrive, whereas unsuccessful firms eventually decline and exit the market (Dosi and Nelson, 2010). Both Schumpeter and Marshall suggested that firms are heterogeneous and dispersed throughout the economy and that they differ in terms of their size, age, technology, and capabilities.

An important aspect of the forest metaphor and the idea of creative destruction is that firms are part of a larger integrated ecology comprising all firms. Thus, firm dynamics is not just about the "rise and fall of large businesses" (Marshall, 1920, IV.XIII.6) but also about aspects of the ecology (Metcalfe, 2010). One particular property of this ecology was discovered by the French engineer Robert Gibrat (1931), who observed that the sizes of French manufacturing firms exhibited a robust right skew distribution. Whereas most firms were small, some firms grew to a substantial size. Based on this observation, Gibrat devised a model of the dynamics of individual firms that predicts that all firms grow at the same proportional rate, irrespective of their initial size (Gibrat's law). This idea was later popularized by Herbert Simon and his coauthors in a series of papers in the 1950s and 1960s (notably Simon and Bonini, 1958; Ijiri and Simon, 1964; 1967).⁴ Simon realized that if firms that produced different outputs could have the same minimum costs, traditional cost curve analysis in the spirit of Viner (1932) would not be able to predict the observed dispersion of firm size (Lucas Jr, 1978).⁵

Later, Lucas Jr (1978) and Garicano and Rossi-Hansberg (2004) were able to demonstrate the relationship between managerial talent and the size distribution of firms. Essentially, they argued that the shape of the size distribution is based on the (largely tacit) distribution of managerial talent. Other theories emphasized the existence of an evolutionary system in which the survival of the fittest predicts the right skew distribution of firm sizes. Selection can occur when firms learn of their actual productivity once they have entered the market,

⁴Significant contributions were also made by Mandelbrot (1963) and Champernowne (1953) in other areas. Even Schumpeter (1949) visualized what the accumulating evidence would mean for the future development of social science.

⁵See De Wit (2005) for a summary of statistical steady state models, capable to generate the observed distributions of firm size.

as in Jovanovic (1982), or following a string of negative productivity shocks, as modeled in for instance Klette and Kortum (2004), Ericson and Pakes (1995) and Luttmer (2007). In Luttmer (2007), the right skew distribution emerges when there are high costs of entry or when it is difficult to imitate successful practices.

A related set of analytical models explains the distribution of firm size as a function of rigidities and frictions in financial markets (Cabral and Mata, 2003; Cooley and Quadrini, 2001; Angelini and Generale, 2008). According to Cabral and Mata (2003), small firms cannot reach their desired size due to financial constraints. In the theory of Rossi-Hansberg et al (2007), however, the size distribution is endogenous to the accumulation of industry-specific human capital. Essentially, a small share of human capital leads to greater diminishing returns in human capital, which, in turn, increases the degree of mean reversion in its stocks and therefore also increases scale dependence in firm sizes in the industry. The resulting firm size distribution thus features fewer large firms in industries with little specific human capital. This theory has made an important contribution to industry dynamics. Based on the share of industry-specific factors of production, it explains why the variation in firm size distributions may differ across industries.

There is a connection between the above theories and Gibrat's original model, which conceptualizes the relationship between firm size and growth in Gibrat's law. In fact, Gibrat's law has generated a large body of literature as attested by several authoritative surveys (e.g. Hall, 1987; Evans, 1987a,b; Geroski, 1995; Dunne and Hughes, 1994; Sutton, 1997; Audretsch et al, 2004).

Lately, this law has enjoyed renewed interest along with the emerging research on firm growth, for which it serves as a fundamental cornerstone. In fact, Gibrat's law has direct implications for the properties that dictate the process of firm growth. In its strictest sense, the law means that individual firm growth is random, whereas firm size is the accumulation of aggregated randomness. The process as a whole has also been argued to be governed by Gaussian laws. In fact, this was the predominant view until Stanley et al (1996) observed that firm growth is inherently lumpy: a few firms experience tremendous growth, but most are static, at least in the short run. The discovery of a tent-shaped Laplace distribution of growth rates was in many ways comparable to Gibrat's original discovery of a lognormal for firm size.⁶

⁶Actually, the discovery of spectacular firm growth rates predates Gibrat (1931). Studying textile firms in the British Oldham district (in 1884-1924), Ashton (1926) discovered that

Several statistical models have been introduced that are capable of generating a tent-shape and narrower Laplace function for growth rates (c.f., Alfarano et al, 2012; Fu et al, 2005; Bottazzi and Secchi, 2008; Coad and Planck, 2011). In Alfarano et al (2012), the tent-shaped distribution of firm growth is related to the notion of competition. Among the classical economists, competition was seen as a dynamic process in which capital is constantly moving across industries, attracted by higher profit rates. However, as prices eventually increase and wages are bid up, profit rates tend to equalize over time. By encoding the mean reversing tendency of profit rates in the moments of the profit distribution, Alfarano et al (2012) are able to solve for the predicted profit distribution. Disregarding the complex relationship between profits and growth, they find the resulting distribution to be tent-shaped.⁷

Other theories of firm growth, not directly related to its distribution, have also been introduced. For instance, firm growth is viewed within a standard profit maximizing framework in Baumol (1962). Under constant prices and a homogenous production function, revenues grow in tandem with inputs. In perfect competition, firms then maximize profits by choosing the growth rate for which marginal revenue equals marginal cost to growth. According to Nelson and Winter (1982), firm growth is positively related to profitability, wherein selection acts on firms by redistributing market shares from the less profitable firms to the more profitable ones. Another theoretical model is presented in Metcalfe(2007), wherein firm growth is related to productivity in a Marshallian setting. Firms only grow if they are within their respective investment margins.

3 Statistical models of firm dynamics

The original contributions of Robert Gibrat and Herbert Simon were quite influential for the later literature on firm dynamics, which still uses their statistical models. The next subsections outlines some of the early contributions that are still frequently used in current research on the distribution of firm size and growth.

growth rates were characterized by heavy tails.

⁷The limit distribution to the maximum entropy problem in their paper is the Subbotin distribution, which encompasses both the Gaussian and Laplacian (tent-shaped) distributions as special cases. However, only for the Laplace does competition affect all firms equally irrespective of profit level/firm size.

3.1 Gibrat's law and the distribution of firm size

Gibrat's law has had important implications for the size and growth-rate distribution of firms. The law also serves as a common benchmark and resource in empirical studies. The law states that firms grow at the same proportional rate independent of their size.⁸

Consider a small service firm with 10 employees. A 20 percent growth rate translates into 2 additional employees. For another larger service firm with 1,000 employees, a 20 percent growth rate will increase the labor force with 200 additional people. According to Gibrat's law, "the probability of a given proportionate change in size during a specific period is the same for all firms in a given industry - regardless of their initial size at the beginning of the period" (Mansfield, 1962 p. 1030).

Gibrat's law and the lognormal shape of the distribution of firm size follow from a simple dynamic. Let S_t be the size of a representative firm at time t . Then, its percentage growth rate from period $t - 1$ is given by ϵ_t

$$\frac{S_t - S_{t-1}}{S_{t-1}} = \epsilon_t. \quad (1)$$

Solving for the dynamic of firm size S_t , we obtain

$$S_t = (1 + \epsilon_t) S_{t-1}. \quad (2)$$

Using recursion, the dynamic can be pushed back until the initial entry size S_0 as follows:

$$S_t = (1 + \epsilon_t)(1 + \epsilon_{t-1})(1 + \epsilon_{t-2}) \cdots (1 + \epsilon_1) S_0, \quad (3)$$

which describes a multiplicative growth process. Taking the logarithm of both sides and realizing that $\log(1 + \epsilon) \simeq \epsilon$, at least for small ϵ , results in

$$\log S_t = \epsilon_t + \epsilon_{t-1} + \epsilon_{t-2} + \cdots + \epsilon_1 + \log S_0, \quad (4)$$

$$\log S_t = \sum_{i=1}^t \epsilon_i + \log S_0. \quad (5)$$

⁸Gibrat's law has also found ready use in a number of other areas in economics, such as the growth of cities and the city size distribution (See the survey by Gabaix and Ioannides, 2004). In Elert and Halvarsson (2012), the properties of Gibrat's law are used to examine for economic institutional convergence and test Francis Fukuyama's (1989) claim that the present democratic order constitutes an end state for political governance.

Thus, the (log) firm size at time t is reduced to the accumulation of random shocks ϵ_i and the (log) entry size. From the central limit theorem, it follows that $\log S_t$, when appropriately normalized, tends to a normal distribution as the number of shocks t goes to infinity (or, equivalently, that S_t is lognormal).⁹

Interpreted in the language of time series analysis, (log) firm size can be described by a *random walk*. On the surface, the concept of a random walk does not seem to offer any deeper insight into firm dynamics. However, this means that managers are endowed with an initial supply of resources $\log S_0$, that comprises firm capabilities, technology, and social and financial capital (Helfat and Lieberman, 2002; March and Shapira, 1992, p. 173). Over time, $\log S_0$ is accumulated or depleted by a series of independent draws from a Gaussian performance distribution, which generates a composite measure of firm size (Coad et al, 2012).

Moreover, a random walk means that firm size is path dependent. Using Page's (2006) taxonomy of path dependence, a random walk is related to the notion of *Phat* and *Early* dependence in Freeman and Jackson (2012). According to this theory, past events have the same impact on current outcomes regardless of the order in which they occur, whereas initial events have a disproportionate impact, according to Arrow (2000). The lognormal distribution, however, does not constitute a steady state distribution, as the variance of (log) firm size approaches infinity as t becomes larger. Simon and Bonini (1958) introduce a slightly different model in which the size distribution becomes a Pareto distribution, also known as a power-law distribution.¹⁰

3.1.1 Pareto's law

“Few if any economists seem to have realized the possibilities that such invariants hold out for the future of our science. In particular, nobody seems to have realized that the hunt for, and the interpretation of, invariants of this type might lay the foundations of an entirely novel type of theory.” (Schumpeter, 1949, p.155)¹¹

Vilfredo Pareto (1896) observed a very simple relationship between the number

⁹In a lognormal firm size distribution, most firms are small but there exists a number of firms with exceptional size.

¹⁰The simplest way to obtain the power-law distribution is to introduce some friction into the model. Gabaix (1999) considered introducing a minimum firm size, which functions as a reflective boundary in the spirit of Champernowne (1953) and Kesten (1973).

¹¹The quotation refers to Pareto's law of income distribution and appeared in Gabaix (2009), which provides a comprehensive survey of the power laws found in economics and finance.

of people N with wealth or income greater than x . This relationship can be described using the following simple equation:

$$\log N = \log A - m \log x. \quad (6)$$

This relationship became known as Pareto's law and, or alternatively, as a power law. The remarkable finding was that the number of people N is exclusively determined by the constant m . Simon and Bonini (1958) incorporated Pareto's law into studies of firm size to explain the number of large firms N above some size x , provided that x is large. A special instance of equation (6) occurs when m takes a value of 1. This rule is known as Zipf's law after the Harvard linguist George Zipf (1936), who found that frequency of any word in the English language could be described using the relationship in (6).

One reason for the popularity of Pareto's law is the observed stability of the constant m encountered in empirical phenomena, which has generated a large body of literature on potential statistical mechanisms that are capable of reproducing the distribution in (6). Other factors in its popularity are its statistical properties, such as the 80-20 rule, its scale invariance, and its lack of higher moments for small values of m . Power laws also reached a wider audience with a series of popular science books e.g. *The Long Tail* (Anderson, 2004) and *The Black Swan* (Taleb, 2010).

3.2 Laplace's second law of error and the growth-rate distribution of firms

Like the Gaussian distribution in Gibrat's model, the tent-shaped Laplace distribution often encountered in firm growth rates can be traced back to Pierre-Simon Laplace who formulated the *first* and *second law of error*. The second law of error was formulated in 1778 and describes a quadratic function for the logarithmic frequency of error. Better known as the Gaussian (normal) distribution, this law of error is the one describing the distribution of firm growth rates in Gibrat's law. The first law of error was discovered in 1774 and associates a linear function with the logarithmic frequency of the absolute error, known as the Laplace distribution (Wilson, 1923 p.841).

Like the normal distribution, the Laplace distribution also emerges as a limit distribution, but to a different scheme of summation than in (5). As in the central limit theorem for sums of random variables, a random sum of random variables, when appropriately normalized, tends toward a tent-shaped Laplace

distribution (see e.g., Klebanov et al, 2006).

This tendency can be illustrated using a slight modification of the random walk model. If the number of random shocks ϵ_i itself is a random variable v_p that follows a geometric distribution with probability p and mean $1/p$, the Gibrat model can be restated as a random sum of random variables:

$$\log S_{v_p} = \sum_{i=1}^{v_p} \epsilon_i + \log S_0, \quad (7)$$

where p is the probability that a firm will exit in the next period. Assume that all firms die with a constant probability p ; the random variable v_p then describes a cross-sectional distribution of firm age as a geometric distribution (Toda, 2012).¹² This simple modification of Gibrat's law provides an explanation for the emergence of a tent shape in the firm growth-rate distribution that tends to a Laplace distribution when p becomes small. Hence, if the number of shocks facing the firm is roughly constant, the distribution tends to be a normal distribution, whereas if they are random, the distribution instead tends to be a Laplace distribution (Manas, 2012).¹³

The interpretation of firm size is similar to the above, but $\log S_0$ is accumulated or depleted by series of independent draws from a Laplace performance distribution subject to a probability p of exit. The probability of exit also results in a size distribution that is double Pareto (Reed, 2001; 2003; Reed and Jorgensen, 2004) instead of lognormal (Toda, 2012).

3.3 Growth persistence

The Gibrat model presented in equation (1) to (5) puts a number of restrictions on growth (ϵ). For growth to be statistically independent of size, firm growth must be independent and identically distributed. Essentially, this means that the growth rates in period t cannot be correlated with the growth rates in previous periods and that they must have the same probability distribution. This insight is often attributed to Chesher (1979), who showed that if growth rates are autocorrelated in the sense that current growth rates are dependent on previous growth rates, Gibrat's law cannot hold.

¹²The argument in Toda (2012) refers to the distribution of wealth and the death probability for individuals, but it is readily applicable to the distribution of firm growth.

¹³Except for Manas (2012), the above simple modification of Gibrat's model seems not to have been fully realized in research on the growth-rate distribution.

Growth persistence is often modeled using a first-order autoregressive structure, as in the following equation:

$$\epsilon_t = \theta\epsilon_{t-1} + v_t, \tag{8}$$

where the parameter θ captures the effect of previous growth rates. Thus, for Gibrat's law to hold $\theta = 0$. Say that $\theta > 0$ ($\theta < 0$), current growth rates must be "encouraged" ("discouraged") by previous growth rates, and hence firm growth is persistent (Chesher, 1979).¹⁴

As noted by Boeri and Cramer (1992) and Coad and Hölzl (2009), persistence in growth rates can be predicted using the theory of dynamic labor demand and the nature of adjustment costs (Gould, 1968; Hamermesh and Pfann, 1996; Cooper and Haltiwanger, 2006). The problem facing the firm is the need to maximize discounted expected profits while selecting the optimal number of employees. However, if the hiring of new employees and the firing of old ones entail a cost, the firm also needs to choose an appropriate adjustment path to reach its desired labor stock. Under standard assumptions, the adjustment costs are assumed to be convex, with a symmetric and quadratic U-shape. For higher costs, it becomes more profitable for the firm to spread out its adjustments, which will result in small, gradual changes in employment over time and thus should predict a value of $\theta > 0$.¹⁵

4 Previous empirical literature

The subsequent chapters of this thesis mainly address empirical questions and problems that are related to firm dynamics. An overview of the existing empirical literature is therefore in order. Like the theoretical overview discussed above, this section focuses on empirical findings and serves as the backdrop for the more in-depth discussions provided in later chapters.

¹⁴Mansfield (1962) and Tschoegl (1983) formulated one additional condition that also must be satisfied for Gibrat's law to hold: that small and large firms are not allowed to have growth rates with different standard deviations. Statistically, this means that the standard deviation as a function of firm size is a constant; hence, $\sigma(S_t) = \sigma$.

¹⁵However, the assumption of quadratic costs is strong. According to Hamermesh and Pfann (1996), a good approximation should also account for eventual asymmetries and non-convexities like piecewise and linear segments of the cost function. Although convex costs have been criticized, they appear frequently in the literature, as they provide simple closed form solutions to the profit maximization problem.

4.1 Gibrat's law and the firm size distribution

The long history of empirical research on Gibrat's law has generated an impressive body of literature that has been the subject to many comprehensive literature surveys (see, e.g., Geroski, 1995; Sutton, 1997; Caves, 1998; Lotti et al, 2003; Audretsch et al, 2004). The main focus in the overwhelming majority of these studies is the question of whether Gibrat's law holds. The answer to the seemingly simple question of whether firm growth is independent of size is complicated by the fact that there are many versions of Gibrat's law.

In a seminal paper, Mansfield (1962) identifies at least three versions: (1) Gibrat's law may apply to all firms without reference to market turbulence, characterizing the entry and exit of firms; (2) Gibrat's law only holds for surviving firms; or (3) the law holds for firms with a size that is sufficient for them to produce at a long term minimum average cost, the industry's minimum efficient scale (Mansfield, 1962).

Further consideration regarding the strong and weaker versions of Gibrat's law is also required, as emphasized by Chesher (1979) and Tschoegl (1983). The empirical evidence when all firms are included is quite clear and rejects Gibrat's law based on the more rapid growth of smaller firms, i.e., versions (1) are rejected (Evans, 1987a; 1987b; Hall, 1987; Dunne et al, 1989; Dunne and Hughes, 1994; Audretsch et al, 2004; Reichstein and Michael, 2004).¹⁶ In Mansfield's original piece, all three versions of the law are rejected, but more recent empirical research finds evidence in favor of version (3) (e.g., Mowery, 1983; Hart and Oulton, 1996; Lotti et al, 2003; Geroski and Gugler, 2004; Audretsch et al, 2004). This finding suggests that average costs are increasing for sizes below some minimum efficient scale and are roughly the same for sizes above it (Simon and Bonini, 1958; Mansfield, 1962).

For reasons of data availability the early studies have mainly studied Gibrat's law for manufacturing firms. Audretsch et al (2004) argue that results from the service industry might differ. Based on the observation that *minimum efficient scales* is likely lower in services, they find evidence that Gibrat's law appears to hold for a number of Dutch service industries.

As was shown in Section 3, there is a direct relationship between Gibrat's law and the shape of the size distribution of firms. The same holds for the existence of some size threshold (e.g. a minimum efficient scale) that generates

¹⁶Even when exits are controlled for (version 2), smaller firms seem to grow faster than large firm (Harhoff et al, 1998)

a Pareto distribution or power-law distribution for large firms (Gabaix, 1999). The empirical literature on firm size distribution is largely statistical, indicating the validity of the special case of Zipf's law. Considering all firms in the U.S Census, Axtell (2001) finds that Zipf's law provides a remarkable fit. Later, the same findings were largely confirmed for many European firms and for some firms in G7 countries (Fujiwara et al, 2004; Gaffeo et al, 2003). A power law was also further confirmed for Italian and Japanese firms by Cirillo and Hüsler (2009) and Okuyama et al (1999). There is, however, evidence that a power law and thus also Zipf's law do not hold at lower levels of aggregate industry data. This inconsistency is known as the industry scaling puzzle (Quandt, 1966; Axtell et al, 2006; Dosi, 2007)

Furthermore, there are a number of empirical results of economic causes behind the shape of the firms size distribution. In a study of 23 countries, Champonnois (2008) finds that industry-specific fixed effects explain approximately three times as much of the variation in the firm size distribution than do fixed effects at the country level. Further evidence of industry-level variations in firm size distribution is provided in Rossi-Hansberg et al (2007), where industries with little specific human capital are found to have fewer large establishments and, thus, thinner tails in their size distributions. Empirical (graphical) evidence also suggests that financial constraints may be an important explanation of firm size dispersion (e.g., Cabral and Mata, 2003). However, based on their study of firms in the World Business Environment Study (WBES), Angelini and Generale (2008) find that financial constraints are not likely to be the major determinant of the shape of the firm size distribution in countries that are financially developed.

4.2 Firm growth and the growth-rate distribution

A large number of variables, including firm-level, industry-level and macro-level variables, has been used in regression analysis to explain firm growth (Coad and Hölzl, 2010). Fortunately, this literature has been summarized in excellent surveys by Coad (2009) and Coad and Hölzl (2010). Research on firm growth embrace essentially every branch of industrial organization, small business and management research, of which this brief overview only covers a small portion. If Gibrat's law is rejected because small firms grow faster than large firms, size will have a negative impact on growth in a regression setting. Firm age is closely related to firm size, and most empirical studies find a significant negative effect

from age on firm growth (e.g., Evans, 1987a; Dunne and Hughes, 1994).

The positive theoretical relationship between firm growth and profits has been fundamentally questioned by a number of empirical papers that find a weak link between the two. In fact, profits seems to explain very little of the variation in growth rates (Coad, 2007a; Bottazzi et al, 2008). In studying a sample of French manufacturing firms, Coad (2007a) is able to find a small positive contribution of profit rates to growth rates, but the relationship is unclear. Conversely, Coad (2007a) finds that growth rates have a significant and positive effect on later profit rates. The weak relationship between profits and growth can also be observed from the high levels of persistence found in profit rates Mueller (1977), whereas growth persistence is often negative (see the next section for the empirical results for growth persistence).

Coad and Hözl (2010) conclude that there is a comparatively stronger link between productivity and profit rates. Examining Italian firms, Bottazzi et al (2008) find a strong positive connection between the two in the manufacturing and service industries. However, in relation to firm growth, productivity appears to have only a limited influence (Bottazzi et al, 2008). With regard to innovation, Coad and Hözl (2010) find essentially the same results as for profit rates, and researchers such as Geroski et al (1997b) find no significant effect of the number of patents on subsequent growth rates. Interestingly, however, there is some evidence that high-growth firms (HGFs) are, on average, more innovative than other firms (Hözl, 2009). For a discussion on HGFs see Section 4.4.

Still, perhaps the most striking finding in the empirical literature on firm growth is the high amount of variance that is left unexplained by standard regression analysis. In surveying the mostly empirical literature on firm growth, Coad (2009) finds that R^2 is often surprisingly low (often approximately 5 percent), which testifies to the large degree of randomness that is present in the data on firm growth rates. Despite the number of empirical studies that reject Gibrat's law, this result gives some credence to Gibrat's stochastic model, at least as a reasonable benchmark.

If one considers the numbers of interrelated and correlated forces that simultaneously act on firms, the amount of randomness, especially in aggregate measures such as the growth-rate distribution, is not entirely unexpected. This fact is well captured by the following quotation by Singh and Whittington (1975):

“The chances of growth or shrinkage of individual firms will depend

on their profitability as well as on many other factors which in turn will depend on the quality of the firm's management, the range of its products, availability of particular inputs, the general economic environment, etc. During any particular period of time, some of these factors would tend to increase the size of the firm, others would tend to cause a decline, but their combined effect would yield a probability distribution of the rates of growth (or decline) for firms of each given size." (Singh and Whittington, 1975, 1975. p.16.)

The result of such churning of economic activity is the now ubiquitous tent-shaped distribution, which is characterized by a high singular mode and heavy tails similar to the Laplace distribution (observed in e.g. Stanley et al, 1996; Lee et al, 1998; Bottazzi and Secchi, 2004; Erlingsson et al, 2012). In a study of pharmaceutical companies, Bottazzi and Secchi (2005) finds evidence that indicates that firm growth has a tent-shaped distribution.¹⁷ The researchers find similar results for U.S. manufacturing firms (Bottazzi and Secchi, 2004).

The degree of fit is often quite remarkable, and the tent-shape is robust to various measures of growth indicators (i.e., measures of firm size), including value added, sales and employment, as well as over more disaggregated levels of industry (Dosi and Nelson, 2010). Thus, there seems to be no industry scaling puzzle here as there was for the distribution of firm size.

There are however some observed variations in the observed tent-shaped distribution of the growth rates. In a study of Danish firms, Reichstein and Jensen (2005) find evidence of substantial skewness along with signs of heavier tails than are accounted for by the Laplace distribution, especially for the right tail, containing the fastest growing firms. Heavy tails was also found in studies such as Bottazzi et al (2011), who remarked that

“the Laplace distribution of growth rates cannot be considered as a universal property valid for all sectors. Looking at French manufacturing, we observe growth rates distributions with tails that are consistently fatter than those of the Laplace.” (Bottazzi et al, 2011, p.2).

Rather, Fu et al (2005), Schwarzkopf et al (2010) and Gabaix (2011) shows that the growth-rate distribution is consistent with Pareto's law for firms with

¹⁷Bottazzi and Secchi (2005) use a more general group of probability distributions known as a Subbotin distribution introduced in Bottazzi et al (2002), which encompasses both the Laplace distribution and the normal distribution as special cases.

extreme growth rates. The finding of a possible power-law in the growth-rate distribution poses new challenging empirical and statistical problems to understand the complex micro foundation of firm dynamics.

4.3 Growth persistence

There is longstanding tradition in the industrial organization literature of emphasizing Gibrat's law and the relationship between firm growth and size. Surprisingly few studies focus on the dynamics of growth rates. Although growth persistence is some times considered in the analysis of Gibrat's law, it is often regarded as a nuisance that can ideally be controlled for.

The early literature on growth persistence began with Ijiri and Simon (1967), who found strong evidence of positive persistence (30 percent) among 90 large firms in the U.S. In roughly the same period, for similar U.K. companies, Singh and Whittington (1975) found the same result but also that the effects of previous growth rates were much smaller. Both studies employed longer growth rates measured during two consecutive periods. The existence of positive persistence was later supported by data obtained by Kumar (1985) and Chesher (1979) for annual growth rates for similar firms in the U.K. Other important evidence of past growth encouraging subsequent growth include e.g. Wagner (1992), Geroski et al (1997a).

These positive results, however, have been contested in a number of later studies that find growth persistence to be negative. These studies include Oliveira and Fortunato (2006) and Goddard et al (2002a), who studied growth persistence for manufacturing firms. In Oliveira and Fortunato (2006), growth persistence across 8000 Portuguese firms was found at a magnitude of -10 percent, and for Japanese firms Goddard et al (2002a) estimated it to be at approximately -30 percent. Unlike Ijiri and Simon (1967), who find that "[r]apidly growing firms 'regress' relatively rapidly to the average growth rate of the economy" (Ijiri and Simon, 1967 p.355), negative persistence suggests oscillating regression, in which growth is likely followed by decline.

The above studies mostly examine large firms in manufacturing or related industries. The results for services seem to point towards negative growth persistence, but some studies also find no evidence of any persistent component of growth rates. Important studies in this area include for instance Coad and Hölzl (2009), Oliveira and Fortunato (2008) and Goddard et al (2002b). In examining 6.840 federal credit unions in the U.S., Goddard et al (2002b) reaches the

conclusion that persistence is negative, whereas Oliveira and Fortunato (2008) were unable to detect any sign of significant persistence among 400 Portuguese service firms.

The results found in the empirical literature is mixed, to say the least. Unsurprisingly, the early results were consistent because they studied roughly the same sample of contemporary large manufacturing firms; however, the results likely were not generalizable to the remainder of the economy. The samples used by more recent studies are more heterogeneous, and those studies have used different methods. However, new evidence has come from a number of studies that use quantile regression to study how persistence may vary throughout the growth-rate distribution (Coad, 2007b and Coad and Hözl, 2009).

The emerging picture is that small firms generally tend to experience negative persistence in their growth rates, whereas larger firms tend to experience positive or no growth persistence (Coad and Hözl, 2009). In addition, the positive results for large firms would suggest that larger firms experience U-shaped costs in adjusting their size. This finding suggests a gradual transition leading to a positive autocorrelation in growth rates. The results also seem to differ for firms in different segments of the growth-rate distribution. Of particular interest are the firms with the highest growth rates: the so-called HGFs or gazelles. They will be the topic of next section.

4.4 High-growth firms and net job creation

Today, an entrepreneurial firm tends to be small, young and productive, with innovative capabilities that positively contribute to overall job creation (Van Praag and Versloot, 2008). However, it was not until Birch (1979) emphasized the importance of small and medium-sized firms that these traits were recognized; up until that point, such firms were in the shadow of their larger counterparts. Large firms were long believed to exhibit superior growth, benefiting from increasing returns to scale (Schumpeter, 1942).¹⁸

The marginalization of small firms becomes evident in Galbraith, (1956; 1967), who deemed them inefficient and almost wasteful. However, what Birch (1979) argued was that small- and medium-sized firms provided a disproportionately large share of the jobs created in the U.S. economy. Birch realized that although large firms employed a large share of the workforce, their employment

¹⁸This view partly explains the industrial policy in Sweden, post-World War II that was mainly directed towards large firms to stimulate economic development (Henrekson and Johansson, 1999).

figures decreased over time and smaller firms that had grown larger tended to provide more of those positions.

Birch (1979) thus emphasized the dynamic character of these changes (Henrekson and Johansson, 2010). Nevertheless, it was not until Birch's claim was criticized in the late 1990s, by Davids et al. (1996a; 1996b), Haltiwanger and Krizan (1999) and others, that small business research really took off. The evidence from Gibrat's law suggests that young (and hence often small) firms must grow at a rapid pace to acquire a minimum efficient scale, become productively efficient and survive (Mansfield, 1962). At the same time, most small firms do not seem to grow at all, which is evident from the shape of the growth-rate distribution. Davidsson and Delmar (2006) argue that "[m]ost firms start small, live small and die small" (Davidsson and Delmar, 2006, p.7).

However, the empirical research shows that the few firms that do grow, HGFs, provide most or even all of the net job creation (Birch and Medoff, 1994; Storey, 1994; Davidsson and Henrekson, 2002; Delmar et al, 2003; Halabisky et al, 2006; Acs and Mueller, 2008). Storey (1994) surveys the literature, identifies 14 relevant studies and estimates that approximately 4 percent of firms are HGFs and that these firms generate approximately 50 percent of jobs created. Yet, studies differ as to what what percentage of firms creates what share of the jobs. In addition, there exists no established definition of HGFs in the literature.¹⁹ One attempt by OECD/ EUROSTAT and Ahmad (2008) defines an HGF as a firm with an annualized growth rate higher than 20 percent over three years, provided the firm has at least 10 people employed in the beginning of the period.²⁰

Given the disparate measures, methods and data used study HGFs, it is somewhat surprising that it is generally agreed that "[a] few rapidly growing firms generate a disproportionately large share of all new net jobs compared to non high-growth firms" (Henrekson and Johansson, 2010, p.15.).

There are different measures of job creation, such as gross job creation and gross job destruction that refer to the total number of jobs created and destroyed over a particular period, as analyzed in Davis and Haltiwanger (1992).²¹ Almost all of the studies surveyed in Henrekson and Johansson (2010) focus exclusively

¹⁹Daunfeldt et al (2010; 2011) provide an overview and a critical examination of various measures used to define HGFs.

²⁰Daunfeldt et al (2012) argue critically that the OECD definition systematically discriminates against small firms.

²¹Davis and Haltiwanger (1992) found that high rates of gross flows were pervasive in the U.S. manufacturing industry, and that gross flows amounted to as much as 10 percent of employment each year.

on net job creation. In addition to their job creating capabilities, the following properties of HGFs emerge: (1) HGFs are younger than average; however, (2) their size does not seem to matter, as although small firms are over represented, large firms constitute a non-negligible share; and (3) HGFs exist in all industries and are somewhat overrepresented in the service industries but are not overrepresented in the high-tech industries.

In a rare international study of small and medium-sized HGFs in 16 countries, Hölzl (2009) finds evidence that investment in R&D is important if the country is close to the technological frontier. In these countries, HGFs also tend to be more innovative than other firms. The closer to the frontier, the less plentiful opportunities are, which is why, according to Hölzl (2009), innovation becomes increasingly important for these firms if they hope to grow rapidly. Another important empirical study was made by Parker et al (2010) who study 100 high-growth firms located in the UK and emphasize the role played by dynamic strategic management for HGFs seeking to become and remain large. Parker et al (2010) also studied the persistence of growth rates among HGFs and found little evidence for continued growth.

4.4.1 Persistence in high growth rates

The study by Parker et al (2010) is an exception in the empirical literature on growth persistence. Although they do not focus on HGFs directly, a few other studies have examined persistence in high growth rates (Coad, 2007b; Coad and Hölzl, 2009; Capasso et al, 2009; Hölzl, 2011). Coad and Hölzl (2009) find persistence to be negative for Austrian firms with high growth rates but not for firms with negative or declining growth. The effect was found to be strongest for micro firms (<10 employees), which suggests that high growth is likely temporary. Larger HGFs on the contrary seem to experience a positive effect of previous growth rates. Although persistence is found to be negative, Capasso et al (2009) discovers that there are some micro HGFs that experience positive feedback from earlier growth. The overall findings regarding negative shocks from past growth rates made Hölzl (2011) remark that “[m]ost HGFs are one-hit wonders” (Hölzl, 2011, p.30.). The title of Chapter 2 of this dissertation is derived from that statement.

5 Data, limitations and measurements

Because three of the chapters of this dissertation are empirical in nature, subsections 5.1 and 5.2 provide short introductions to the two data sets used in the empirical analysis, while the subsequent subsections 5.3 and 5.4 discuss some general problems with these types of data. A more detailed description is found in the data section for each chapter. In the last subsection (5.5) measurements of firm size and growth are discussed.

5.1 The PAR-dataset

Self-employed in Sweden can incorporate their business, turning it into a limited liability firm (aktiebolag), which has a legal personality and is treated as a separate tax subject, i.e. corporate income tax is levied on the net return. All limited liability firms are required to submit annual reports to the Patent and registration office (PRV), including e.g. number of employees, wages, and profits.²²

The industry-specific data in Chapter 1 (Industry Differences in the Firm Size Distribution) and Chapter 3 (Identifying High-Growth Firms) came from PAR, a Swedish consulting firm that gathers information from PRV, for use primarily by decision makers in Swedish commercial life. The data cover all Swedish limited liability firms active at some point during 1997-2010, yielding 3,831,854 firm-years for 503,958 firms.

The panel contains both continuous incumbents and firms that entered or exited during the period. Since the last years saw a marked drop in the number of firms, the 2010 was dropped. Firm activities are specified by branch of industry down to the 5-digit level according to the European Union's NACE classification system.

The PAR dataset was recently updated to cover the aforementioned time-period, whereas it had previously covered the years 1995-2005. Information on mergers and acquisitions, missing in the earlier version of the dataset, was also included. Since Chapter 1 was completed prior to the update, it uses this earlier dataset. However, the years 1995, 1996 and 2005 saw a similar drop in the number of firms, which is why the study in Chapter 1 covers the years 1997-2004.

²²Regarding accounting data on corporations in Sweden, Bradley et al (2011) argues, is more reliable than data on e.g. partnerships or proprietorships, for which auditing is not regulated by law to the same extent.

5.2 The IFDB-dataset

The database used in Chapter 2 (Are High-Growth Firms One-Hit Wonders? Evidence from Sweden) came from the IFDB database that was kindly provided to us by Growth Analysis; the Swedish agency of growth policy analysis (Myn-digheten för tillväxtpolitiska utredningar och analyser). The IFDB database comprises a selection of longitudinal register data from Statistics Sweden (SCB) and contains business-related information on firms and establishments operat-ing in Sweden, irrespective of their legal status. In addition, the database also includes tax information and employment statistics collected from Swedish tax authorities and RAMS register database. Since businesses are obliged by law (SFS; 2001:99 and 2001:100) to submit information to SCB, the coverage is next to complete. In Chapter 2, the dataset used essentially includes all Swedish firms and covers the period 1998-2008.

5.3 Generalizability

As in all empirical domestic studies generalizability to other countries can be discussed. Unfortunately, cross-country micro data are exceptionally difficult to obtain. However, to the extent possible, precaution has been taken and attempts have been made to scrutinize empirical findings when comparable international studies could be found.

5.4 Firms vs. establishments

In the empirical research on firm dynamics, there are some potential problems associated with using firms rather than establishments, which essentially comes down to the industry scaling puzzle described in Section 4.1. At lower levels of industry aggregation (e.g. NACE 4-5 digits), stable patterns like the distribution of firm size seems to break down, displaying a much more erratic micro structure. Heterogeneity furthermore seems to be difficult to escape even at the finest levels of industry aggregation. According to Griliches and Mairesse (1999):

“we [...] thought that one could reduce heterogeneity by going down from general mixtures as ‘total manufacturing’ to something more coherent, such as ‘petroleum refining’ or ‘the manufacture of ce-ment’. But something like Mandelbrot’s fractal phenomenon seem to be at work here also: the observed variability-heterogeneity does not really decline as we cut our data finer and finer. There is a sense

in which different bakeries are just as much different from each others as the steel industry is from the machinery industry.”²³

In other words, if a researcher analyzes firms rather than establishments, he or she may be faced with significant heterogeneity, even at the unit of analysis. However, establishment data were not accessible from either of the datasets used. In addition, with a few exceptions (notably, Rossi-Hansberg et al, 2007), most relevant studies referred to in later chapters still use the firm as a unit of analysis, which makes the presented results more comparable to theirs.

5.5 Measuring firm size and growth

Firms are heterogeneous and differ in terms of many dimensions, as exemplified by the disparate empirical literature on HGFs. In Delmar et al., (2003, p.192-197), a number of different dimensions are identified for which previous studies on HGFs made differing choices. Because all of these dimension have the potential to impact the individual firm’s growth rate, they must be considered an integral part of the empirical research. Some of these points warrant further comments, which are provided below. These dimensions are as follows:

1. The choice of size measure (or growth indicator), such as employment, sales, output, profits, or market share.
2. The choice of how growth is measured, i.e., as a percentage, using first differences, or using composite indicators.
3. The choice at what frequency growth is measured: year-to-year (annual growth), over longer periods of time, or from the first observed period to the last.
4. The choice of whether to consider organic growth, inorganic growth or total growth. Organic growth refers to endogenous growth through increasing sales volume or hiring, whereas inorganic growth occurs through actions such as company mergers or acquisitions. Total growth is the sum of organic and inorganic growth.
5. The choice of firm demographics, i.e., difference in firm sizes, age profiles, and industries.

²³The following quote appears in Dosi and Nelson (2010).

Regarding the choice of size measure (1), it should be noted that many studies take an agnostic approach to this decision. Although most of these measures are highly correlated, there are some important nuances that allow them to reflect different aspects of firm growth. In the empirical literature on firm growth and HGFs, the most common growth indicators are total sales and employment (Daunfeldt et al, 2010; Chandler et al, 2009; Coad and Hölzl, 2010; Delmar, 2006). Measuring size based on the number of employees (rather than, e.g., sales) relates size more to the internal characteristics of firms, such as their organizational structure and operational activities (Aldrich, 1999). For example, searching for, hiring and monitoring new employees is costly, even more so for professionals in their area (Aldrich, 1999; Chandler et al, 2009). Furthermore, the process of integrating new employees into the workplace requires organizational effort.

In knowledge-based service industries, employment growth is also related to how firms measure their increased productivity (Greenwood et al, 2005; Hitt et al, 2001). From a management perspective, sales growth does not enter into the decision making process concerning organizational changes. Rather, it captures slightly different aspects of growth that better reflect external conditions such as demand for the firm's products and services. Sales can also vary with inflation, which makes them potentially more volatile.

Other indicators, such as value added and profits, can be distinguished from growth as performance indicators (Coad, 2009), as is evident from the literature that addresses the relationship between the two (e.g. Coad, 2007a). Another dimension that matters to the choice of the size measure is the policy dimension. For policy makers, measuring size using the number of employees is often more convenient and interesting because this measure generates macroeconomic figures for job creation, employment and unemployment.

How growth is measured (2) may also affect growth rates. According to Coad and Hölzl (2010), there are two common measures of firm growth: the percentage change in firm size and the logarithmic difference between the sizes of a firm in consecutive periods. Other growth measure is the first differences measure used to calculate the gross employment change for a firm, and also the Birch Index. The Birch index, which was created by David Birch, is a composite measure of percentage growth weighted using first differences. The purpose of the index is to weight the growth rate using the firm's employment contribution. This index is frequently used in the HGF literature (see e.g. Hölzl, 2011).

Regarding (3), it is worth noting that shorter growth rates are often noisier than longer growth rates. In the empirical literature of firm growth, shorter frequencies are often used to increase the number of observations to compensate for limited number of data periods.

Concerning (4), most studies focus on total growth because accurate data on mergers and acquisitions are difficult to obtain. However, there are potential problems with excluding M&A activities, especially for HGFs, for which high growth is likely to partially be a function of such activities. For instance, if a small firm acquires a larger firm, that will be reflected in a massive burst of growth and will register the firm as an HGF. Finally, the empirical evidence on Gibrat's law and on firm growth illustrates the importance of considering firm demographics (5) such as size and age, which both tend to assert a negative effect on firm growth in empirical research.

6 Chapter summaries

In the following subchapters, a short summary is provided for each of the four later chapters comprising this thesis. The first chapter concerns the size distribution of firms, whereas the following two chapters deal with HGFs, where the last chapter covers a topic in distributional estimation theory.

6.1 Chapter 1. Industry Differences in the Firm Size Distribution

This paper empirically examines industry determinants of the shape of the firm size distribution. Recent theoretical contributions in the field suggest that such determinants may be variables such as friction in financial markets and the intensity of industry-specific human capital. Despite the large body of literature on the topic, which is partly focused on establishing which of the alternative distribution functions has the best fit, more systematic empirical studies are needed. This chapter adds to the existing literature by addressing this gap.

This study also contributes to relevant empirical methodology by developing an appropriate two-stage empirical strategy that incorporates recent methodological developments in the estimation of firm size distributions. The benchmark distribution considered is Pareto's law, which is referred to as a power law in the chapter. In the first step, the parameter m in Pareto's law, is estimated across 3-digit (NACE) industries, as well as possible (quadratic) deviations to the law, where the latter captures industries with fewer large firms than predicted from Pareto's law in equation (6). The dependent variable is number of

employees, and the industry-level firm size distribution is estimated using the PAR-dataset for surviving Swedish firms in the period 1997-2004.

The main result from first-stage estimation suggests that a power law is an appropriate model for 611 out of 770 industry-time observations. Yet the results display substantial variation in the firm size distribution across industries, for which Zipf's law ($m = 1$) is validated within one standard deviation of the mean industry estimate of m in 445 out of 770 instances.

The first-stage estimates of a power law and observed deviations from the law are then used to construct the dependent variable of a second-stage regression analysis, which for \hat{m} ranges between 0.425 to 4.936 and has a mean of 1.304. To accommodate for known problems associated with OLS, a number of different regression strategies are used to test the effect of a set of industry variables hypothesized to influence the shape of the firm size distribution. The main finding confirms the hypothesized effects from financial friction (measured by industry average liquidity relative to revenue) and capital intensity (measured by industry average tangible fixed assets relative to revenue). Greater financial friction and higher capital intensity are found to lead to a size distributions with thinner tails, hence, fewer large firms. The results for other variables, such as firm age, industry instability and industry growth, are mixed, although expenditures on R&D seem to have a positive effect on the number of large firms in the industry.

In summary, I find that firm size distributions (at the 3-digit industry level) exhibit significant heterogeneity, both over time and across industries. Moreover, the evidence supports the notion that economic forces shape the distribution of firms over time. In addition, the findings also contribute to knowledge regarding public policy. According to Guner et al (2008), size-dependent governmental regulations have a direct impact on firm productivity, output and the size distribution of firms, for instance, by limiting the growth of larger firms or by encouraging the growth of smaller firms. Guner et al (2008) argue that size-dependent policies likely account for much of the observed difference between size distributions across countries.²⁴ Furthermore, according to Cabral and Mata (2003), financial friction particularly prevents small firms from realizing their potential size. Hence, the results presented in this paper suggest that easier access to financial capital has a positive effect on the number of large

²⁴Henrekson and Johansson (1999) argues that Sweden has a high concentration of large firms mainly due to governmental policies that historically have disfavored new firm entry and firm dynamics.

firms in the economy over time.

6.2 Chapter 2. Are High-Growth Firms One-Hit Wonders? Evidence from Sweden

This chapter (co-authored with Sven-Olov Daunfeldt) examines whether the growth of Swedish HGFs is persistent over time. One motivation is the increasing attention that policy makers are paying to HGFs as potential vehicles for overall job growth. Our paper contributes to this policy discussion by taking a dynamic perspective on HGFs, arguing that persistent growth rates are required for the policy implications of HGFs to be relevant. To relate to the many relevant empirical studies, a comprehensive survey of the previous literature is also included.

Using the comprehensive IFDB-database, thus covering essentially all Swedish firms, HGFs are defined as the one percent fastest-growing firms in the population. The study concerns HGFs in three consecutive periods active in 1998-2008, where employment is used as growth indicator. Two types of methods are used to examine the growth persistence of HGFs. First, transition matrix analysis is implemented to gauge the probability that HGFs will transition into other categories of growth. Second, growth persistence is studied in the standard setting of a dynamic panel. To overcome potential problems related to dynamic bias, an estimator suggested to be appropriate in the previous literature is used (Han and Phillips, 2010).

The main result of the regression analysis is that HGFs are not positively persistent. Rather, the persistence among HGFs is found to be strongly negative, meaning that periods of high growth are likely to be preceded by periods of negative growth rates. The transition matrix analysis adds to this picture, by showing that HGFs have a larger probability than other firms of experiencing strong negative growth rates in subsequent periods.

In summary, this chapter demonstrates that most HGFs are very likely one-hit wonders that exhibit no persistent growth over time. Policy recommendations based on static analysis of existing HGFs are therefore at best likely to be of little relevance, at worst counterproductive to the overall goal of a more productive economy, since firms perceived as winners in this time-period are in fact less likely than other firms to be so in following periods. The findings in this paper suggest that policy-makers should recognize the dynamic characteristics of firm growth, and, rather than trying to pick winners, ensure better conditions

for all firms.

6.3 Chapter 3. Identifying High-Growth Firms

The main motivation for this study are the disparate definitions of HGFs that are used in the literature and the arbitrary notion of HGFs as a fixed percentage of firms with the highest growth rates, or as firms that grow faster than a fixed growth rate. This paper contributes to the existing literature by providing an alternative method of distinguishing HGFs from other firms without having to make an explicit choice regarding which percentage of the fastest growing firms to include as HGFs.

Using the empirical fact that Pareto's law has been found to hold in the tails of firm growth-rate distributions, this paper suggests that HGFs can be approached as firms with growth rates that follow a power law. If a power law exists, its statistical properties imply that there is a minimum growth threshold for high growth rates. The hypothesis is that the statistical properties of firm growth should change above this threshold. In particular, there may exist a growth rate that signifies a higher probability for extreme bursts of growth. Instead of making an arbitrary choice, one can hence estimate the threshold boundary and provide an empirical benchmark for the minimum growth rate required in order for firms to be said to have high growth.

The approach is illustrated on Swedish firms using the PAR-database on incorporated firms for the period 2000-2009. This study uses number of employees as growth indicator. The existence of a minimum growth threshold is estimated and tested for the complete firm growth-rate distribution as well as for the growth-rate distribution of 2-digit (NACE) industries.

The main result is that the right tail of the firm growth-rate distribution sometimes follows a power-law distribution. In this respect, there are no essential differences between the case when all industries are included in the firm growth-rate distribution and the case when the power law is tested for each industry separately. However, in certain industries and periods for which a power-law distribution could not be rejected, the number of firms with growth rates higher than the estimated growth threshold was considerably smaller than for the predominant 1-percent definition. Only in the case of three (2-digit) industries in manufacturing, retail trade and wholesale could a power law never be rejected.

The overall findings suggest that there are no systematic differences in dis-

tributional properties across industries, confirming the empirical results in the previous HGF-literature. However, a benefit/limitation of adopting a distributional definition of HGFs is that it allows for situations in which HGFs are not present in an industry. This finding contradicts previous findings regarding HGFs, where such firms are apparently present in all industries and at all times. An exception is the OECD definition, in which HGFs are regarded as firms with an annualized employment growth rate of at least 20 percent over a three-year period. However, due to the inclusive nature of this definition, this type of situation rarely arises.

The main contribution of this paper is the idea that high growth might be separable from moderate or low growth if we consider the presence of a power-law in the growth-rate distribution. As such, the chapter works towards merging the literature on HGFs with the literature on growth-rate distributions. In addition, this paper also adds to the statistical literature by being the first, to my knowledge, to actually test the purported existence of a power law in the firm growth-rate distribution.

6.4 Chapter 4. On the Estimation of Skewed Geometric Stable Distributions

This chapter contributes to the statistical literature by developing a new estimator for skewed geometric stable distributions. The motivation for this study is the stylized fact that firm growth exhibits a Laplace distribution. Yet this “fact” has been contested by the current finding of heavier tails than the Laplacian would entail in the data, in the sense that extreme growth rates (both negative and positive) are distributed according to a power-law (Fu et al, 2005).

Focusing on a statistical property of the Laplace distribution called geometric stability (see Appendix A.1 for a discussion of the concept), this paper considers a larger family of distributions known as geometric stable distributions. They incorporate the Laplace distribution as well as the heavier power laws observed in the data. Unfortunately, the practical use of this family has been restricted due to the lack of easily accessible estimators (Kozubowski, 2001).

With researchers’ increasing interest in modeling heavy-tailed phenomena, there is a pressing need for simpler and more accessible ways to estimate and test geometric stable distributions. In a recent paper, Cahoy (2012) developed a surprisingly accessible method-of-logarithmic-moments (LM) estimator for the symmetric geometric stable distribution (also known as the Linnik distribution).

Based on the property of geometric stability, this estimator could serve as a natural starting point for estimating the nested Laplace distribution. However, as researchers such as Reichstein and Jensen (2005) have noted, the firm growth-rate distribution is notoriously skewed. This is why an accessible estimator is also needed for the skewed geometric stable distribution. The ambition of Chapter 4 is to provide such an estimator.

Thus building on Cahoy (2012) and Kozubowski (2001) this chapter therefore develops an estimator for the family of skewed geometric stable distributions. By the method of fractional lower-order moments (FLOM) and LM analytical expressions are derived for the parameters of geometric stable distributions. For the FLOM-based estimators, the system of empirical moments can be solved analytically for all parameters of the centered distribution. For LM, however, the system can only be solved for two out of three parameters.

To validate these methods, I rely on a Monte Carlo study. The simulation results are obtained using mean squared errors, and indicate that the FLOM-based estimators are unbiased for a considerable parameter space. Although LM did not provide a ready solution for all of the parameters, the solvable parameters are found to be unbiased, albeit for a more restricted parameter space.

Possible practical applications of the estimators are not constrained to the growth-rate distribution of firms but should be readily applicable to that of other distributions such as that of asset returns in finance, for which a geometric stable distribution has already been implemented successfully (e.g. Kozubowski and Rachev, 1994).

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A Appendix

A.1 The firm growth-rate distribution and statistical geometric stability

An additional property of firm growth in Gibrat’s model (5) is the statistical property of *stability*. This stability means that any sum of the i.i.d. growth rates ϵ_i , when appropriately normalized, also has a Gaussian distribution. A similar form of stability applies to the modified Gibrat model in (7), called *geometric stability*; any random sum of i.i.d. growth rates ϵ_i , when appropriately normalized, has a Laplace distribution.²⁵ However, stability and geometric stability refer to two larger families of distributions in which the Gaussian distribution and the Laplace distribution are the limiting distributions when the standard deviation of firm growth is $\sigma(\epsilon_i) < \infty$. Unsurprisingly, these two families are referred to as *stable distributions* (Feller, 1971) and *geometric stable distributions* (Klebanov et al, 1985) and contain an infinite number of distributions for which the standard deviation (here, firm growth) also is $\sigma(\epsilon_i) = \infty$. Even if growth rates (or any other social phenomena, for that matter) cannot fluctuate to infinity, it serves as an approximation and allows for extreme outliers in a way that the Laplace distribution and the Gaussian distribution do not. These four parameter distributions are characterized by a parameter $m \in (0, 2]$. When $m = 2$, the stable distribution becomes the Gaussian distribution, and the geometric stable distribution becomes the Laplace distribution. However, for $m \in (0, 2)$, the parameter m becomes the constant in Pareto’s law from (6). For these two families of distributions, this means that the tails exhibit a power-law distribution when growth rates ϵ become large.

As discussed above, a power-law distribution has been observed for high growth, e.g., in Fu et al (2005). Furthermore, Gabaix (2011) and Schwarzkopf et al (2010) both suggest that the stable distribution is the correct specification. In a state of the art model in which firm size follows Pareto’s law, Gabaix (2011) provides proof that ϵ has a stable distribution. He also remarks that Lee et al (1998) “plotted this empirical distribution, which looks roughly like a Lévy stable distribution. It could be that the fat-tailed distribution of firm growth comes from the fat-tailed distribution of the subcomponents of a firm” (Gabaix, 2011, p. 784). However, the stable family of distributions does not contain the Laplace distribution. With numerous accounts of the Laplace

²⁵The random summation is terminated by a geometric distribution as in (7).

distribution in the literature on firm growth-rate distributions, the geometric stable distribution could also be applicable to firm growth along with the stable distribution.

Nevertheless, the attractiveness of both the Gaussian and the Laplace distribution derives partly from their simple mathematical properties, and larger families of stable and geometric stable distributions are not as simple. Except for a few special cases, these distributions do not have explicit analytical expressions for their distribution functions. Despite their otherwise attractive properties, this inconvenience has limited their practical implementation – particularly that of the less well known geometric stable distribution. Still, the families of stable and geometric stable distributions have been used in a number of practical areas. Regarding stable distributions, see, e.g., Mandelbrot (1963) and Fama and MacBeth (1973) for the modeling of asset prices and Gabaix (2011) and Schwarzkopf et al (2010) for the growth-rate distribution of firms. Regarding geometric stable distributions, see, e.g., Kozubowski and Rachev (1994) for the modeling of asset returns.