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**Size, Age and the Growth of  
Firms: New Evidence from  
Quantile Regressions**

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#### Summary

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**Keywords:** Firm Growth, Size, Age, Conditional Quantiles

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*We would like to thank Ron Smith for his insightful and constructive comments. All remaining errors are our own. Distante gratefully acknowledges the European Union Seventh Framework Programme (FP7/2007-2013) grant agreement n. 308481 (ENTRACTE)*

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# Size, Age and the Growth of Firms: New Evidence from Quantile Regressions\*

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## Abstract

The nexus between firm growth, size and age in U.S. manufacturing is examined through the lens of quantile regression models. A number of interesting features are unveiled that linear frameworks could not detect. Size pushes both low and high performing firms towards the median rate of growth, while age is never advantageous, and more so as firms grow faster.

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# 1 Introduction

The industrial dynamics literature has devoted a great deal of attention to unveiling the nexus between firm size and growth. In this respect, the theoretical proposition known as Gibrat’s law (Gibrat, 1931) – which predicts randomness of firm growth rates – has been widely tested. Linear econometric frameworks employed to validate this hypothesis have delivered mixed evidence.<sup>1</sup> While earlier studies have found a tendency for large firms to grow faster than small ones (Samuels, 1965; Singh and Whittington, 1975), later studies have appreciated a tendency for small firms to grow faster (Hall, 1987; Evans, 1987a,b; Dunne *et al.*, 1989).<sup>2</sup> Recent evidence reported by Haltiwanger, Jarmin, and Miranda (2013) has shown that, after conditioning on firm age, no systematic relationship between firm size and growth exists. This note shows how a consensus among these views may be reached, once firm heterogeneity is properly accounted for. It does so by re-examining the size-growth conundrum through the lens of conditional quantile regressions.

Empirical tests of Gibrat’s law have typically relied on cross-section regressions or short-panel econometric techniques imposing homogeneity in the parameters across units and over time. On the one hand, the first approach is problematic in that it ignores the information contained in firm-specific time variation in growth rates. On the other hand, while considering information available for all periods and all cross-sectional units, a major drawback of the second approach is to pool potentially heterogeneous firms as if their data were generated by the same process. To overcome these problems, we examine firm growth through the lens of conditional quantile regressions, so as to understand how factors such as size and age may have different effects depending on the speed at which firms expand/contract. In this respect, estimation methods that go ‘beyond the mean’ may be usefully employed. In fact, there is no reason to anticipate that the marginal effects of the covariates on the shape of the density are invariant over the domain of firm growth. To this end, conditional quantile regressions have become increasingly popular and may usefully serve our purpose (Koenker and Bassett, 1978 and Koenker, 2005). While these techniques have been successfully employed in the study of firm size distributions (see, e.g., Machado and Mata, 2000 and Cabral and Mata, 2003), firm growth and its drivers have not been examined from such a standpoint.

We detect marked heterogeneity in the impact of both size and age on firm growth. Size exerts a negative (positive) effect on firms that grow above (below) the median rate, thus reflecting a phenomenon of competitive convergence (see Fama and French, 2000). As to age, this is never advantageous to firm growth, and more so as firms grow faster. These results complement the evidence of Haltiwanger, Jarmin, and Miranda (2013), enlarging their picture to what happens at each point of the distribution of firm growth. In fact, according to the quantile analysis reported in this paper firm growth is

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<sup>1</sup>See Sutton (1997) for a comprehensive review of the literature.

<sup>2</sup>Consistent with the assumption of decreasing returns to scale, these works show that small firms tend to grow faster than large ones. This implies a mean reversion effect on firm size, which introduces an overall limit to the variance of the size distribution, as firm size converges in the long run towards an optimal level.

not affected by firm size – even after conditioning on age – only as long as we look at the median, or if we assume that units growing at different speeds are invariantly affected by firm-specific characteristics. Moreover, our findings are robust to distinguishing between firms operating in durable and non-durable goods manufacturing, though in the first case age represents less of an obstacle to firm growth. This can be explained by the fact that incumbents in the durable goods sector are less vulnerable to competitive pressures brought by new entrants, whose entry rate is traditionally lower than that observed in non-durable goods manufacturing.

The remainder of the paper is laid out as follows: Section 2 introduces the quantile regression framework; Section 3 presents the data and reports quantile-based evidence on the relationship between firm growth, size and age; Section 4 concludes.

## 2 Quantile Regression Analysis

The main aim of the present study is to describe the relevance of firm size and age at different points of the distribution of firm growth. To this end, we rely on quantile regressions, which are especially useful when dealing with non-identically distributed data. In these situations one should expect to observe significant discrepancies in the estimated ‘slopes’ at different quantiles with respect a given set of covariates (Machado and Mata, 2000). Such discrepancies may reflect not just into location shifts, but also into scale shifts (i.e., changes in the degree of dispersion) and/or asymmetry reversals (i.e., changes in the sign of the skewness). Define the  $\tau^{th}$  quantile of the distribution of a generic variable  $y$ , given a vector of covariates  $\mathbf{x}$ , as:

$$Q_\tau(y|\mathbf{x}) = \inf \{y | F(y|\mathbf{x}) \geq \tau\}, \quad \tau \in (0, 1), \quad (1)$$

where  $F(y|\mathbf{x})$  denotes the conditional distribution function. A least squares estimator of the mean regression model would be concerned with the dependence of the conditional mean of  $y$  on the covariates. The quantile regression estimator tackles this issue at each quantile of the conditional distribution. In other words, instead of assuming that covariates shift only the location of the conditional distribution, quantile regression looks at the potential effects on the whole shape of the distribution. The statistical model we opt for specifies the  $\tau^{th}$  conditional quantile of firm-level growth,  $g_{it}$ , as a linear function of the vector of covariates,  $\mathbf{x}_{it}$ :<sup>3</sup>

$$Q_\tau(g_{it}|\mathbf{x}_{it}) = \mathbf{x}'_{it}\boldsymbol{\beta}_\tau, \quad \tau \in (0, 1). \quad (2)$$

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<sup>3</sup>Ideally, one would prefer to implement quantile panel regressions, allowing for both firm-specific and time effects (see, e.g., Powell, 2010). However, this is computationally demanding, even in the presence of a limited number of covariates. In Distante, Petrella, and Santoro (2013) we show that quantile estimates are robust to the exclusion of firm-specific effects. We compare Powell’s panel estimates with those from a quantile regression with pooled data, concluding that alternative assumptions about the error structure are of second order importance.

Quantile estimation is influenced only by the local behavior of the conditional distribution of the response near the specified quantile. Therefore, no parametric form of the error distribution is assumed. Estimates depend on the signs of the residuals: outliers in the values of the response variables influence the model’s fit to the extent that they are above or below the fitted hyperplane (Koenker, 2005).

### 3 Firm Growth, Size and Age

We employ annual accounting COMPUSTAT data on manufacturing firms. Nominal sales are deflated by the GDP deflator. The resulting measure of real sales is taken as a proxy for firm size, which is denoted by  $s_{it}$ .<sup>4</sup> We then compute firm  $i$ ’s growth rate as  $g_{it} \equiv (s_{it} - s_{it-1}) / [(s_{it} + s_{it-1})/2]$ .<sup>5</sup> This definition has become standard in the literature on industrial dynamics, as it shares some useful properties of log differences and has the advantage of accommodating entry and exit (see Haltiwanger et al., 2013).<sup>6</sup> Figure 1 graphs the quantiles of firm growth over the 1950-2012 period. A first observation to be made is that different parts of the distribution do not follow the same time path, neither over long, nor shorter time horizons. As documented by Comin and Philippon (2006) and Comin and Mulani (2006), the density has slowly become more sparse over time. However, increasing dispersion emerges as a phenomenon that primarily hinges on the evolution of firms in the tails of the distribution, while the interquantile range only displays a very moderate trending behavior. Heterogeneity is also pervasive at higher frequencies, with different quantiles denoting different correlations with the business cycle. This tendency is at odds with the view that aggregate fluctuations must reflect spread-preserving shifts in the mean of the distribution, which would instead imply all quantiles having the same cyclical behavior.<sup>7</sup> Altogether, these findings emphasize the importance of employing quantile regressions to deal with firm-level growth.

Insert Figure 1 here

In line with the industrial dynamics tradition, the econometric framework includes firm-level ( $t - 1$ ) size and age in the vector of covariates. In addition, we include time dummies – which aim at controlling for the evolution of the distribution over time – as well industry dummies at the 3-digit SIC code level, so as to account for the fact that firm growth, size and age distributions vary by industry. The resulting framework generalizes the first order Galton–Markov model  $g_{it} = \beta s_{it-1} + u_{it}$ , where  $u_{it}$  is an error

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<sup>4</sup>Various measures – including the value of assets of a firm, employment and sales – have been traditionally used to proxy firm size. Where data have been available for the various measures the results have generally been invariant to the measure of size (see Evans, 1987 and Hall, 1987).

<sup>5</sup>We remove firms growing (declining) beyond a 100% rate. Replicating the analysis with growth rates defined as log-differences or under alternative cut-off intervals does not qualitatively affect the analysis.

<sup>6</sup>Along with being symmetric around zero and bounded between -2 (exit) and 2 (entry), this growth rate represents a second order approximation of the log-difference for growth rates.

<sup>7</sup>Distante, Petrella, and Santoro (2013) focus on the business cycle properties of the distribution of firm growth, highlighting a number of interesting regularities.

term, assumed to be *i.i.d.* across firms and over time. Note that  $\beta < 0$  implies that small firms grow faster than bigger ones, while for  $\beta > 0$  the opposite holds true. Gibrat's Law holds instead if the estimated parameter  $\hat{\beta}$  is not significantly different from zero, so that growth turns out to be stochastic and independent of size.

Figure 2 plots the quantile treatment effects (QTE) associated with each quantile, together with the OLS estimate from the pooled sample. The QTE of firm size results as an affine transformation of the control distribution and crosses the zero axis at zero. In other words, size acts as a scale shifter that exerts positive (negative) effects on LHS (RHS) of the median rate of growth. This is consistent with a pattern of competitive convergence, as reported by Fama and French (2000) with respect to firm profitability. In fact, firms that grow below the median growth rate tend to have a comparatively better performance the larger they are, whereas size represents an obstacle to fast growing firms. This key finding emphasizes the potential dangers of neglecting heterogeneity in the influence of firm size on firm growth for companies that grow at different speeds. Analogous observations apply when considering the role of firm age. Throughout the entire spectrum of firm growth the QTE is negative. This is in line with Evans (1987a), who finds that firm age is also important for the variability of firm growth and the probability of dissolution. Therefore, age is never advantageous, and more so for quantiles above the median rate of growth.<sup>8</sup>

Insert Figure 2 here

These findings need to be contrasted with recent evidence by Haltiwanger, Jarmin, and Miranda (2013), who show the existence of no systematic relationship between firm size and growth, once they control for firm age. According to our study this is a valid conclusion only if look at the median estimate, or if we consider a mean estimator that forces the slope to be the same across productive units. In fact, the OLS estimate from the pooled sample is close to null in the case of firm size, whereas age exerts a negative effect. It is also important to stress that the tendencies we report do not result from composition effects due to pooling together firms operating in different industries. In this respect, Figures 3 and 4 graph the QTE associated with firm size and age for firms operating in non-durable and durable manufacturing, as well as the respective OLS point estimates.

Insert Figures 3 and 4 here

Interestingly, whereas the QTE associated with  $s_{it-1}$  does not display sizeable differences across different manufacturing industries, the negative effect exerted by firm age is more marked on non-durables producing firms.<sup>9</sup> Also the OLS estimates indicate a

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<sup>8</sup>Notably, this relationship is in line with the predictions of Jovanovic (1982), whose theory of firm growth is based on entrepreneurs learning about their abilities over time.

<sup>9</sup>Moreover, age has virtually no effect on the first 20 quantiles of the growth density for firms operating in durable goods manufacturing.

stronger sensitivity of growth to the age of firms in non-durable goods manufacturing. This is broadly consistent with Haltiwanger, Jarmin, and Miranda (2013), who show that firm entry rates are especially low in durable goods manufacturing, so that incumbents operating in this sector may be less vulnerable to competitive pressures brought by new entrants. Under these circumstances, age represents less of an obstacle to growth in the durable goods sector, as compared with firms operating in non-durable goods manufacturing.

## 4 Concluding Remarks

The literature exploring the empirical validity of Gibrat’s law (Gibrat, 1931) has typically restricted the parameter capturing the influence of firm size on firm growth to be the same across units, as if firm-level data were generated according to the same process. We relax such restriction, exploring firm growth through the lens of conditional quantile regressions, so as to allow size and age to exert heterogeneous effects over the domain of firm growth. Size acts as a symmetric centripetal force – pushing both low and high performing firms towards the median rate of growth – while age is never advantageous to firm growth, and more so as firms grow faster. We also highlight sizeable differences in the impact of age on firms’ growth depending on whether they operate in durable or non-durable goods manufacturing. Altogether, these findings emphasize the importance of employing regression methods that go ‘beyond the mean’ to cope with firm-level heterogeneity.

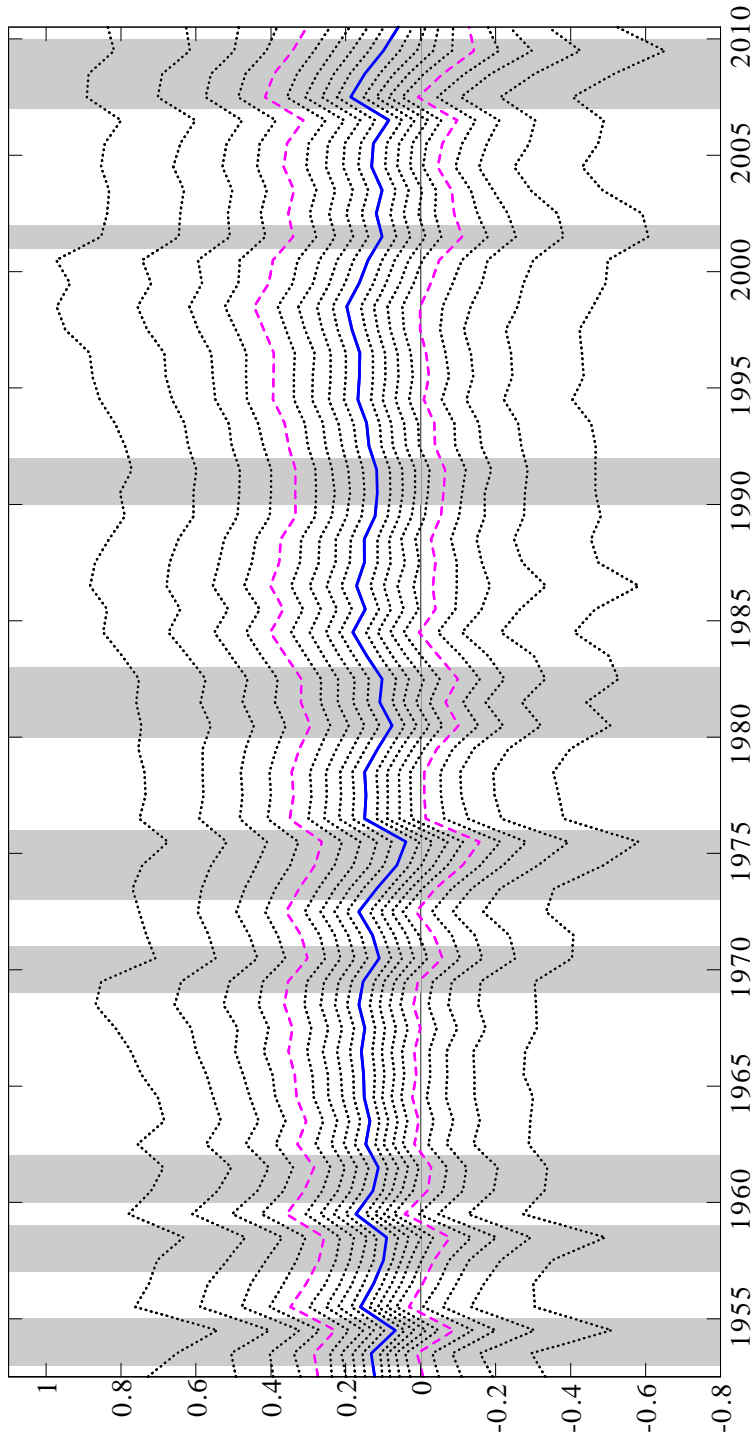
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FIGURE 1. QUANTILES OF FIRM GROWTH



Notes: Figure 1 graphs the quantiles of firm-level growth of real sales over the 1950-2010 time window. The continuous line denotes the median, while the dashed lines denote the 25<sup>th</sup> and 75<sup>th</sup> quantiles. Recessionary episodes as identified by the NBER are denoted by the vertical bands.

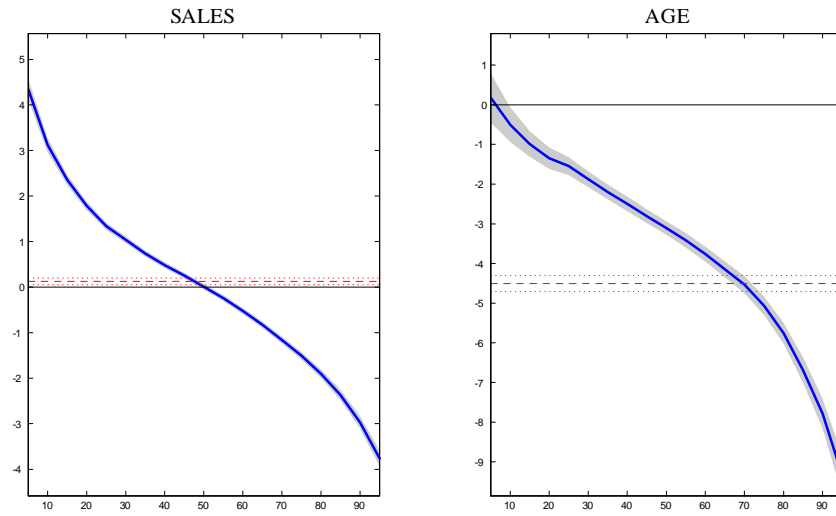
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FIGURE 2. QUANTILE TREATMENT EFFECTS

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Notes: The continuous (blue) line is the estimated QTE associated with firm-specific lagged real sales (left panel) and age (right panel). The dashed (red) line indicates the OLS estimates from the pooled sample. All confidence intervals are obtained as the point estimate  $\pm$  twice its standard error.

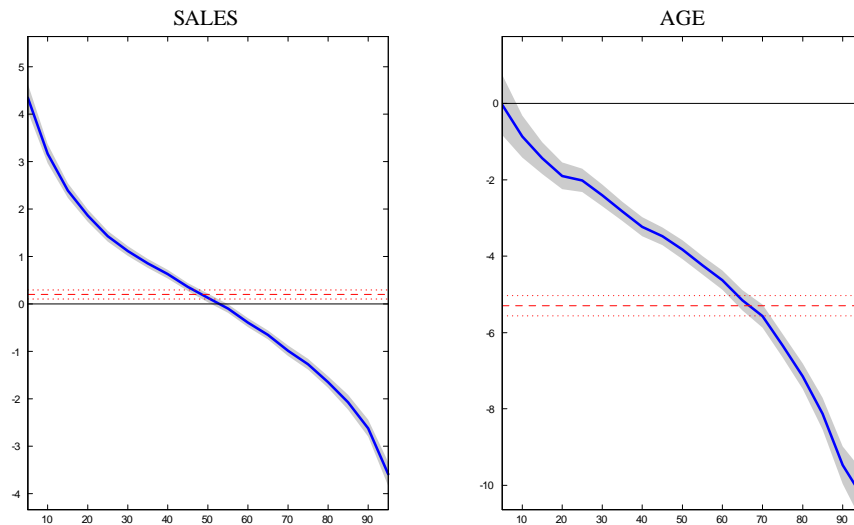
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FIGURE 3. QUANTILE TREATMENT EFFECTS (Non-durables)

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Notes: See the notes to Figure 2.

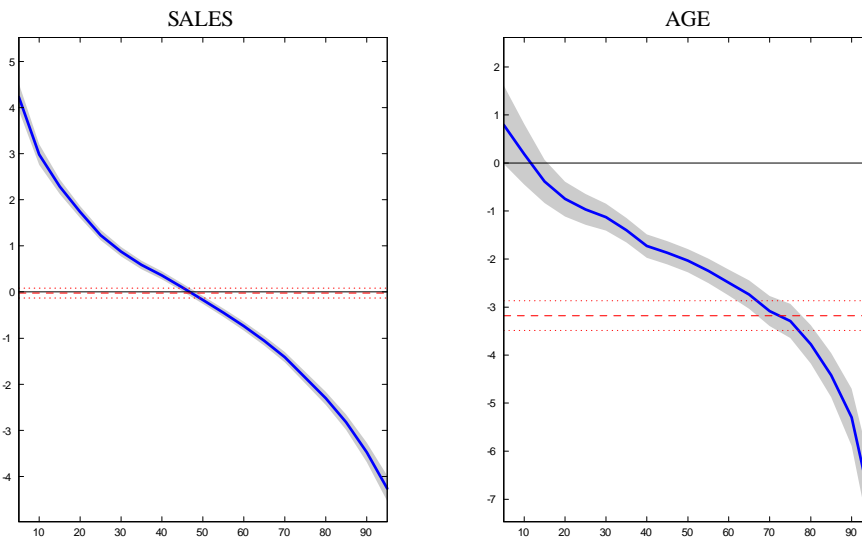
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FIGURE 4. QUANTILE TREATMENT EFFECTS (Durables)

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Notes: See the notes to Figure 2.

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