# Vertical organization of production and firm growth

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This paper empirically explores if different vertical organizational forms (i.e. vertical integration *versus* dis-integration) give rise to unlike growth "behaviors" within the same industry. An econometric analysis is conducted in a sample of around 500 Italian machine tool (MT) builders for the period 1998-2007. *Ceteris paribus*, vertically integrated firms result to be characterized by a less dispersed distribution of growth rates than their dis-integrated counterparts. By means of analyzing how different organizational forms map into the distribution of output growth rates, this work provides insight into the firm dynamics in a mature industry in which both vertically integrated and dis-integrated firms coexist.

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# Vertical organization of production and firm growth

*(for peer review)*

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This paper empirically explores if different vertical organizational forms (i.e. vertical integration *versus* dis-integration) give rise to unlike growth "behaviors" within the same industry. An econometric analysis is conducted in a sample of around 500 Italian machine tool (MT) builders for the period 1998-2007. *Ceteris paribus*, vertically integrated firms result to be characterized by a less dispersed distribution of growth rates than their dis-integrated counterparts. By means of analyzing how different organizational forms map into the distribution of output growth rates, this work provides insight into the firm dynamics in a mature industry in which both vertically integrated and dis-integrated firms coexist.

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## 1. Introduction

Many industries are characterized by a marked heterogeneity in vertical boundaries among their firms (see Perry, 1984; Elberfeld, 2001; Cabral and Vasconcelos, 2011; Pieri and Zaninotto, 2013a; among others, for some theoretical contributions on vertical equilibrium models and Christensen et al., 2002; Bigelow and Argyres, 2008; Manello et al. 2016; among others, for the empirical evidence). Such remarkable within-industry differences constitute a compelling issue for researchers and several factors have been proposed to explain the coexistence of firms with different degrees of vertical integration.[1]

Even if a lot of attention has been paid to explain the determinants of firms' vertical integration decisions and several works have inquired into the consequences of these in terms of efficiency and market power (see Lafontaine and Slade, 2007; pp. 662-667, among others), very few studies have concentrated on the growth "behaviors" of firms which adopt different organizational forms, namely vertical integration *versus* dis-integration. This is unfortunate because the coexistence of firms characterized by different degrees of vertical integration along the same production chain may definitely denote the existence of market opportunities for unlike organizations.

This paper empirically explores if unlike vertical organizational forms give rise to different growth "behaviors", described by the distribution of firm growth rates. To this end, an econometric analysis is conducted in a sample of around 500 Italian machine tool (MT) producers for the period 1998-2007. The industry which gathers the producers of metal working machinery and components is a natural candidate for this analysis given the marked heterogeneity in terms of vertical organization among the Italian MT producers (Rolfo, 2000; Wengel and Shapira, 2004) and the high level of both domestic and foreign competition which qualifies the industry, creating many opportunities for rapid growth and shrinking (Kalafsky and MacPherson, 2002).

In order to study the relation between the vertical organization of production of the Italian producers of MT and their distributions of growth rates, two complementary methods are applied. First, the econometric relation between the within-firm standard deviation of annual output growth rates in three succeeding 3-year periods (2000-2003, 2002-2005, 2004-2007) and the previous average degree of vertical integration (respectively in 1998-2000, 2000-2002, 2002-2004) is estimated; second, quantile regressions of 1-year growth rates are estimated as functions of the degree of vertical integration at the beginning of the year.

Results indicate that, once a set of relevant firm-level characteristics and common-to-the-sector temporal shocks and have been controlled for, vertically integrated firms show a less dispersed (i.e. characterized by a lower standard deviation) distribution of growth rates than the one shown by their dis-integrated counterparts. In other words, vertically integrated firms show a distribution of growth rates with a higher number of episodes of "moderate" growth, and this is true in case of both output expansion and contraction.

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[1] Transaction (see Williamson, 1975, among others) and agency costs (see Lafontaine and Slade, 2001, among others), market-power issues (see Chipty, 2001, among others), firms' specific capabilities (see Malerba et al., 2008, among others) and systematic differences in terms of productivity and costs among firms (see Elberfeld, 2001; Antràs and Helpman, 2004, among others).

Several concurring factors (discussed at length in Section 2), such as adjustment costs, organizational slacks and a better management of fluctuations in the markets of intermediate and final products may explain the more "stable" growth profile of vertically integrated firms.

The contribution of this paper is twofold. First, it sheds light on the (rather neglected) relation between the vertical organization of production and firm growth by looking at how different organizational forms map into the distribution of positive and negative growth rates. Previous studies have mostly looked at how dis-integration (outsourcing and sub-contracting) strategies impact on positive growth.[2]

Second, the paper provides insight into the firm dynamics in a mature sector in which both vertically integrated and dis-integrated firms coexist (see Christensen et al., 2002; Bigelow and Argyres, 2008, among others). In a mature industry, such as that of producers of MT, different dynamics by unlike organizations may be linked to ways in which firms manage the available technology and the innovation process in order to appropriate returns from different tiers of the market (see the discussion provided in Section 5).

The rest of the paper is organized as follows: Section 2 introduces the theoretical background; Section 3 describes the employed dataset and the related descriptive statistics; Section 4 presents the econometric analysis; Section 5 discusses the results. Section 6 concludes.

## 2. Theoretical background

Vertical integration has been traditionally defined in the IO literature (see Perry, 1989; p. 185, among others), as the strategy through which firms substitute market transactions of inputs and output with exchanges of these within the boundaries of the firm. Thus, in order to sell a final good, a firm may either produce the required intermediate goods and services "in-house" (by means of its own labor and physical capital) or buy them from other firms in the market. The former type of organization is vertically integrated in the production of the intermediates, while the latter outsources to other firms a significant part of the value added contained in its final product.

But why should different organizational forms (i.e. vertical integration *versus* dis-integration) give rise to unlike growth "behaviors"? It is useful to outline the theoretical framework, by separately looking at the left (below the median/zero-growth) and right (above the median/zero-growth) part of the distribution of firm growth rates.

### 2.1. Vertical structure and positive growth

As for positive growth, the first factor which may explain differences in growth behavior between vertically integrated and dis-integrated firms is the relevance of adjustment costs in the process of firm expansion.[3] These costs are linked to the change in the level and/or the composition of labor and physical capital due to demand shocks and/or changes in technology adopted by the firm. Adjustment costs may well translate into output losses (Hamermesh and

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[2] Mazzola and Bruni (2000) analyze the role of subcontracting (vertical dis-integration) strategies and inter-firm linkages in firm success (sales, employment and productivity growth) employing a sample of 160 Southern Italian firms. Giunta et al. (2012) study the growth profiles of a sample of Italian subcontracting firms by looking at how they position themselves along the production chain.

[3] Several models of firm dynamics do not contemplate adjustment costs in the process of firm expansion (see Jovanovic, 1982; among others). Conversely, Lucas (1967, p.323) introduces a model with (capital) adjustment costs in the form of output foregone in the firm growth process.

Pfann, 1996, pp. 1266-1268): in case that a firm faces a positive demand shock (growth opportunity) the existence of adjustment costs imply slower changes in labor and physical capital employed[4] and, consequently, a more "moderate" positive output growth than if they would not exist.

Given that vertically integrated firms use more intensively physical capital and labor (and less intensively acquired intermediate goods and services), when they change these inputs to tune their capacity at dawn of some market opportunities, these firms will face higher adjustment costs (output losses) then their dis-integrated counterparts.

Organizational slacks also shape the relation between the vertical structure of production and firm growth. Indeed, in case current resources are fully employed (no slacks), growth is only possible with the addition of new ones. Coad (2012) proposes a model with non-constant marginal costs of expansion that depend upon the degree of utilization of a firm's resources: the addition of one unit of an input may lead to the employment of additional units of other (complementary) inputs which generates a reinforcing effect (accompanied by cascading investments) in terms of a firm's capacity and output. A firm in this condition may experience faster (more "extreme") growth episodes. Conversely, in the presence of organizational slacks, these may accommodate output growth with no additional resources, pushing the firm towards more "moderate" growth episodes. Of course, even if slacks affect any type of firm, they should be more associated with vertically integrated organizations[5], given the higher proportion of discrete inputs --such as physical capital (machinery and plants) and labor (employees)-- they use to produce the final product. Firm growth may feed off them.

Finally, firms which adopt dis-integration strategies may definitely benefit of lower fixed costs (Elberfeld, 2001), more consistent inter-firm relations with specialized suppliers (Mazzola and Bruni, 2000) and a greater focus on core functions (Giunta et al. 2012), which are all keys to ensure high growth.  These arguments may reinforce the effects exerted by both adjustment costs and organizational slacks.

Overall, the existence of adjustment costs and organizational slacks, together with the beneficial effects of dis-integration strategies, may definitely lead vertically integrated firms to experience "moderate" episodes of positive growth more frequently than their dis-integrated counterparts.

### 2.2. Vertical structure and negative growth

As for negative growth (shrinking episodes), at least two arguments may justify the association of more "modest" episodes of output contraction with integrated structures in front of negative external shocks.

First, as suggested by Perry (1984), in case that an intermediate good/service market is characterized by "highs and lows" and there are economies of synchronization in the final good production --due to better co-ordination across succeeding stages-- vertical integration may

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[4] It seems reasonable to assume that changes in the amount of physical capital and labor employed imply higher adjustment costs than changing the use of acquired intermediate goods and services; nonetheless, an increase in the use of the latter inputs may entail higher transaction costs.

[5] Organizational slacks should be associated with a higher volatility of efficiency for vertically integrated firms. Indeed, the within-firm standard deviation of labor productivity calculated in the period under analysis for the three groups of firms (*low*, *medium* and *high* vertically integrated firms, as they are defined in Section 3.1.2.) shows that the most integrated firms are those characterized by its highest value (respectively, 23.78, 23.03 and 38.05).

work as a strategy to guarantee a stable input supply. Thus, in front of negative supply shocks in the intermediate market, in the above setting vertically integrated firms are advantaged with respect to their dis-integrated rivals. Moreover, in a supplier-buyer relationship in which a downstream firm requires intermediate goods and services from an upstream source, vertical integration is expected to reduce the uncertainty that arises from the lack of communication between the two parties (Helfat and Teece, 1987; p. 48).

The second argument specifically relates to the final good market. A vertically integrated firm may better cope with improvements in customers' needs in terms of product functionality and design in each one of its components. Such changes negatively affect a firm's output growth leading to a contraction; however, with an effective control exerted over a higher number of phases of production, integrated organizations may better co-ordinate the designs of new interdependent components within the overall system architecture (Christensen, et al. 2002, p. 962).

Both arguments suggest that vertically integrated firms should better cope with negative external shocks and would experience a higher number of episodes of "modest" negative output growth (i.e., a slower contraction) than their dis-integrated counterparts.

***Hypothesis***

Given the arguments presented in Sections 2.1. and 2.2.:

> Vertically integrated firms are expected to show, *ceteris paribus*, a distribution of output growth rates which is less dispersed away from its central tendency (that is, a distribution with a higher number of "moderate" positive and negative growth rates) than the one shown by their dis-integrated counterparts.

## 3. Data and descriptive analysis

### 3.1. Data and industry synopsis

This study uses an original dataset, compiled by recovering data from several sources: it contains economic and financial information on around 500 Italian MT producers for the period 1998-2007. The reference list of MT producers comes from the Italian Machine Tools, Robots and Automation Manufacturers Association (UCIMU) and includes information on firms' principal product; nominal revenues from sales and services, nominal value added, nominal value of tangible and intangible assets, the number of employees, the year of establishment and nominal value of firm liabilities are from Bureau Van Dijk's AIDA dataset, which contains information for firms with annual revenues of over 500,000 euro; sectoral deflators for revenues, value added, tangible and intangible assets come from the Italian National Institute of Statistics (ISTAT). Moreover, only for a sub-sample of MT producers, detail information on firms' product portfolios was recovered in several issues (published between 1998 and 2007) of *Tecnologie Meccaniche*, a leading technical magazine for the MT industry.[6]

The MT industry is an interesting case study for several reasons. First, a trend towards modularization and customization of the machinery has taken place in the last decades indicating a certain degree of maturity of the MT industry (Arnold, 2001; p.1; p.5). In this stage

[6] The database has been used in two articles investigating the relation between vertical integration and technical efficiency: see Pieri and Zaninotto (2013a, 2013b).

the coexistence of vertically integrated and dis-integrated producers may be explained by the attitude of the most experienced firms to backward integrate in the production of some critical components in order to capture returns from their superior integrative capabilities (Bigelow and Argyres, 2008; pp. 794-795). Indeed, at present time the industry is characterized by an array of different organizational forms (Wengel and Shapira, 2004). Second, the Italian MT industry is characterized by a strong export orientation (in 2007 Italy was the third place for export value in the worldwide ranking of MT production) and firms have to face a considerable international competition (Arnold, 2001; Kalafsky and MacPherson, 2002): the tough competition faced by the Italian producers of MT may create both opportunities for fast expansion and threats for output shirking.

The Supplementary material provides a more detailed overview of the industry (Supplementary Section 1), how the dataset was built and the representativeness of the sample with respect to the overall Italian MT industry (Supplementary Section 2.1). Supplementary Table 2 furnishes a breakdown of firms by principal product sold and – only for the sub-sample of firms for which this information is available – the breakdown of observations by product categories.

#### 3.1.1. Firm growth rates

The main variable of interest is the 1-year growth rate of the $i^{th}$ firm in the $t^{th}$ time period, which is computed as the difference in log size across two consecutive years,

$$GR_{i,t} = \ln(Y_{i,t}) - \ln(Y_{i,t-1}). \quad (1)$$

Firm size, $Y_{i,t}$, is defined in terms of sales deflated by the proper industry-level index. This measure has been preferred to others like total employees or the value of tangible fixed assets, because the purpose of this work is to study the relation between firm growth and the way in which a firm "vertically organizes" its production process: either *in-house*, basing the process on its own capital and labor, or mostly depending on external suppliers (of intermediate goods and services).

#### 3.1.2. Vertical integration

Given the unavailability of detailed information on the number of stages that each firm undertakes along the vertical chain, the degree of vertical integration of the $i^{th}$ firm in the $t^{th}$ time period is indirectly measured as the ratio of value added to sales (both deflated by their proper industry-level indexes), as proposed by Adelman (1955):

$$VINT_{i,t} = \frac{VA_{i,t}}{Y_{i,t}}. \quad (2)$$

This index is related to the extent of a firm's dependence on external suppliers for the needed inputs (intensity of acquired intermediate inputs with respect to the value of production). A value of $VINT_{i,t}$ equal to 1 characterizes a firm which is vertically integrated while a value equal to 0 points to a firm which is totally dis-integrated.[7]

[7] The IO literature has recognized the limitations of the Adelman index and suggested alternative indicators based on the use of Input-Output tables (see Maddigan, 1981; among others). Unfortunately, the breakdown of sales by industry is not available in the present work, thus it is not possible to calculate such indicators. Nonetheless, recent empirical papers have applied the Adelman index or some "complementary" indexes (i.e. the cost of acquired

Three dummies indicating the terciles of the $VINT_{i,t}$ distribution have been employed as a proxy for the "type" of vertical organization. After having calculated the value of $VINT_{i,t}$ at the 33th and 66th percentile of its distribution, a vector of *(p-1)* dummy variables has been built, $QVINT^{p}$, where:

$$p = \begin{cases} 1, & if\ VINT_{i,t} \leq VINT^{33pct}; \\ 2, & if\ VINT^{33pct} < VINT_{i,t} \leq VINT^{66pct}; \\ 3, & if\ VINT_{i,t} > VINT^{66pct}. \end{cases} \quad (3)$$

The three dummies take the value 1 in the above specified cases and 0 otherwise and are mutually exclusive. The interpretation is straightforward: observations (firm/year) belonging to the $QVINT^{1}$ category (tercile) are those characterized by vertically dis-integrated structures and observations pertaining to the $QVINT^{3}$ category are the most vertically integrated ones. The $QVINT^{2}$ category denotes intermediate levels of integration.

The use of a categorical variable as a proxy for the "type" of vertical organization is based on three main reasons. First, it allows one to group firms into similar organizational "types", thus gathering their most relevant features. Second, it is a way to model a possible non-linearity in the relation. Third, it is a "first" attempt to minimize the likely endogeneity issue: a firm may observe its growth rate in a given year, consequently modifying the relative use of acquired intermediates and changing the $VINT_{i,t}$ level to reach a more "stable" growth profile. However, it is infrequent that a firm is able to modify its vertical structure so dramatically in one year as to move to another tercile of the $VINT_{i,t}$ distribution.[8] The endogeneity issue will be discussed at greater length in Sections 4.1. and 4.2.

It is relevant to minimize the possibility that differences in growth behaviors among firms belonging to different terciles of the $VINT_{i,t}$ distribution are due to other firm characteristics. For this purpose, a vector of firm-level controls is introduced in Section 3.1.3. and used in the multivariate econometric analysis.

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intermediates, materials and services over total costs of production) to measure the degree of vertical integration in samples of homogenous firms (see Pieri and Zaninotto, 2013a, 2013b; Manello et al., 2016), which is the most favorable setting for its application (see Perry, 1989; p. 238).

[8] Supplementary Table 3 shows yearly transition across terciles of the $VINT_{i,t}$ distribution.

### 3.1.3. Control variables

The vector of control variables includes measures of: *firm size* (deflated sales in the $t^{th}$ time period), *firm age* (the difference between year *t* and the year of establishment of the firm), *labor productivity* (the ratio of real value added to the number of employees in the $t^{th}$ time period), a proxy for *access to external finance* by the firm (the ratio of long-term obligations to total assets in the $t^{th}$ time period) and *firm intangible intensity* (the ratio of deflated intangible assets to the number of employees in the $t^{th}$ time period). Furthermore, two measures of *product diversification* (the count of products sold by the $i^{th}$ firm in the $t^{th}$ time period) have been introduced and employed in Section 4.3 (see Eqs. 8 and 9) to control for possible heterogeneous diversification strategies adopted by integrated and dis-integrated firms. All regressors have been included in the econometric analysis in logs (except the ratio of long-term obligations to total assets).

The choice of the control variables is based on the existing literature on the drivers of firm growth and the "correlates" of the firm organizational choice: the reader is cross-referred to Supplementary Section 2.4 for a detailed discussion on these variables and their measurement.

## 3.2. Descriptive analysis

In Figure 1 the distribution of output growth rates by (1-year lagged) vertical integration category, $QVINT^{p}_{i,t-1}$ is drawn. The plot suggests that dis-integrated firms at the beginning of the year ($QVINT^{1}$) show a higher probability of experiencing both higher (in absolute value) positive and negative growth rates than their most vertically integrated counterparts ($QVINT^{3}$). These figures are confirmed in Table 1, showing different percentiles of the growth rate distribution by vertical integration category. At each observed percentile of the distribution, more vertically integrated firms show lower (in absolute value) rates of growth than their dis-integrated counterparts, and this is true both for positive and negative growth rates. Differences in growth rates between observations in $QVINT^{1}$ and those in $QVINT^{3}$ can more clearly be appreciated by moving away from the 50th percentile, i.e. looking at the tails of the distribution of growth rates.

This evidence implies that vertically integrated firms (especially those belonging to $QVINT^{3}$) show a less dispersed distribution of growth rates than the one shown by their most dis-integrated rivals. The Brown and Forsythe (1974) test is performed and reported at the bottom of Table 1 in order to statistically validate the difference in terms of standard deviation of growth rates across the three categories of MT producers: the three groups show standard deviations which are statistically different with a probability of 5%.

Some general properties of the distributions of growth rates are worthy to point out. Bottazzi and Secchi (2006b, p. 237-241) provide evidence supporting their tent-shape: indeed, the empirical density of corporate growth rates is fitted well by a Laplace (symmetric exponential) distribution. Moreover, they prove that this shape is not the result of mere statistical aggregation of many distinct sectors: by estimating the parameters of the Laplace distribution in 55 industries (3-digit Ateco) of the Italian economy for the period 1989-1996, they find a perfect agreement between the empirical density and the Laplace distribution in 40 over 55 industries (with only 5 industries heavily departing from the Laplace shape). The characteristic tent-shape of these distribution points out the existence of "fat tails", i.e. the higher incidence of episodes of fast growth and heavy contraction with respect to what a Gaussian (normal) distribution would predict. Bottazzi and Secchi (2006b) and Dosi (2007) put forward that the "fat tails" of the distributions of firm growth rates may be the result of different causes. Opportunities and negative shocks are not infrequently assigned in large numbers to a single firm, thus underlying the existence of increasing returns dynamics. "Lumpy" growth events are expected in an evolutionary setting and can be justified with the introduction of new products and the "clusterization" of innovations among firms, the construction and closure of plants, the process of entry and exit in specific markets.

The presence of "fat tails" justifies the attention paid in this work to the differences in growth behavior between vertically integrated and dis-integrated firms which is almost entirely located in the tails of the distribution, as shown in Figure 1. The reader is cross-referred to Supplementary Section 2.5 for a graphical analysis of the distribution of 1-year sales growth rates of the Italian MT builders: data seem to be well matched by a Laplace distribution.

***Insert Figure 1 here in the text***

***Table 1 –*** (deflated) Sales growth rates at different percentiles, by vertical integration category (tercile)

| Vertical integration category (tercile) | Percentiles of the growth rate distribution | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | p1 | p5 | p25 | p50 | p75 | p95 | p99 | σ | Observations |
| Low ($QVINT^1$) | -1.132 | -0.433 | -0.103 | 0.021 | 0.146 | 0.468 | 1.047 | 0.430 | 1,263 |
| Medium ($QVINT^2$) | -0.585 | -0.370 | -0.089 | 0.024 | 0.133 | 0.369 | 0.684 | 0.294 | 1,291 |
| High ($QVINT^3$) | -0.518 | -0.295 | -0.089 | 0.024 | 0.125 | 0.340 | 0.746 | 0.377 | 1,268 |
| Total | -0.624 | -0.367 | -0.092 | 0.023 | 0.134 | 0.379 | 0.826 | 0.371 | 3,822 |
| **Brown and Forsythe test** | | | | | | | | $F_{(0.05,2,3819)} = 10.688$ | |
| $H_0$: equal standard deviations across vertical integration categories (terciles) | | | | | | | | Critical value (5%) = 2.998 | |

Table 2 furnishes some further descriptive statistics about the sample: these figures are in line with general statistics on the MT industry appearing in technical reports (see UCIMU, 2007). First, looking at the values referring to the whole sample (last column, "Total"), the "median" MT builder shows a relative low level of vertical integration (0.327). This is in line with previous results, as those shown by Arrighetti (1999), who reports an average value of the Adelman index equal to 0.35 for the Italian mechanical engineering firms at the end of the 1990s. Moreover, the large interquartile range for firm size indicates a high fragmentation in terms of market shares, where many SMEs are surrounded by a small group of large firms. Overall the median age, 22 years, is slightly above that found in studies analyzing the whole Italian manufacturing sector (see Barba Navaretti et al. 2014; among others), being this a sign of the relative maturity of the MT industry.

Second, by comparing firms' characteristics across the vertical integration terciles, it emerges that vertically integrated and dis-integrated firms are indeed different in several dimensions. Vertically integrated firms are older and more productive than the median firm in the sample. They have a more effective access to long-term external finance, as predicted by Helfat and

Teece (1987; p. 49) than their vertically dis-integrated counterparts. Conversely, vertically dis-integrated firms are more intensive in intangible assets than their more vertically integrated counterparts. Firms belonging to the intermediate tercile ($QVINT^2$) are the largest ones and the most diversified ones, pointing to a possible non-linear relationship of both firm size and firm diversification with the degree of vertical integration (the reader is cross-referred to Section 4.3, where these three dimensions are jointly considered in the empirical analysis).

It is worth underlying that the nature of the data (i.e., exits are not observed and only firms with annual revenues of over 500,000 euro are considered) may affect the results regarding the relation between vertical integration and firm growth in two opposite directions. On the one hand, conditioning on survival, we may overestimate the effect of vertical dis-integration on firm growth;[9] on the other hand, by using data on relatively older (and larger, given the observational minimum threshold of 500,000 euro) firms with respect to the entire population, a downward bias may affect the results. Unfortunately, it is not possible to directly control for these two possibilities.

## 4. Econometric analysis

Two different but related econometric methods are applied to study the relation between the vertical organization of production and firm growth behavior. First, after having collapsed the available information into three cross-sections, the relation between the standard deviation of growth rates of the $i^{th}$ firm in the periods 2000-2003, 2002-2005, 2004-2007 and the average degree of vertical integration of the $i^{th}$ firm in the periods 1998-2000, 2000-2002, 2002-2004 is estimated. Second, a quantile regression approach is applied (Koenker and Basset, 1978) to the pooled cross-section of 1-year growth rates from 2000 to 2007, to study the role of the degree of vertical integration in firm growth across different percentiles of the growth rate distribution.

The two approaches are related: Capasso et al. (2013, p. 630) have formally shown (for the growth-size *nexus*) that if a variable has a reducing-variance effect on the growth rate distribution, this is a sufficient condition for the quantile regression coefficients of the same variable to be higher at the bottom quantiles and lower at the top quantiles of the conditional growth rates distribution. However, the application of both of them is advisable. On the one hand, analyzing the relation between the within-firm standard deviation of growth rates and the (previous) average degree of vertical integration is the natural empirical strategy if one wants to assess the effect of the vertical organizational form on the dispersion of succeeding growth episodes. On the other hand, quantile regression techniques allow one to uncover possible asymmetries in the relation, i.e. those parts of the (conditional) growth rate distribution in which the relation is statistically stronger.

[9] Actually, (i) the youngest firms tend to be the ones with the lowest degree of vertical integration in the sample (see Table 2); moreover, (ii) if younger firms show both more volatile (positive and negative) growth rates and a higher probability of exiting the market than their older counterparts (Haltiwanger et al., 2013), only those MT builders which experience episode of fast growth would be observed among the young firms.

***Table 2*** **-** Descriptive statistics

| Variable | Notation | Unit of measure | Statistics | Vertical integration categories (terciles): Low ($QVINT^1$) | Medium ($QVINT^2$) | High ($QVINT^3$) | **Total** | **Observations** |
|---|---|---|---|---|---|---|---|---|
| Vertical integration: Adelman index = deflated value added/ deflated sales | $VINT_{i,t}$ | Percentage | median | 0.221 | 0.328 | 0.441 | 0.327 | 3,824 |
| | | | IQR | 0.083 | 0.078 | 0.118 | 0.161 | |
| Size: deflated sales | $SIZE_{i,t}$ | Thousands of euro; constant (2000) prices | median | 5,132.399 | 5,766.713 | 4,238.574 | 4940.771 | 3,827 |
| | | | IQR | 8,334.813 | 12,051.543 | 7,419.084 | 9307.115 | |
| Age: # years since firm establishment | $AGE_{i,t}$ | Years | median | 18 | 23 | 26 | 22 | 3,901 |
| | | | IQR | 15 | 15 | 20 | 17 | |
| Labor productivity: deflated value added/ #employees | $PRODUCTIVITY_{i,t}$ | Thousands of euro per employee; constant (2000) prices | median | 46.081 | 46.161 | 47.517 | 46.554 | 3,240 |
| | | | IQR | 25.392 | 21.673 | 23.493 | 23.579 | |
| Long-term obligations intensity: long term obligations/ total assets | $LTDEBT_{i,t}$ | Ratio | median | 0.123 | 0.200 | 0.151 | 0.155 | 3,095 |
| | | | IQR | 0.637 | 0.671 | 0.563 | 0.623 | |
| Intangible intensity: deflated intangible assets/ #employees | $INTANG_{i,t}$ | Thousands of euro per employee; constant (2000) prices | median | 1.541 | 1.398 | 1.010 | 1.347 | 3,161 |
| | | | IQR | 3.903 | 4.317 | 3.536 | 3.948 | |
| Diversification 1: count of the number of products a firm is currently producing | ${DIVERSIFICATION^1}_{i,t}$ | Count | median | 1.000 | 2.000 | 1.000 | 1.000 | 1,155 |
| | | | variance-to-mean ratio | 0.912 | 0.880 | 0.784 | 0.862 | |
| Diversification 2: count of the number of groups of products (grouped by similar technology and applications) a firm is currently active in | ${DIVERSIFICATION^2}_{i,t}$ | Count | median | 1.000 | 1.000 | 1.000 | 1.000 | 1,155 |
| | | | variance-to-mean ratio | 0.375 | 0.349 | 0.309 | 0.345 | |

### 4.1. The dispersion of growth rates as a function of the vertical organization of the firm

In this first part of the empirical analysis the following equation is estimated:

$$ln\sigma_{GR_{i,t}} = \alpha_0 + \beta'\overline{\text{QVINT}}^{\text{p}}_{i,previous} + \gamma'\overline{\text{Z}}_{i,previous} + \tau_t + \epsilon_{i,t}, \qquad (4)$$

where $ln\sigma_{GR_{i,t}}$ is the (log of the) standard deviation of growth rates of the $i^{th}$ firm during the periods 2000-2003, 2002-2005, 2004-2007, $\overline{QVINT}^{p}_{i,previous}$ stands for the tercile ($p = \{1,2,3\}$) of the vertical integration distribution the $i^{\text{th}}$ firm belongs to --on average-- in the previous respective periods 1998-2000, 2000-2002, 2002-2004 and $\overline{\text{Z}}_{i,previous}$ is a vector of firms' characteristics (size, age, productivity, long-term obligations and intangible intensity) calculated as averages over the periods 1998-2000, 2000-2002, 2002-2004. Two out of three time dummies (referring to years 2003 and 2005) are included in the regression to control for sectoral shocks common to all firms. Given the multiple cross-section nature of the data, cluster-robust standard errors are reported in parentheses to control for the lack of independence of observations referring to the same firm over time.

It is worthy to point out that the empirical model contained in Eq. (4) employs measures (standard deviations of growth rates and averages) calculated over multi-year periods. These should be less sensitive to noise and measurement errors than yearly measured variables, such as variations in the Adelman index due to yearly fluctuations in prices which have nothing to do with the organization of the firm.

Table 3 shows the estimates for Eq. (4).

At first, the equation is estimated by OLS inserting the average firm size in the previous period as the sole control variable: results are shown in col. (1). Being characterized by high degrees of vertical integration in the previous period ($\overline{QVINT}^{3}_{previous}$) is associated with a lower standard deviation of succeeding growth rates than the most dis-integrated firms (those belonging to $\overline{QVINT}^{1}_{previous}$, omitted category). Moreover, firms characterized by "intermediate" degrees of vertical integration ($\overline{QVINT}^{2}_{previous}$) also show a lower standard deviation than their more dis-integrated counterparts but the difference is not statistically significant.

This first econometric evidence is in line with the hypothesis of the paper: a lower standard deviation of growth rates stands for a more "stable" growth profile for vertically integrated firms with respect to their dis-integrated counterparts. This may be the result of several concurring factors (see Section 2).

Firm size, $\overline{SIZE}_{i,previous}$, shows a negative relation with the standard deviation of succeeding growth rates, suggesting that larger firms show more "stable" growth profiles. This result, which is in line with previous works on the variance-size scaling relation (see Bottazzi and Secchi, 2006a; Capasso et al. 2013; among others), will be developed at greater length in Section 4.3. For the time being, col. (1) shows that after having controlled for firm size, a further "moderating" effect on the dispersion of corporate growth rates is played by the vertically integrated structure of the firm. Time dummies coefficients point to a higher volatility of firms' sales in the periods 2000-2003 and 2002-2005 with respect to the period 2004-2007, which is confirmed in all regressions contained in Tables 3 and 7.

In order to limit the risk of omitted variable bias, in col. (2) the $\overline{\text{Z}}_{i,previous}$ vector of controls has been included in the empirical model. The previous result is confirmed. Once firm size, age, labor productivity, long-term obligations, intangible assets intensity and temporal shocks have all been controlled for, more vertically integrated structures are associated with a lower standard deviation of succeeding growth rates.

As for controls, firm size confirms its negative coefficient. Firm age ($\overline{AGE}_{i,previous}$), labor productivity ($\overline{PRODUCTIVITY}_{i,previous}$), access to external finance ($\overline{LTDEBT}_{i,previous}$) and intangible assets intensity ( $\overline{INTANG}_{i,previous}$) do not statistically affect the dispersion of succeeding growth rates. It is nonetheless relevant to control for these firm characteristics which may well be correlated with firm growth and the vertical integration choice. Moreover, the non-significant coefficients in col. (2) may be the result of a consistent (either positive or negative) effect played by these variables across the different percentiles of the growth rate distribution which ends up in a not significant effect over the standard deviation (see Section 4.2. for a further discussion on this result).

In cols. (3) - (9) several robustness checks have been reported. In col. (3), Eq. (4) is estimated by means of the Least Absolute Deviation (LAD, median) estimator, assuming that residuals are Laplace distributed (Capasso and Cefis, 2012; Capasso et al., 2013):[10] results are in line with those reported in col. (2), even if the estimated coefficient $\overline{QVINT}^3_{previous}$ is lower in magnitude and not statistically significant.

A further control concerns the implicit hypothesis in Eq. (4) that the vertical organization of production affects firm growth volatility with some lag. In order to support this hypothesis, in col. (4) the categories of vertical integration are introduced as contemporaneous to the dependent variable (i.e. averages over the periods 2000-2003, 2002-2005, 2004-2007), and in col. (5) both contemporaneous and lagged categories are jointly considered. Results support the hypothesis contained in Eq. (4): once introduced both contemporaneous and lagged categories, only the latter ones show a significant negative relation with the standard deviation of growth rates. Moreover, the use of the lagged categories should lessen the simultaneity issue.

As highlighted by Capasso and Cefis (2012, p. 194), coefficients' estimates of the lagged terciles of the $VINT_{i,t}$ distribution in col. (2) may suffer from an upward bias. This bias may arise whenever, a threshold limits the observational range of data on the same proxy that is used to calculate the growth rates.[11] To check for this possibility, Eq. (4) is re-estimated with the correction suggested by these authors by calculating firm size as deflated sales minus the value of the exogenous threshold (500,000 €). Indeed, as shown by col. (6) of Table 3, the negative relation between $\overline{QVINT}^3_{previous}$ and the within-firm standard deviation of subsequent growth rates is stronger in magnitude, once the correction has been applied. Specification in col. (2) is nonetheless kept as the reference, given the more "conservative" results.

Even if this paper is ultimately interested in estimating the effect of different vertical organization choices on the firm growth behavior, the relation may also go the other way round. If (i) vertically integrated structures ensure a distribution of growth rates with lower standard deviation (as hypothesized in Section 2) and (ii) firms characterized by "extreme" growth

[10] The reader is cross-referred to Section 3.2 and Supplementary Section 2.5 for a discussion on the general characteristics of the distributions of firm growth rates.

[11] In the case of the present paper, an exogenous threshold on firm sales applies to the sample under analysis: indeed, the Bureau Van Dijk's AIDA dataset contains information for firms with turnovers of over 500,000 euro. Moreover, a significant non-linear relation between firm size and the degree of vertical integration is at work (see Supplementary Table 4). For these two facts results contained in col. (1) of Table 5 may well suffer of an upward bias.

episodes are prone to vertically integrate to get more "stable" growth profiles, the negative OLS coefficients referring to $\overline{QVINT}^{2}_{previous}$ and $\overline{QVINT}^{3}_{previous}$ in col. (6) may be biased.

Two approaches have been adopted to check for this possible reverse causality. First, a dynamic model has been specified in col. (7): if a more dispersed distribution of growth rates in the past (respectively in 1998-2000, 2000-2002 and 2002-2004) was the reason for becoming more vertically integrated and there was a persistence in the dispersion of growth rates, the static model specified in col. (2) may have captured a spurious correlation. Results contained in col. (7) are encouraging: after controlling for the measure of past dispersion of growth rates, $ln\sigma_{GR_{i,previous}}$, more vertically integrated firms continue to be characterized by a less dispersed distribution of succeeding growth rates. In particular, the $\overline{QVINT}^{3}_{previous}$ coefficient is rather stable in magnitude (comparing it to the correspondent coefficient in cols. (2) and (6)) even if less precisely estimated, possibly due to a reduction in sample size from around 1040 to 885 observations.

Second, an instrumental variable (IV) approach has been adopted. The degree of asset (un-)specificity (indicated by the theory of Transaction Costs as one of the key determinants of vertical integration; see Williamson, 1975, among others), $\overline{ASS\_UNS}_{i,1998-2000}$, proxied by the ratio of firm total debts to total assets -- averaged over the period 1998-2000 (beginning of the overall period) -- may serve as an instrument because it should be (negatively) correlated with the degree of vertical integration[12] but it should not be correlated with the standard deviation of succeeding growth rates (unconditional correlations are shown in Supplementary Table 4). In order to identify Eq. (4), the $\overline{ASS\_UNS}_{i,1998-2000}$ variable is categorized into three dummies corresponding to the terciles of the $\overline{ASS\_UNS}_{i,1998-2000}$ distribution. Thus, Eq. (4) has two endogenous regressors ($\overline{QVINT}^{2}_{previous}$ and $\overline{QVINT}^{3}_{previous}$) and two excluded instruments ($\overline{ASS\_UNS^{2}}_{i,1998-2000}$ and $\overline{ASS\_UNS^{3}}_{i,1998-2000}$). 2SLS estimates of the exactly identified equation are reported in col. (8): while the Kleibergen-Paap test rejects the null hypothesis of underidentification, the F statistic points to a possible weak relation between the instruments and the endogenous regressors;[13] finally, the endogeneity test cannot reject the null hypothesis that both $\overline{QVINT}^{2}_{previous}$ and $\overline{QVINT}^{3}_{previous}$ are exogenous (P-value=0.327). Thus, even if the IV approach brings to higher negative coefficients (as expected, given the direction of the bias) of the dummies measuring the degree of vertical integration, OLS estimates should be preferred to 2SLS ones.

It is relevant to clarify that given (i) the sole consistency and the bias affecting IV methods in small samples (see Wooldridge, 2002; p. 101) and (ii) given that the principal purpose of the specifications in cols. (8) is that of making an argument about the direction of causation from the vertical structure to the volatility of firm growth rates, the IV approach has to be considered a robustness check while results contained in col. (2) are maintained as the reference point.

Finally, in col. (9), the standard deviation of growth rates of the *i*[th] firm in the period 2002-2007 is regressed over the average degree of vertical integration of the *i*[th] firm in the non-

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[12] As Antonietti and Cainelli (2007) underline, the idea behind the use of this proxy is that the more assets are specific to the set of activities conducted by the firm, the higher costs are attached in the case of bankruptcy, due to the lower redeployability. In this sense, it would be more expensive to finance these kinds of assets (e.g., R&D investments) with debt. Thus, the debt-to-asset ratio should be negatively related to the amount of firm-specific assets, and, consequently, to the firm degree of vertical integration.

[13] See the critical values tabulated by Stock and Yogo (2005).

overlapping period 1998-2001. Notwithstanding a relevant shrinkage in sample size with respect to the specification contained in col. (2) –the number of observations move from 1047 to 369--, the use of the period 2002-2007 for the dependent variable and the period 1998-2001 for the measure of vertical integration (plus controls) allows one to better cope with the simultaneity issue. The magnitude of the $\overline{QVINT}^{3}_{previous}$ coefficient is consistent with that reported in col. (2), but due to the reduction in sample size it is less precisely estimated and statistically significant at 10%.

All in all, once controlled for firm size, firm age, productivity, access to external finance, the intensity of intangible assets, temporal shocks and the endogeneity of the organizational form in the relation, the most vertically integrated firms experience a more "stable" growth profile.

***Table 3*** - The role of the vertical organization of production in explaining the (log of the) standard deviation of succeeding growth rates

| Dependent variable: $ln\sigma_{GR_{i,t}}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| | OLS | OLS | LAD | OLS | OLS | OLS | OLS | IV-2SLS | OLS |
| | | controls | controls | cont. VINT | cont. + lag VINT | C&C (2012) | dynamic | exactly | controls |
| | | | | | | | | | single |
| | | | | categories | categories | correction | model | identified | cross-section |
| | | | | | | | | | (2002-2007) |
| Vertical integration category (tercile) | | | | | | | | | |
| $\overline{QVINT}^2_{i,previous}$ | -0.066 | -0.114 | -0.053 | | -0.188* | -0.106 | -0.093 | -0.576 | -0.027 |
| | (0.074) | (0.083) | (0.091) | | (0.096) | (0.082) | (0.079) | (0.830) | (0.089) |
| $\overline{QVINT}^3_{i,previous}$ | -0.184** | -0.203** | -0.159 | | -0.299** | -0.222*** | -0.143* | -0.768* | -0.165* |
| | (0.074) | (0.084) | (0.106) | | (0.131) | (0.084) | (0.085) | (0.395) | (0.090) |
| $\overline{QVINT}^2_{i,contemporaneous}$ | | | | -0.051 | 0.099 | | | | |
| | | | | (0.084) | (0.097) | | | | |
| $\overline{QVINT}^3_{i,contemporaneous}$ | | | | -0.133 | 0.117 | | | | |
| | | | | (0.085) | (0.132) | | | | |
| Control variables | | | | | | | | | |
| $ln\sigma_{GR_{i,previous}}$ | | | | | | | 0.156*** | | |
| | | | | | | | (0.026) | | |
| $\overline{SIZE}_{i,previous}$ | -0.126*** | -0.110*** | -0.099*** | -0.112*** | -0.108*** | -0.211*** | -0.083*** | -0.101* | -0.091*** |
| | (0.027) | (0.031) | (0.037) | (0.031) | (0.031) | (0.029) | (0.031) | (0.055) | (0.032) |
| $\overline{AGE}_{i,previous}$ | | 0.001 | 0.002 | 0.000 | 0.001 | 0.001 | 0.002 | 0.005 | -0.000 |
| | | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.002) | (0.003) | (0.003) |
| $\overline{PRODUCTIVITY}_{i,previous}$ | | 0.006 | -0.060 | 0.005 | 0.007 | 0.060 | -0.146 | 0.022 | -0.110 |
| | | (0.129) | (0.122) | (0.129) | (0.128) | (0.065) | (0.112) | (0.114) | (0.075) |
| $\overline{LTDEBT}_{i,previous}$ | | 0.022 | 0.006 | 0.024 | 0.021 | -0.016 | -0.005 | 0.018 | 0.002 |
| | | (0.021) | (0.011) | (0.022) | (0.021) | (0.023) | (0.025) | (0.022) | (0.015) |
| $\overline{INTANG}_{i,previous}$ | | 0.016 | 0.009 | 0.017 | 0.016 | 0.008 | 0.003 | 0.009 | 0.015 |
| | | (0.019) | (0.021) | (0.019) | (0.019) | (0.017) | (0.019) | (0.018) | (0.023) |
| Year 2003 | 0.111** | 0.178** | 0.137* | 0.177** | 0.177** | 0.153** | 0.271*** | 0.182** | |
| | (0.056) | (0.069) | (0.072) | (0.069) | (0.070) | (0.070) | (0.074) | (0.073) | |
| Year 2005 | 0.133*** | 0.193*** | 0.245*** | 0.191*** | 0.193*** | 0.200*** | 0.152** | 0.194*** | |
| | (0.048) | (0.051) | (0.060) | (0.052) | (0.052) | (0.051) | (0.062) | (0.071) | |
| Constant | -0.866*** | -1.139** | -0.998** | -1.146** | -1.176** | -0.201 | -0.506 | -1.008** | -0.468 |
| | (0.238) | (0.482) | (0.497) | (0.489) | (0.486) | (0.467) | (0.430) | (0.410) | (0.340) |
| Observations | 1298 | 1047 | 1047 | 1047 | 1047 | 1043 | 885 | 1047 | 369 |
| Firms | 496 | 403 | 403 | 403 | 403 | 403 | 377 | 403 | 369 |
| Adjusted $R^2$ | 0.032 | 0.032 | - | 0.028 | 0.031 | 0.099 | 0.065 | -0.038 | 0.033 |
| $R^2$ | - | - | 0.035 | - | - | - | - | - | |
| Centered $R^2$ | - | - | - | - | - | - | - | -0.029 | |
| Uncentered $R^2$ | - | - | - | - | - | - | - | 0.832 | |
| Parente-Santos Silva test for intra-cluster correlation | - | - | | - | - | - | - | - | |
| H0: No intra-cluster correlation | | | T=8.471; P>\|T\|=0.000 | | | | | | |
| Tests on IV estimates | | | | | | | | | |
| Underidentification; Kleibergen-Paap rk *LM statistic* (P-value, 1-stage) | | | | | | | | 0.012 | |
| Weak identification; Kleibergen-Paap rk Wald *F statistic* (1-stage) | | | | | | | | 3.130 | |
| Endogeneity test (OLS vs. IV) (P value) | | | | | | | | 0.327 | |

Cluster-robust SE in parentheses

Significance levels: * 10%, ** 5%, *** 1%

In cols. (1)-(8), standard deviations of growth rates calculated over the periods 2000-2003, 2002-2005, 2004-2007 are respectively regressed on the category of vertical integration (average) measured in the 1998-2000, 2000-2002 and 2002-2004 periods plus the vector of firms' characteristics calculated as averages over the same previous periods. In col. (9) the standard deviation during the period 2002-2007 is regressed on the vector of independent variables calculated as averages over the period 1998-2001.

### 4.2. Quantile regressions

The results contained in Table 3 indicate that more vertically integrated firms are characterized by a less dispersed distribution of succeeding growth rates. However, this may be either the result of:

i. a negative relation between vertical integration and positive growth (see Section 2.1.);
ii. a negative relation between vertical integration and output contraction (see Section 2.2.);
iii. both of them.

Eq. (4) does not allow one to appreciate possible asymmetries and quantile regressions are suited for verifying the magnitude and the statistical significance of this relation at different percentiles of the (conditional) distribution of growth rates.

The empirical model may be written as:

$$GR_{i,t} = \alpha_\theta + \beta'_\theta QVINT^{p}_{i,t-1} + \gamma'_\theta \boldsymbol{Z_{i,t-1}} + \eta_{\theta j} + \tau_{\theta t} + \varepsilon_{\theta i,t} \qquad (5),$$

where $GR_{i,t}$ refers to the 1-year growth rate of the $i^{th}$ firm in the $t^{th}$ time period, $QVINT^{p}_{i,t-1}$ stands for the tercile of the vertical integration distribution the $i^{th}$ firm belongs to in *t-1*, $Z_{t-1}$ is the vector of (1-year lagged) control variables. In order to control for unobserved heterogeneity in the principal product (machinery) produced, *(j-1)* dummies, $\eta_j$, are included in Eq. (5), where *j={1: metal cutting machines; 2: metal forming machines; 3: other machines}* (see Supplementary Table 2 for a breakdown of firms by principal product sold). $\tau_t$ is a vector of year dummies to control for sectoral shocks common to all firms. After having defined $X_{i,t-1} = [QVINT^{p}_{i,t-1}, \boldsymbol{Z_{i,t-1}}, YEAR_t, PRODUCT_j]$ and $\delta'_\theta = [\beta'_\theta, \gamma'_\theta, \eta_{\theta j}, \tau_{\theta t}]$, the quantile regression estimator (Koenker and Basset, 1978) is the vector of parameters $\delta$ which solves the following operation:[14]

$$\underset{\delta}{min} \frac{1}{n} \left\{ \sum_{i,t:GR_{i,t} \geq \delta' X_{i,t-1}} \theta \left| GR_{i,t} - \delta' X_{i,t-1} \right| + \sum_{i,t:GR_{i,t} < \delta' X_{i,t-1}} (1-\theta) \left| GR_{i,t} - \delta' X_{i,t-1} \right| \right\}. \qquad (6)$$

Results are reported in Table 4. Given the multiple cross-section nature of the data, cluster-robust standard errors are reported in parentheses to control for the lack of independence of observations referring to the same firm over time. Moreover, for each percentile at which Eq. (5) is estimated the Parente-Santos Silva test for intra-cluster correlation is reported (Parente and Santos Silva, 2016).[15]

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[14] Eq. (6) is the objective function and is an asymmetric linear loss function. $\theta$ is the quantile defined as $Q_\theta(GR_{i,t}|X_{i,t-1}) \equiv inf\{GR_{i,t}: F(GR_{i,t}|X_{i,t-1}) \geq \theta\}$, in which $0 < \theta < 1$ and $GR_{i,t}$ is a random sample from a random variable with a conditional distribution function $F(\cdot\,|X_{i,t-1})$. For $\theta = 0.5$ the estimator is a Least Absolute Deviation (LAD, median) regressor. At least two properties of the quantile regression model are worthy to point out: (i) the normally distributed errors assumption (assumed in the "average" OLS regression model) may be relaxed. This is relevant given the distributions with "fat tails" depicted in Figure 1 (see also Supplementary Section 2.5); (ii) quantile regressions acknowledge some heterogeneity: slope parameters may vary at different quantiles of the conditional growth rate distribution.

[15] Quantile regressions with cluster-robust standard errors have been estimated by using the Stata package `qreg2` written by J. A. F. Machado, P. M. D. C Parente and J. M. C. Santos Silva.

The role of the organizational form is analyzed in five points of the growth rate distribution, namely the 5th, 25th, 50th, 75th and 95th percentiles. In order to limit the risk of omitted-variables bias, the $\boldsymbol{Z_{i,t-1}}$ vector of controls at the beginning of the year is included. Once firm size, age, labor productivity, intangible assets intensity, long-term obligations, the principal product and yearly sectoral shocks have all been controlled for, [16] higher vertical integration is systematically associated with both constrained growth at the top and slower output contraction at the bottom of the distribution of growth rates. However, this result may be further qualified. First, it is statistically significant only for the most vertically integrated firms (category $QVINT_{t-1}^{3}$). Second, it is especially relevant in the left-tail of the distribution (the 5th and 25th percentiles) which gathers (the heaviest) output contraction episodes, while it is practically not significant in the right-tail (fast growth). The value of coefficients referring to other variables is also worthy of comment. The coefficient of firm size confirms its “declining” path, being consistent with the negative coefficient found by estimating Eq. (4). Firm age shows the expected negative sign along the entire growth rate distribution, even if it is found to be significant only at the 75th percentile: this may be a confirmation of the relative maturity of the Italian MT industry. Labor productivity shows a negative relation with succeeding growth (albeit significant at the 50th and 75th percentiles only). This result is in line with Dosi et al. (2015), who find that the reallocation of market shares is not confirmed when regressing firm growth rates on lagged levels of productivity (a negative coefficient is actually found by the authors); however, market selection does “work” – in dynamic terms—by rewarding (in terms of succeeding growth rates) those firms with higher efficiency growth (Dosi et al. 2015; pp. 655-658). Both access to external finance, proxied by the $LTDEBT_{i,t-1}$ variable, and intangible assets intensity show a positive relation with firm growth along the entire growth rate distribution.[17] This is consistent with the not significant effects played by the two variables in Eq. (4): the access to external finance and the intensity of intangible assets “shift” the whole distribution of growth rates to the right.

Given the likely endogeneity of the vertical organizational form in Eq. (5), coefficients of $QVINT_{t-1}^{2}$ and $QVINT_{t-1}^{3}$ may suffer from an upward bias (see Section 4.1 for a discussion on the endogeneity issue and the likely direction of the bias). Thus, as in Section 4.1., an IV approach is advisable as a robustness check for the hypothesized direction of causation from the vertical structure to firm growth. The 2-step procedure proposed by Chernozhukov and Hansen (2008; pp. 382-383) for estimating an instrumental variable quantile regression (IVQR) model is employed. Given the (weighted) quantile function,

$$\frac{1}{n}\left\{\sum_{i,t:GR_{i,t}\geq\delta' X_{i,t-1}} \theta\left|GR_{i,t}-\beta'\mathrm{QVINT}^{\mathrm{p}}_{\mathrm{i,t-1}}-\gamma'\mathrm{Z}_{t-1}-\tau_t-\eta_j-\lambda'\,\mathrm{ASS\_UNS}_{i,t}\right| + \sum_{i,t:GR_{i,t}<\delta' X_{i,t-1}} (1-\theta)\left|GR_{i,t}-\beta'\mathrm{QVINT}^{\mathrm{p}}_{\mathrm{i,t-1}}-\gamma'\mathrm{Z}_{t-1}-\tau_t-\eta_j-\lambda'\,\mathrm{ASS\_UNS}_{i,t}\right|\right\} \quad (7)$$

i. for a given value of β, the ordinary quantile regression estimator (Eq. 6) is applied in order to obtain $\widehat{\gamma'}_{\theta}(\beta), \widehat{\tau'_{\theta t}}(\beta), \widehat{\eta'_{\theta j}}(\beta)$ and $\widehat{\lambda'}_{\theta}(\beta)$;

[16] For the sake of comparison with the results shown in col. (1) of Table 3, Eq. (5) has been estimated by including firm size as the sole control variable. The interested reader is cross-referred Supplementary Table 5.

[17] The only exception being the negative relation of intangible intensity with firm growth at the 5th percentile, which is –however—not statistically significant.

ii. to find the estimate for $\beta_\theta$ it is necessary to look for a value that makes the coefficient of the instrumental variable $\widehat{\lambda'}_\theta(\beta)$ as close as 0 as possible.[18]

Results are shown in Table 5:[19] in line with col. (8) of Table 3, once the endogeneity of vertical organization is taken into account, the "moderating" effect of vertical integration on firm (positive and negative) growth rates is stronger than the one obtained by applying the quantile regression estimator. This can be appreciated by the larger coefficients referring to $QVINT_{t-1}^2$ and $QVINT_{t-1}^3$ dummy variables which are positive for episodes of heavy output contraction (q05) and negative for those episodes of fastest growth (q95). All coefficients of control variables are in line with those shown in Table 4.

As in Section 4.1., the IVQR approach has to be considered as a robustness check to make an argument about the hypothesized direction of causation and coefficients reported in Table 4 are kept as the reference point, because they are more "conservative".

[18] Formally, $\hat{\beta}_\theta = \inf[W_n(\beta)]$, where $W_n(\beta) = n[\widehat{\lambda'}_\theta(\beta)]\hat{A}(\beta)[\widehat{\lambda'}_\theta(\beta)]$ and $\hat{A}(\beta)$ is set equal to the inverse of the asymptotic covariance matrix of $\sqrt{n}\left(\widehat{\lambda'}_\theta(\beta) - \lambda'_\theta(\beta)\right)$.

[19] Estimates shown in Table 5 have been computed by using the Stata package `ivqreg` written by Do Wan Kwack and available from Christian Hansen's and Do Wan Kwack's research pages. The reader is cross-referred to http://faculty.chicagobooth.edu/christian.hansen/research/; http://dwkwak.weebly.com/research.html and Kwak (2010).

***Table 4*** **-** Quantile regressions: the relation between the vertical organization of production and firm growth once other firm characteristics have been taken into account

| Dependent variables | (deflated) Sales growth | | | | |
|---|---|---|---|---|---|
| | q05 | q25 | q50 | q75 | q95 |
| Vertical integration category (tercile) | | | | | |
| $QVINT_{t-1}^{2}$ | 0.021 | 0.007 | 0.003 | -0.004 | -0.025 |
| | (0.029) | (0.011) | (0.010) | (0.012) | (0.037) |
| $QVINT_{t-1}^{3}$ | 0.089*** | 0.019* | 0.006 | 0.005 | -0.045 |
| | (0.031) | (0.011) | (0.010) | (0.013) | (0.036) |
| Control variables | | | | | |
| $SIZE_{i,t-1}$ | 0.022** | 0.013*** | 0.005 | -0.012*** | -0.037*** |
| | (0.010) | (0.004) | (0.003) | (0.004) | (0.012) |
| $AGE_{i,t-1}$ | 0.000 | -0.000 | -0.000 | -0.001* | -0.000 |
| | (0.001) | (0.000) | (0.000) | (0.000) | (0.001) |
| $PRODUCTIVITY_{i,t-1}$ | -0.030 | -0.010 | -0.017** | -0.032** | -0.060 |
| | (0.028) | (0.016) | (0.008) | (0.016) | (0.060) |
| $LTDEBT_{i,t-1}$ | 0.012*** | 0.006*** | 0.006 | 0.016 | 0.049*** |
| | (0.002) | (0.001) | (0.014) | (0.010) | (0.002) |
| $INTANG_{i,t-1}$ | -0.004 | 0.004 | 0.009*** | 0.013*** | 0.030*** |
| | (0.006) | (0.003) | (0.002) | (0.004) | (0.008) |
| Constant | -0.399*** | -0.117* | 0.094* | 0.445*** | 0.965*** |
| | (0.133) | (0.068) | (0.039) | (0.064) | (0.212) |
| Year dummies ($\boldsymbol{\tau_t}$) | Yes | Yes | Yes | Yes | Yes |
| Principal product dummies ($\boldsymbol{\eta_j}$) | Yes | Yes | Yes | Yes | Yes |
| Observations | 2,182 | 2,182 | 2,182 | 2,182 | 2,182 |
| Firms | 421 | 421 | 421 | 421 | 421 |
| $R^2$ | 0.051 | 0.061 | 0.072 | 0.095 | 0.076 |
| Parente-Santos Silva test for intra-cluster correlation | | | | | |
| H0: No intra-cluster correlation | T = 4.199<br>P>\|T\| = 0.000 | T = 2.463<br>P>\|T\| = 0.014 | T = -0.909<br>P>\|T\| = 0.363 | T = 1.218<br>P>\|T\| = 0.223 | T = 5.294<br>P>\|T\| = 0.000 |

Cluster-robust SE of coefficients in parentheses

Significance levels: * 10%, ** 5%, *** 1%

***Table 5 –*** Instrumental variable quantile regressions: the conditional effect of the vertical organization of production on firm growth

| Dependent variable | (deflated) Sales growth | | | | |
|---|---|---|---|---|---|
| | q05 | q25 | q50 | q75 | q95 |
| Vertical integration category (tercile) | | | | | |
| $QVINT_{t-1}^{2}$ | 0.121** | 0.008 | -0.029 | -0.004 | -0.354*** |
| | (0.060) | (0.037) | (0.034) | (0.036) | (0.069) |
| $QVINT_{t-1}^{3}$ | 0.238** | 0.022 | -0.059 | 0.007 | -0.459*** |
| | (0.108) | (0.066) | (0.061) | (0.065) | (0.124) |
| Control variables | | | | | |
| $SIZE_{i,t-1}$ | 0.026** | 0.014* | -0.000 | -0.011 | -0.039*** |
| | (0.013) | (0.008) | (0.007) | (0.008) | (0.014) |
| $AGE_{i,t-1}$ | -0.001 | -0.000 | 0.000 | -0.000 | -0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| $PRODUCTIVITY_{i,t-1}$ | -0.074** | -0.007 | -0.013 | -0.033 | -0.060 |
| | (0.035) | (0.021) | (0.020) | (0.021) | (0.040) |
| $LTDEBT_{i,t-1}$ | 0.013* | 0.006 | 0.005 | 0.016*** | 0.044*** |
| | (0.007) | (0.004) | (0.004) | (0.004) | (0.008) |
| $INTANG_{i,t-1}$ | -0.002 | 0.003 | 0.007 | 0.013** | 0.019* |
| | (0.009) | (0.005) | (0.005) | (0.005) | (0.010) |
| Constant | -0.335** | -0.139 | 0.149* | 0.437*** | 1.262*** |
| | (0.151) | (0.092) | (0.084) | (0.090) | (0.173) |
| Year dummies ($\boldsymbol{\tau_t}$) | Yes | Yes | Yes | Yes | Yes |
| Principal product dummies ($\boldsymbol{\eta_j}$) | Yes | Yes | Yes | Yes | Yes |
| Observations | 2,182 | 2,182 | 2,182 | 2,182 | 2,182 |
| Firms | 421 | 421 | 421 | 421 | 421 |
| Pseudo $R^2$ | 0.090 | 0.052 | 0.057 | 0.049 | 0.1412 |

SE of coefficients in parentheses

Significance levels: * 10%, ** 5%, *** 1%

### 4.3. The scaling of the variance of growth rates: taking firms' product portfolios into account[20]

The evidence provided in Sections 4.1 and 4.2 points to a heterogeneity in the distributions of output growth rates between vertically integrated and dis-integrated producers of MT: a more vertically integrated structure is associated with a lower standard deviation of succeeding growth rates. The result is interesting because it is found in addition to the "moderating" effect played by firm size.

Nonetheless, the scaling of the variance of growth rates with firm size deserves further investigation. Indeed, some heterogeneity in firm characteristics --both correlated with vertical integration and the dispersion of growth rates-- may be partially hidden behind this relation. A natural candidate is the extent of product diversification, as suggested by Bottazzi and Secchi (2006a).[21] These authors (pp. 857-861) show that the negative relation between firm size and the variance of growth rates is accounted for the scale relation between the number of products/"sub-markets" a firm is active in and firm size.

Taking their framework as a starting point, the information on the portfolio of products produced by the top (in terms of sales) 200 Italian MT builders has been collected: data come from *Tecnologie Meccaniche*,[22] a leading monthly technical magazine for the MT industry. Twenty-six products are classified and followed during the period 1998-2007 by means of a consistent taxonomy adopted by the magazine: the reader is cross-referred to Supplementary Table 2 where the taxonomy and a breakdown of observations by product categories is reported. Information regarding product portfolios is only available for 191 firms over the 524 producers of MT initially considered for this work and when the attention is restricted to those observations with also information on vertical integration, growth rates and the other controls, the sample shrinks to 133 firms (see Table 7). Given the remarkable sample shrinkage, the evidence provided in this section should be seen just as a complement to that already shown in Sections 4.1 and 4.2.

The count of the number of products has been calculated for the $i^{th}$ firm in the $t^{\text{th}}$ time period as follows:

$$DIVERSIFICATION^1{}_{i,t} = \sum_k PRODUCT_{i,t,k} \qquad (8)$$

where $PRODUCT_{i,t,k}$ is a dummy variable taking value 1 if the $i^{th}$ firm produces the $k^{th}$ product category in year *t* and 0 otherwise and $k \in K = \{a, \dots, z\}$, a set of 26 product categories.

In some regressions, these products have been further aggregated into seven groups, based on the type of technology contained in the machinery and its main application (Groover, 2010):

[20] The author thanks an anonymous referee for having suggested to further explore the negative relation between firm size and the growth rate variance.

[21] Works on the negative statistical relation between the variance of growth rates and firm size are many and the interested reader is referred to Coad (2007, pp. 14-15) for a compact review: in most of them it is assumed that firms can be decomposed into a number of smaller entities (i.e. "divisions", as proposed by Hymer and Pashigian, 1962; "units" in a hierarchical structure, as in Amaral et al., 1997; "sub-markets" in Bottazzi and Secchi, 2006a) and a variant of central limit theorem is at work at the level of these entities.

[22] *Tecnologie Meccaniche* is published eleven a year by DBInformation (see the magazine web page: http://www.techmec.it/). The magazine provides analyses about the performance of the MT industry. It also publishes, once a year, the ranking of the top 200 (in terms of sales) Italian MT producers together with the information on the categories of products produced by each firm. Products are classified within a consistent taxonomy which comprehends 26 types of product (machinery). Information regarding the products sold by the firms in the relevant sample was gathered from the magazine issues for the period 1998-2007.

$$DIVERSIFICATION^2{}_{i,t} = \sum_m PRODGROUPS_{i,t,m} \qquad (9)$$

where $PRODGROUPS_{i,t,m}$ is a dummy variable taking value 1 if the $i^{th}$ firm produces at least one of the $k^{th}$ products belonging to the $m^{th}$ group of machineries in year $t$ and 0 otherwise and $m \in M = \{1, \dots, 7\}$, a set of 7 groups of products. The variable specified in Eq. (9) may be particularly helpful in identifying "sub-markets", as suggested by Bottazzi and Secchi (2006a, pp. 855-857): growth opportunities of a firm in different $PRODGROUPS_{i,t,m}$ may be considered as independent processes, given the non-substitutability among machineries which belong to different groups. This fact is relevant to treat the variance of the firm growth rates as the sum of the variance of the growth rates in each $PRODGROUPS_{i,t,m}$.[23]

Descriptive statistics on diversification strategies adopted by the firms are reported in Figure 2 and Table 6: around 55% of MT builders (for which the information on product portfolio is available) do not diversify at all (they produce a single product), about 10% produce more than 3 products and the 1.5% most diversified firms sell 7 or more products. Moreover, more than the 75% of firms are only "active" within a single group of machineries, i.e. all the products they sell share a similar technology and common applications.

***Insert Figure 2 here in the text***

***Table 6***- Distribution of observations by the number of products sold

| | Number of products | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $DIVERSIFICATION^1{}_{i,t}$ | #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9+ | Firms |
| Share of observations | 54.52 | 22.49 | 13.02 | 4.77 | 2.70 | 1.00 | 1.14 | 0.28 | 0.07 | 191 |
| | Number of groups of products | | | | | | | | | |
| $DIVERSIFICATION^2{}_{i,t}$ | #1 | #2 | #3 | #4 | #5+ | | | | | Firms |
| Share of observations | 78.43 | 14.52 | 4.77 | 2.21 | 0.07 | | | | | 191 |

Variants of Eq. (4) have been estimated and reported in Table 7, after including $\overline{DIVERSIFICATION}^1{}_{i,previous}$ and $\overline{DIVERSIFICATION}^2{}_{i,previous}$ as further control variables, calculated as averages over the periods 1998-2000, 2000-2002, 2002-2004: results are directly comparable with those contained in Table 3, while due to the heavy reduction in sample size (only 133 firms and 314 observations have information for growth rates, vertical integration, the vector of control variables and product portfolios) neither an IV approach nor a quantile regression model have been estimated.[24]

[23] Information on firms' sales disaggregated by product is not available and the direct test conducted by Bottazzi and Secchi (2006a, p. 856) on the independence of growth rates in different product categories is not possible.

[24] It is well known that IV performs badly in small samples (see Wooldridge, 2002; p. 101); moreover, the quantile regression model may also suffer of a small sample issue: quantiles are empirical quantities and the precision of the estimation depend on the sample size and on the specific quantiles that are considered. Extreme quantiles (that are the most interesting ones in the present work) may be particularly hard to estimate with few observations.

In col. (1) the scaling of the variance of growth rates with firm size is tested by estimating the relation between the log of the standard deviation of annual output growth rates in three succeeding 3-year periods (2000-2003, 2002-2005, 2004-2007), $ln\sigma_{GR_{i,t}}$, and the previous average size (respectively in 1998-2000, 2000-2002, 2002-2004), $\overline{SIZE}_{i,previous}$. The estimated coefficient is -0.126, in line with those found by Bottazzi et al. (2011) and Coad (2008) for French manufacturing firms, confirming the well-known negative relation between the two variables. Col. (2) reports the estimation of Eq. (4) with the full vector of control variables, as in col. (2) of Table 3: when the full vector of controls is included in the analysis, the negative variance-size relation is confirmed but it decreases in magnitude.

In cols. (3) of Table 7 the count of the products a MT builder produces on average during the previous period, $\overline{DIVERSIFICATION^1}_{i,previous}$, is included in the regression and the expected negative relation between the extent of product diversification and the standard deviation of succeeding growth rates is found, even if not statistically significant. The negative but not statistically significant relation is confirmed when the count over the groups of products in which a firm is active is employed as diversification measure (col. 4), $\overline{DIVERSIFICATION^2}_{i,previous}$ .

As specified above, the heavy shrinkage in sample size (moving from 1047 to 314 observations) makes it difficult to identify the relationship between vertical integration and the standard deviation of growth rates, once the effect of product diversification has been taken into account. Indeed, the magnitude of the coefficients $\overline{QVINT}^2_{previous}$ and $\overline{QVINT}^3_{previous}$ reported in cols. (3) and (4) are rather consistent with those which are shown in col. (2), but the former are much less precisely estimated.

The same is true for the coefficient referring to $\overline{SIZE}_{i,previous}$: once firm size is included in the regressions --cols. (5) and (6)-- together with measures of diversification, the first one show a negative relationship with the standard deviation of growth rates, but the coefficient is not significantly different from zero. Nonetheless, we may conduct an interesting exercise. The coefficient of firm size is statistically significant at 10% when the analysis is replicated on the smaller sample in which information on product diversification is available (col. 7) and the measures of diversification are not included in the analysis.

This evidence points to the fact that part of the (negative) relation between the variance of growth rates and the size of the firm is definitely due to the positive relationship between the number of "sub-markets" in which a firm is active and its size (Bottazzi and Secchi, 2006a; p. 859). This is graphically appreciated in Figure 3, where the (log of) average number of products of firms belonging to different size bins is plotted against the bin average (log of) firm size: the magnitude (0.164) and the significance (standard error of 0.025) of the slope are rather in line with that found by Dosi et al. (2017) for around 140,000 Italian firms.

***Insert Figure 3 here in the text***

The negative relation between vertically integrated structures and the standard deviation of succeeding growth rates is confirmed in cols. (3) - (6), but due to the remarkable sample shrinkage, coefficients are poorly estimated and the evidence provided in this section should be seen just as a complement to that already shown in the previous sections.

***Table 7*** - The role of the vertical organization of production in explaining the (log of the) standard deviation of succeeding growth rates: accounting for firm size and product portfolios

| Dependent variable: $ln\sigma_{GR_{i,t}}$ | | | | | | | |
|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | OLS | OLS | OLS | OLS | OLS | OLS | OLS |
| Vertical integration category (tercile) | | | | | | | |
| $\overline{QVINT}^{2}_{previous}$ | | -0.114 | -0.157 | -0.161 | -0.157 | -0.156 | -0.160 |
| | | (0.083) | (0.059) | (0.127) | (0.129) | (0.129) | (0.131) |
| $\overline{QVINT}^{3}_{previous}$ | | -0.203** | -0.224 | -0.227 | -0.246 | -0.243 | -0.251 |
| | | (0.084) | (0.157) | (0.159) | (0.157) | (0.159) | (0.162) |
| Control variables | | | | | | | |
| $\overline{SIZE}_{i,previous}$ | -0.126*** | -0.110*** | | | -0.094 | -0.083 | -0.099* |
| | (0.027) | (0.031) | | | (0.060) | (0.060) | (0.052) |
| $\overline{AGE}_{i,previous}$ | | 0.001 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| | | (0.002) | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| $\overline{PRODUCTIVITY}_{i,previous}$ | | 0.006 | -0.098 | -0.103 | -0.028 | -0.038 | -0.027 |
| | | (0.129) | (0.142) | (0.136) | (0.129) | (0.126) | (0.130) |
| $\overline{LTDEBT}_{i,previous}$ | | 0.022 | -0.010 | -0.006 | -0.010 | -0.006 | -0.011 |
| | | (0.021) | (0.024) | (0.022) | (0.026) | (0.024) | (0.027) |
| $\overline{INTANG}_{i,previous}$ | | 0.016 | 0.028 | 0.032 | 0.034 | 0.038 | 0.033 |
| | | (0.019) | (0.029) | (0.028) | (0.029) | (0.029) | (0.029) |
| $\overline{DIVERSIFICATION^{1}}_{i,previous}$ | | | -0.092 | | -0.029 | | |
| | | | (0.114) | | (0.130) | | |
| $\overline{DIVERSIFICATION^{2}}_{i,previous}$ | | | | -0.242 | | -0.170 | |
| | | | | (0.167) | | (0.192) | |
| Year 2003 | 0.110* | 0.178** | 0.463*** | 0.469*** | 0.457*** | 0.466*** | 0.453*** |
| | (0.056) | (0.069) | (0.103) | (0.104) | (0.102) | (0.103) | (0.103) |
| Year 2005 | 0.133*** | 0.193*** | 0.220*** | 0.225*** | 0.225*** | 0.229*** | 0.225*** |
| | (0.048) | (0.051) | (0.083) | (0.083) | (0.083) | (0.083) | (0.083) |
| Constant | -0.955*** | -1.139** | -1.795*** | -1.774*** | -1.205* | -1.263* | -1.176* |
| | (0.237) | (0.482) | (0.580) | (0.563) | (0.714) | (0.696) | (0.671) |
| Observations | 1298 | 1047 | 314 | 314 | 314 | 314 | 314 |
| Firms | 496 | 403 | 133 | 133 | 133 | 133 | 133 |
| Adjusted $R^2$ | 0.027 | 0.032 | 0.035 | 0.042 | 0.045 | 0.050 | 0.048 |

Cluster-robust SE in parentheses

Significance levels: * 10%, ** 5%, *** 1%

In cols. (1)-(7), standard deviations of growth rates calculated over the periods 2000-2003, 2002-2005, 2004-2007 are respectively regressed on the category of vertical integration (average) measured in the 1998-2000, 2000-2002 and 2002-2004 periods plus the vector of firms' characteristics calculated as averages over the same previous periods.

## 5. Discussion of the results

Vertically integrated producers of machine tools are characterized by a distribution of output growth rates which is less dispersed away from its central tendency than the one shown by their dis-integrated counterparts. Thus, vertically integrated firms show a more "stable" growth profile, while dis-integrated firms are associated with more "extreme" output dynamics.

This result is relevant to managers who (especially in the decades of the 1990s and 2000s) have mostly paid attention to the growth effects of vertical dis-integration (outsourcing and sub-contracting) strategies, the quest for flexibility and the identification of the firm core competences (Stuckey and White, 1993). Dis-integrated firms may certainly take advantage from their flexibility in order to experience episodes of fast expansion but, at the same time, they may be more exposed to negative external shocks both in the intermediate and final good markets. Conversely, integrated firms benefit from a higher stability due a greater synchronization among the different phases (Perry, 1984) and a better control over the whole innovation processes (Teece, 1996, p. 205).

This paper sheds light on the output dynamics of firms characterized by different vertical organizational forms which coexist within a mature industry: thus, this paper is "tangent" to the field of research regarding the evolution of firms' vertical boundaries as industries grow old (Helfat, 2015). Even if data do not allow to directly test this kind of evolution for the Italian MT industry, the framework depicted by Helfat (2015; p. 7) and Bigelow and Argyres (2008, p. 794) may be useful for a broader interpretation of the results. Heterogeneous firms may coexist within a mature industry such as that of the builders of machine tools in Italy (Wengel and Shapira, 2004). Older, more experienced and productive firms (as supported by the descriptive evidence in Table 2) may stay integrated in the production of critical (cost-enhancing) components --such as electronic assemblies and software in the case of the builders of machine tools— to appropriate the returns from innovation based on their superior integrative competences. These firms may also stay integrated because their capabilities would prove valuable during this phase of industry's maturity, for example by ensuring smoother fluctuations in the supply of the intermediates inputs and a better management of changes in customers' needs. Dis-integrated firms may coexist with them, exploiting their flexibility and managing non-frontier technology with good levels of modularization (Christensen et al., 2002, p.964). Indeed, modularity creates options for a fast catch of market opportunities, reflected by a higher number of fast-growth episodes by dis-integrated firms.

Evidence from the MT industry, as the one provided by Arnold (2001, pp. 22-28) suggests that the market of MT is currently split into two segments. In the first segment, competition is based on the production of lower-cost machineries with non-frontier technological content and good degree of modularization. In the second segment, ultra-modern technological machineries are sold. The first segment may be the natural "field of battle" for vertical dis-integrated firms while, in the second one, more experienced and vertically integrated firms may manage their superior integrative capabilities to sell machinery with a closer-to-the-frontier technological content for the most demanding tier of the market (Christensen et al., 2002, p.961-962).

Before heading towards the concluding remarks, it is worth laying out few *caveats* about the empirical analysis. First, notwithstanding (i) the use of categorical and lagged variables as proxies for the type of vertical organization and (ii) the employment of IV methods in both Sections 4.1 and 4.2., some residual endogeneity may still affect the results. Thus, caution is advisable when one wants to give a strict causal interpretation to the findings of this work. Second, the econometric analysis and the use of balance sheet information allows one to provide a much needed quantitative assessment of the statistical relation between firms' vertical structures and their succeeding growth rates. Single-case/granular studies with a careful description of the stages of the production process which are actually kept in-house would provide valuable insight into the mechanisms underlying this relation. Third, as discussed in Section 3.2., the nature of the data (exits are not observed and only firms with annual revenues of over 500,000 euro are observed) allows one to conduct an analysis of the relation between the organizational form and growth, conditional on survival. At the same time the youngest and smallest (and, possibly, dis-integrated) firms belonging to the industry may not enter the database. Fourth, the focus on a single industry allows one to control for unobserved factors which affect firms' size dynamics and vary across industries (demand shocks, technology employed, R&D intensity). The relation between vertical integration and firm growth is here analyzed in a rather homogenous set of producers (which is, by the way, key to confidently use the Adelman index); however, at the same time, generalizations of results to broader contexts (for example, the whole manufacturing sector) have to be made with caution.

**6. Concluding remarks**

Little attention has been paid to the consequences, in terms growth, of the adoption by firms of unlike organizational structures along the same chain of production. Furthermore, the few studies that have done it, have mostly focused on the consequences of vertical dis-integration (i.e., outsourcing, sub-contracting) for positive growth.

The contribution of this paper consists in analyzing how different vertical organizational forms – that is, vertically integrated and dis-integrated firms– perform along the whole (conditional) distribution of growth rates. By (i) studying the standard deviation-vertical integration scaling relation and (ii) applying quantile regressions in a sample of around 500 Italian producers of machine tools for the period 1998-2007, it is found that: vertically integrated firms show a higher number of episodes of "moderate" growth, with respect to their dis-integrated counterparts, in the case of both output expansion and contraction. This corresponds to a less dispersed (i.e., with a lower standard deviation) distribution of growth rates for vertically integrated firms.

Dis-integrated firms may take advantage from their flexibility and specialized competences to catch opportunities for faster expansion but, at the same time, they are more exposed --with respect to their integrated counterparts-- to negative shocks in both the intermediate and the final product market.

More generally, this work provides insight into the size dynamics in a mature industry in which both vertically integrated and dis-integrated firms coexist (see Christensen et al., 2002; Bigelow and Argyres, 2008; Helfat, 2015, among others). Older, more experienced firms may stay integrated in the production of critical components (Bigelow and Argyres, 2008) to appropriate the returns from innovation based on their superior integrative competences. Dis-integrated firms may coexist with them, exploiting their flexibility and managing non-frontier technology with good levels of modularization (Christensen et al., 2002).

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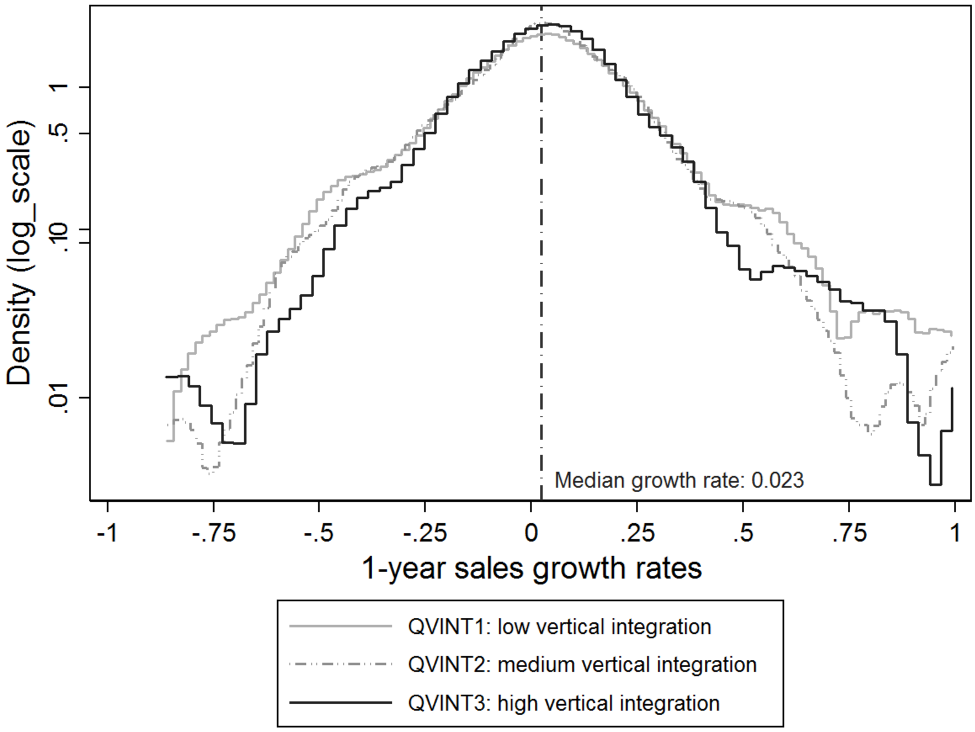
**Figure 1** - Distribution of (deflated) sales growth rates, by vertical integration category




Note: the y-axis is plotted on a logarithmic scale and the kernel density has been fitted using an Epanechnikov kernel

**Figure 2 (left)** - Distribution of observations (firm/year) according to: left (variable DIVERSIFICATION1) - the number of product sold

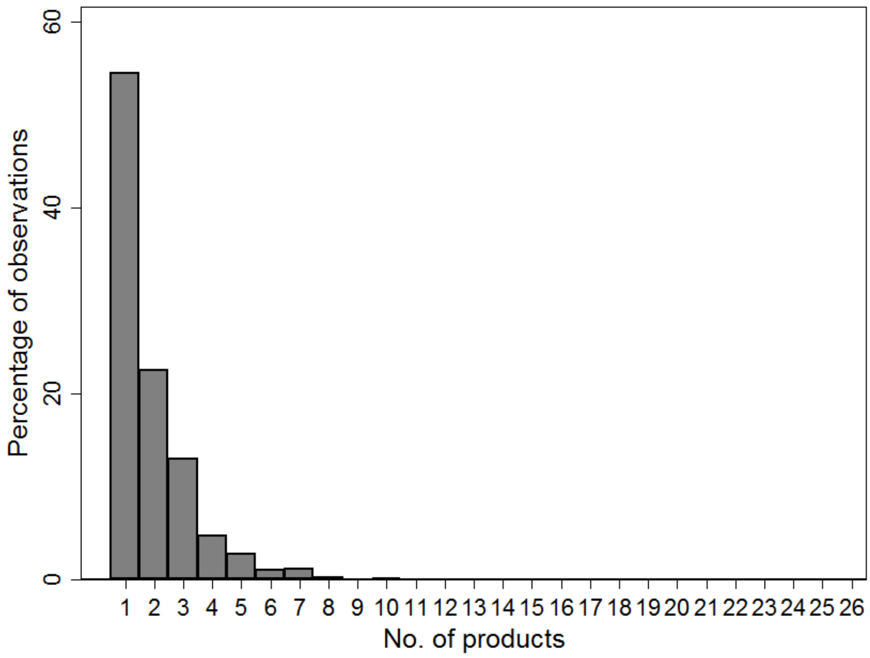


**Figure 3 (right)** - Distribution of observations (firm/year) according to: right (variable DIVERSIFICATION2) - the number of groups of technological similar products ("sub-markets") in which firms sell at least 1 product

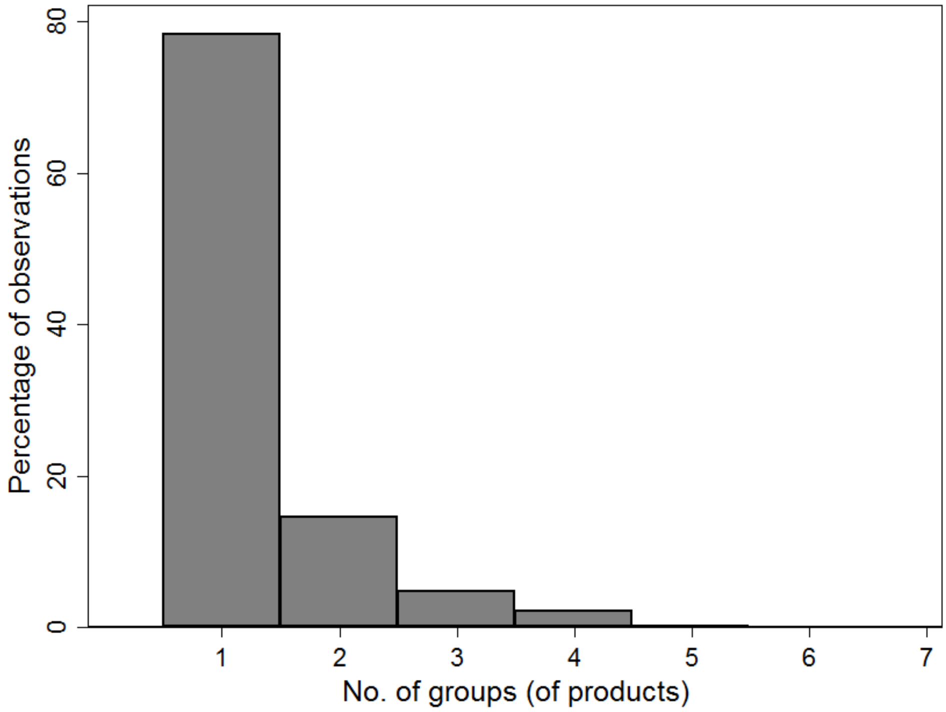



**Figure 3 –** The (log of) average number of products sold by firms belonging to different size bins *versus* the bin average (log of) firm size