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by

Fabio Pieri

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VNIVERSITAT DE VALÈNCIA

Departamento de Estructura Económica (Economía Aplicada II), Facultad de Economía, Universitat de València
Avda dels Tarongers, s/n, 46022 – Valencia, Spain
Phone +34 96 382 83 49 / Fax +34 96 382 83 54
http://www.estructuraeconomica.es
e-mail: investigacion.estructura@uv.es

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Vertical organization of production and firm growth behavior

Fabio Pieri[⊗]
Departamento de Economía Aplicada, Universitat de València

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Abstract

Many industries are characterized by a marked heterogeneity in vertical boundaries among their firms: some firms are vertically integrated in the production of inputs while others adopt dis-integration strategies. This paper empirically explores if different vertical organizational forms are associated with unlike growth "behaviors" within the same industry. To this end, an econometric analysis is conducted over a sample of around 500 Italian machine tool (MT) builders for the period 1998-2007. *Ceteris paribus*, 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*. Adjustment costs, organizational slacks, a better co-ordination along the production chain and a more effective handling of changes in customers' needs may all concur to explain their more "moderate" growth profile with respect to dis-integrated firms. This work provides insight into the output dynamics in a mature industry in which both vertically integrated and dis-integrated firms coexist.

JEL classification: D22, L23, L24, L26, L64

Keywords: Vertical integration, Firm growth, Quantile regression, Variance-vertical integration scaling, Italian machine tool industry

[⊗] *Corresponding author*; Departamento de Economía Aplicada, Universitat de Valencia, Avinguda dels Tarongers s/n, 46022, Valencia (Spain); email: fabio.pieri@uv.es

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 Szenberg, 1971; Christensen et al., 2002; Bigelow and Argyres, 2008; Manello et al. 2015; 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].

However, 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 the practice of market power (see Lafontaine and Slade, 2007; pp. 662-667; Whinston, 2007), very few studies have concentrated on the growth "behaviors" of firms with different organizational forms, namely vertical integration *versus* dis-integration.

The coexistence of firms characterized by different degrees of vertical integration along the same chain of production may definitely denote the existence of market opportunities for unlike organizations in a given industry: these opportunities may take the form of (positive) growth rates. At the same time, different vertical structures may be ways for companies to deal with (factors affecting) adverse shocks along the production chain.

This paper empirically explores if unlike vertical organizational forms are associated with different growth "behaviors", described by the distribution of firm growth rates. To this end, an econometric analysis is conducted over a sample of about 500 Italian machine tool (MT) producers observed during the period from 1998 to 2007, amounting to more than 3,800 observations. 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 choices 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 MT producers and their distributions of growth rates, two complementary methods are applied. First, a quantile regression analysis of the relation between 1-year output growth rates and the degree of vertical integration at the beginning of the period is employed; second, the statistical relation between the within-firm standard deviation of growth rates in a 5-year period and the average degree of vertical integration in the previous (and non-overlapping) 4-year period is estimated.

Results show that, once a set of relevant firm-level characteristics and common yearly sectoral shocks have been controlled for, 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. In other words, 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.

[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 costs and productivity among firms (see Elberfeld, 2001; Antràs and Helpman, 2004, among others).

Several concurring factors (discussed in Section 2) may explain this result. On the one hand, "moderate" positive growth rates may be the consequence of higher adjustment costs and more frequent organizational slacks which primarily affect vertically integrated firms. At the same time, vertical dis-integration may ensure lower fixed costs, better inter-firm relationships and a greater *focus* on core competences that are all necessary to capture fast-growth opportunities. On the other hand, vertically integrated firms may better cope with fluctuations in the markets of intermediate inputs and changes in customers' needs; thus, in front of such unexpected events, integrated organizations may experience more "modest" shrinking episodes than those experienced by their dis-integrated counterparts.

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 entire conditional distribution of (positive and negative) growth rates. Previous studies have mostly looked at how dis-integration (outsourcing and sub-contracting) strategies impact on (positive) firm growth[2]. Actually, managers would benefit of getting a broader view on how different types of organization of production (and not just vertical dis-integration) are systematically associated to firm (positive and negative) growth episodes.

Second, the paper provides insight into the size 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). Results suggest that vertically integrated firms show less extreme (positive and negative) growth rates, thus being characterized by a more "stable" profile, thanks to the control exerted over a greater part of the production chain. Dis-integrated firms experience more "extreme" growth dynamics: they may take advantage from their flexibility and specialized competences to experience episodes of faster expansion but, at the same time, they are more exposed to negative shocks in both the intermediate and final product markets.

The rest of the paper is organized as follows: Section 2 introduces the theoretical background; Section 3 describes the industry, the employed dataset and some 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 decide to produce the required intermediate goods and services "in-house" (by means of its own labor and physical capital) or acquire them from other firms in the market. The former type of organization is vertically integrated in the production of the intermediates, while the latter one outsources a valuable part of the value added contained in its final product to other organizations.

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[2] Mazzola and Bruni (2000) have analyzed the role of subcontracting (vertical dis-integration) strategies and inter-firm linkages on firm success (sales, employment and productivity growth) in a sample of 160 Southern Italian firms. Gilley and Rasheed (2000) have focused on the role of outsourcing on a multidimensional indicator of firm performance (including sales growth) in a sample of U.S. firms employing more than 50 people. Wynarczyk and Watson (2005) examine how, for subcontractors, relationships with other supply chain members are central to corporate survival and growth in a sample of UK manufacturing firms. Giunta et al. (2012) studied the growth profiles of a sample of Italian subcontracting firms by looking at how they position themselves along the production chain.

But why should different organizational forms (i.e. vertical integration *versus* dis-integration) be associated with unlike growth "behaviors", described by the distributions of firm growth rates?

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 or the composition of labor and physical capital motivated by demand shocks and/or changes in technology adopted by the firm. As suggested by Hamermesh and Pfann (1996), adjustment costs may either imply a change in the level of the input but not in the composition of it ("net" costs), or a change in the composition of the input, without any variation in its level ("gross" costs). In both cases, these costs translate into output losses (Hamermesh and Pfann, 1996, pp. 1266-1268[4]). 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[5] and, consequently, a more "moderate" positive output growth than if they would not exist.[6]

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 resources are fully employed (no slacks), growth is only possible with the addition of new resources. As suggested by Coad (2012), the addition of one unit of an input may lead to the employment of additional units of other inputs which generates a reinforcing effect in terms of a firm's capacity and output. Conversely, in the presence of organizational slacks, these may accommodate output growth with no additional resources.

[3] Some of the most cited model of firm dynamics do not contemplate adjustment costs in the process of firm expansion. The Jovanovic (1982) model is an example in which firms "freely" (without costs) adjust output at the desired level in each period of time; the same is true for the model proposed by Erikson and Pakes (1995). Conversely, Lucas (1967, p.323) introduces a model with (capital) adjustment costs in the form of output foregone in the process of firm growth.

[4] Authors suggest that it would be interesting to discover the "correlates" of adjustment costs in order to learn how widespread and relevant they actually are (Hamermesh and Pfann, p. 1288). This work put forward the idea that the vertical structure of production is linked to the relevance of adjustment costs.

[5] It seems reasonable to assume that varying physical capital and labor imply higher adjustment costs than varying the use of acquired intermediated goods and services; the latter inputs may conversely entail higher transaction costs.

[6] Indeed, as for labor, changing the number of employees may bring disruption of production (output) due to workers' assignment to be re-arranged. Equally, changing the identity of workers imply the raise of search- and training-costs, maintaining part of personnel dealing with recruitment and worker outflows. As for physical capital, varying the level of capital services used generates disruptions in workers' routines and re-assignation of tasks. Newly purchased equipment shifts other inputs away from current production; 'learning by doing' of new equipment takes time whilst total amortization of old equipment implies workers to be re-assigned to the remaining equipment.

Of course, even if slacks affect any type of firms, they should be more associated to vertically integrated structures[7], 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 (McLaren, 2000), more consistent inter-firm relationships with specialized suppliers (Mazzola and Bruni, 2000) and a greater focus on core functions (Giunta et al. 2012), which are all keys to ensure higher 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 lead vertically integrated firms to experience episodes of "moderate" 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 factors may justify the association of more "modest" episodes of output contraction with integrated organizations in front of some negative external shocks[8].

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 work as a strategy to guarantee a stable input supply. Thus, in front of negative supply shocks in the intermediate market which may well hinder a firm's production capacity, vertically integrated firms are advantaged with respect to their dis-integrated rivals.

More generally, 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 firms may better cope with changes 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

[7] The association of more relevant organizational slacks to vertically integrated organizations does not necessarily point to a lower (average) efficiency of these firms with respect to their dis-integrated counterparts (which is, by the way, not supported by the empirical analysis of this paper, see Table 2). Conversely, organizational slacks should be indicated by a higher volatility of efficiency for a given type of firm. Indeed, the within-firm standard deviation of labor productivity calculated during the period of observation for the three groups of firms (low, medium and high vertically integrated firms, as they have been defined in Section 3.2.) shows that the most vertically integrated firms are those characterized by its highest value (respectively, 23.79, 23.03 and 38.05).

[8] Admittedly, adjustment costs may also apply to episodes of output contraction. Reductions in labor and physical capital may definitely imply workers re-assignments and shifts of equipment along the production process. These facts may even reinforce the negative output growth caused by a negative shock, and, for the same argument suggested in Section 2.1., they should affect especially the most vertically integrated firms. However, previous studies suggest that firms better tolerate excess than shortage of both labor and physical capital. This is due, in the case of Italian firms, to the bigger relevance of firing costs with respect to the costs of hiring (Jaramillo et al., 1993; Arpaia et al. 2009); moreover, the costs of physical capital disruption have been found to be higher than those of capital adding in several countries (Nielsen and Schiantarelli, 2003 for a panel of Norwegian firms; Carlsson and Laséen, 2005, for Swedish manufacturing firms; Grazzi et al. 2015, for Italian and French manufacturing). Thus, even if it is not possible to rule out the adjustment costs argument in the case of output contraction, this argument should be more effective for positive than for negative output growth.

leading to a contraction; however, with an effective control 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 characterized by more "moderate" positive and negative growth rates (that is, a distribution which is less dispersed away from its central tendency) than the one shown by their dis-integrated counterparts.

3. Industry overview, data and descriptive analysis

3.1. Industry overview

The MT industry gathers together all the producers of metal working machinery: these are used as the principal equipment for manufacturing final goods as automobiles, aircrafts and home appliances. The two most prominent products of the industry are: metal forming machines (presses, sheet metal deformation machines and shearing machines) and metal cutting machines (machining centers, turning machines and lathes, grinding machines). As underlined by Rolfo (2000, pp.706-707) and Arnold (2001, p. 9), Italian firms –as most of their foreign competitors— focus their production portfolio on a single type of machinery[9].

Worldwide, the evolution of the MT industry has been marked by three waves of technological change: NCs[10] have been introduced in the 1950s and the 1960s, and the decades of the 1970s and 1980s attested the insertion of microcomputers into the CNC units; in 1990s PC-based-CNCs appeared on the scene and in 2000s the possibility of exchanging information about the operation of the machine tool through local area networks (LAN) became reality. As time was going by, a trend towards modularization and customization of the machinery has also taken place. This tendency may well be a sign of an industry's maturity phase (Arnold, 2001; p.1; p.5). In the mature phase, as suggested by Bigelow and Argyres (2008, pp. 794-795), the coexistence of 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.

This framework seems useful to explain the prevailing vertical organization of production in the Italian MT industry: indeed, even if a low average level of vertical integration has tended to dominate the industry since the 1970s[11], at present time, the industry is characterized by an

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[9] This is relevant to the present work in order not to confound the effect played by the vertical organization of production on firm growth behavior with the scaling-of-variance relation due to diversification strategies adopted by larger firms, as suggested by Bottazzi and Secchi (2006).

[10] NC=numerical control; CNC= computer numerical control.

[11] In the 1950s, the most important mechanical engineering firms produced their own MT in-house, so that vertically integrated firms prevailed. The 1960s saw a significant increase in domestic demand which stimulated the growth of an independent MT industry, and the 1970s were characterized by the "small firm model" and the consequent vertical

array of different organizational forms. All Italian (and foreign) producers of MT leave the manufacture of electronics components to other companies such as General Electric, Fanuc, Bosch and Siemens (Arnold, 2001; pp. 36-37)[12]; while some firms produce more in-house mechanical components, larger firms generally prefer to keep electronic assembly and software design in-house; almost all firms keep the machinery designing, mechanical assembly and testing in-house (Wengel and Shapira, 2004). If larger firms tend to be also the older and most experienced ones, these may vertically integrate in several critical phases of production, such as electronic assembly and software design, in order to exploit their accumulated competences.

In most developed countries, the MT industry is characterized by a strong export orientation and firms have to face a considerable international competition (Arnold, 2001; Kalafsky and MacPherson, 2002). In Italy, the industry is highly competitive: in 2007, Italy was the third place for export value and fourth for value of production in the worldwide ranking of builders of MT (UCIMU, 2007). The high degree of competition faced by the Italian MT producers may create both opportunities for fast expansion and threats for output shirking episodes.

3.2. Data and descriptive analysis

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' type of production (see Table A.2 in the Data Appendix for a breakdown of observations by type of production); balance sheet information, such as nominal revenues from sales and services, the nominal value of tangible and intangible assets, the number of employees, the year of establishment and the 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).[13] The Data Appendix provides additional information regarding how the dataset was built and the representativeness of the sample with respect to the overall MT industry in Italy.

3.2.1. Firm growth rates

The main variable of interest is the 1-year growth rate of firm *i* at time *t*, 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 chosen, instead of others like total employees or tangible fixed assets, because the purpose of the present work is to study the relation between firm growth and the way in which a firm "vertically organizes" its production process as a combination of inputs:

dis-integration. From the end of the 1970s a low average level of vertical integration has tended to dominate among the Italian MT firms (Rolfo, 2000).

[12] In this paper (see Section 3.2.2.), given the unavailability of detailed information on the number of stages that each firm undertakes along the vertical chain, an indirect measure of the vertical integration degree (the Adelman index) is employed.

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

either *in-house*, basing the process on its own capital and labor, or mostly depending on external suppliers (of intermediate goods and services).

3.2.2. Vertical integration

The degree of vertical integration of firm *i* at time *t* is measured as the ratio of value added to sales (both deflated by their proper industry-level indexes), as originally proposed by Adelman (1955):

$$VINT_{i,t} = \frac{VA_{i,t}}{Y_{i,t}}. \tag{2}$$

This measure is an indicator of a firm's degree of vertical integration: a value 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[14]. 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)[15].

Three dummies indicating the respective 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 33[th] and 66[th] percentile of its distribution, a vector of *(p-1)* dummy variables has been built, $QVINT^{p}$, where:

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

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 organizations and observations pertaining to the $QVINT^{3}$ category are the most vertically integrated ones. The $QVINT^{2}$ category denotes those firms with intermediate levels of vertical integration.

The use of the categorical variable, $QVINT^{p}$, is based on three main reasons. First, it allows one to group firms into similar vertical organization "types", thus gathering and capturing their most relevant features. Second, it is an attempt to minimize likely endogeneity issues: a firm may observe its growth rate in a given year, consequently modifying the relative use of acquired intermediates, thus changing the $VINT_{i,t}$ level. However, it is unlikely that a firm would be able to modify its vertical structure so dramatically from one year to another as to move to another tercile of the $VINT_{i,t}$ distribution.[16] Third, it allows one to capture a possible non-linearity in the relation.

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[14] 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 intermediates, materials and services over total costs of production) to measure the degree of vertical integration within samples of homogenous firms (see Antonietti et al., 2013; Pieri and Zaninotto, 2013a, b; Manello et al., 2015), which is the most favorable setting to its application (see Perry, 1989; p. 238).

[15] By definition, value added equals sales less the costs of intermediate inputs (goods and services) or equivalently, it is equal to the sum of returns to labor and capital.

[16] By calculating the yearly transition across terciles of the $VINT_{i,t}$ distribution in the reference sample of 3,282 observations (see Table A.3. in the Data Appendix), it is possible to appreciate that, for example, only the 17.8% of

Combining the information on vertical integration and growth rates, it is possible to start to describe the relation between them by drawing the distribution of output growth rates by (1-year lagged) vertical integration category, $QVINT_{i,t-1}^{p}$, in Fig. 1.

The plot suggests that dis-integrated firms ($QVINT^{1}$) at the beginning of the year show a higher probability of experiencing both higher (in absolute value) positive and negative growth rates than their most vertically integrated counterparts ($QVINT^{3}$), while the latter ones display a higher frequency of episodes of either zero (no-growth state) or small (in absolute value) positive and negative growth. These figures are confirmed in Table 1, showing different percentiles of the growth rates 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. In other words, vertically integrated firms (especially those belonging to $QVINT^{3}$) show a less dispersed distribution of growth rates with respect to their dis-integrated rivals. The Brown and Forsythe (1974) test is performed in order to statistically proof the difference in terms of standard deviation across the three categories of MT producers. Actually, as reported at the bottom of Table 1, the three groups of firms show values of standard deviations which are statistically different (with a probability of 5%)[17].

This impressionistic evidence regarding a more stable (i.e. around the central tendency) growth profile of integrated firms is in line with the hypothesis contained in Section 2 both for episodes of output expansion and output shrinking. It is now relevant to minimize the possibility that differences in growth rates by firms belonging to different terciles of the $VINT_{i,t}$ distribution are due to uncontrolled specific characteristics. For this purpose, a vector of firm-level variables is introduced in Section 3.2.3. and used (as control) in the multivariate econometric analysis.

3.2.3. Control variables

Firm *size*, as deflated sales in year *t*, is taken into account in the tradition of an extensive literature testing Gibrat's Law (Gibrat, 1931) of proportional effects (see Hall, 1987; among others). At the same time several studies have reported a significant --even if not linear-- relation between firm size and vertical integration (see Wengel and Shapira, 2004, for some evidence on the MT industry; see Manello et al. 2015, for an analysis of the automotive industry).

Firm *age*, measured as the difference between year *t* and the year of establishment of the firm, has been recently pointed out as a key factor for explaining differences in growth profiles across firms (see Haltiwanger et al., 2013, among others). Moreover, different degrees of vertical integration may well be associated to firm age across different phases of an industry life cycle (Bigelow and Argyres, 2008).

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observations which pertained to $QVINT^{1}$ in time t-1 have moved to $QVINT^{2}$ in time t. The percentage of those firms which have moved from $QVINT^{1}$ to $QVINT^{3}$ further decreases to 2.3%. All other (80%) of observations in $QVINT^{1}$ have not moved away from this category in the "t-1:t" period of time. That is, persistence within the same vertical integration category is frequent.

[17] Given that some firms move across terciles of the $VINT_{i,t}$ distribution during the 1998-2007 period, this fact may create an inconsistency in the statistical test. Thus, the Brown and Forsythe test has been replicated only in the group of firms which never change of tercile during the period. The sample shrinks from 3,822 to 1,319 observations but standard deviations are confirmed to be different across vertical integration terciles with a probability of 5%: F-statistic = 6.203; critical value equal to 3.002.

Fig. 1 - Distribution of (deflated) sales growth rates, by vertical integration category.
Note: The y-axis is on log-scale, and the kernel density has been fitted using an Epanechnikov kernel.

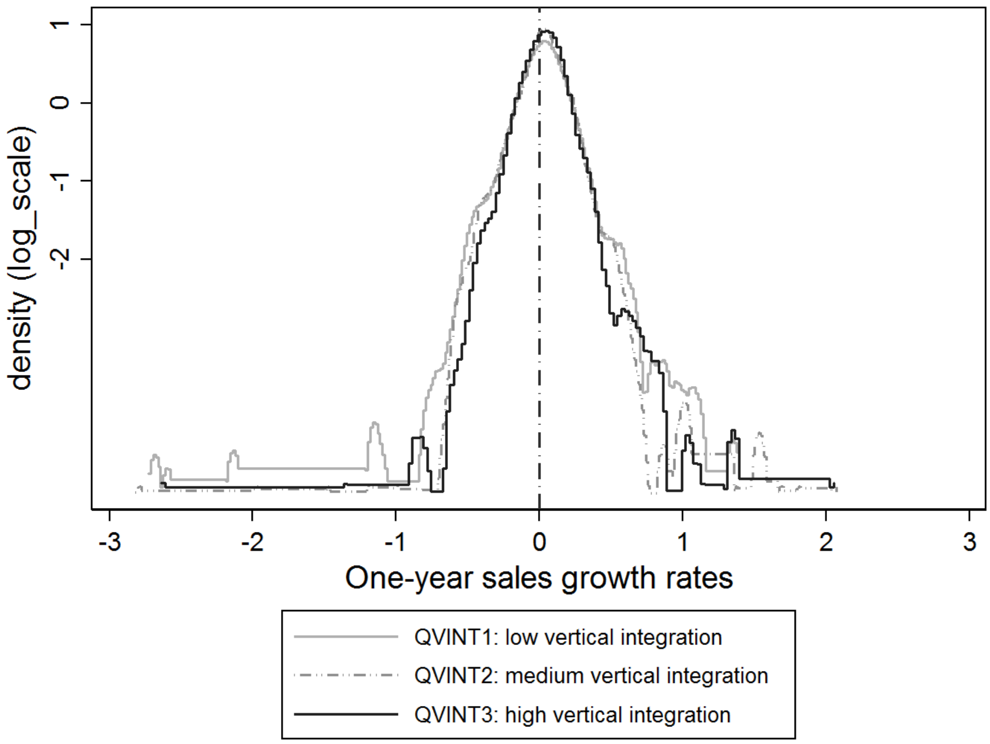


***Table 1 –** (deflated) Sales growth rates at different percentiles, by vertical integration category (tercile)*

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	

Labor productivity (the ratio between real value added and the number of employees in year *t*) is introduced as a proxy for firm efficiency. Both competitive learning models (Jovanovic, 1982; Ericson and Pakes, 1995) and the evolutionary theory (Winter, 1984) point out efficiency as a key predictor for firm growth. Moreover, the competitive markets approach has underlined the relevance of firm efficiency for explaining the self-selection into different vertical organizations of production within the same industry (see, Antràs and Helpman, 2004, among others).

In the light of the theory and evidence showing that financial constraints are related to firm growth opportunities (Cooley and Quadrini, 2004) and that financing possibilities may be related to vertical integration (see, for example, the motivation provided by Helfat and Teece, 1987; p. 49), the ratio between *long-term obligations* and *total assets* in year *t* is introduced in the multivariate econometric analysis.

Finally, *intangible intensity* (the ratio between deflated intangible assets and the number of employees in year *t*) is introduced as control variable. This variable, which is a proxy for a heterogeneous set of immaterial assets available to the firm, (i) may well be correlated with the technological capital employed by the firm (R&D investments, costs related to the use of patents and trademarks) and (ii) it includes a measure of corporate goodwill which is related to the appropriateness of management practices in the previous years. Both characteristics are certainly related to firm growth opportunities (Coad and Rao, 2008; Stenholm and Toivonen, 2009). Furthermore, Atalay et al. (2014) have recently shown that firms own production chains in order to spread intangible assets across different phases of the vertical chain.

All regressors are included in the econometric analysis as 1-year lagged in order to reduce potential endogeneity problems.

3.2.4. Descriptive analysis

Table 2 furnishes some descriptive information on the sample of Italian MT builders. These figures are in line with general statistics on the industry appearing in technical reports (see UCIMU, 2007; Data Appendix, Table A.1.). First, looking at the values referring to the whole sample (last column, "Total"), a low level of vertical integration (0.327) which characterizes the "median" MT builder can be appreciated. This value is totally in line with previous results, as those shown by Arrighetti (1999), who reports an average value of the Adelman index of 0.35 for 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 by studies analyzing the whole Italian manufacturing sector (Fagiolo and Luzzi, 2006 find a median age value of 21 years), being this another sign of the relative maturity of the industry.

Second, by comparing firms' (median) 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 are more indebted (or 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 bigger (in terms of output) than the median firm in the sample and more intensive in intangible assets than their more vertically integrated counterparts. Given this evidence, it is necessary to conduct a multivariate econometric analysis and examine the role of vertical integration when the moderating effect of other firm characteristics is taken into account. This will be the focus of the next section.

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. One the one hand, conditioning on survival, we may overestimate the effect of vertical dis-integration on firm growth; in fact, (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 (see Haltiwanger et al., 2013; among others) and a higher probability of exiting the market than their older counterparts (Dunne et al. 1989, pp. 678-680), only those MT builders which experience episode of fast growth would be observed among the young firms. On the other hand, by using data on relatively larger (minimum threshold of 500,000 euro) and older firms with respect to the entire industry population, a downward bias may affect the results. Unfortunately, it is not possible to directly control for these two possibilities.

Table 2 - Descriptive statistics

Variable	Notation	Unit of measure	Statistics	Vertical integration categories (terciles)			
				Low ($QVINT^1$)	Medium ($QVINT^2$)	High ($QVINT^3$)	**Total**
Vertical integration (Adelman index= real value added/ real sales)	$VINT_{i,t}$	Percentage	median	0.221	0.328	0.441	0.327
			iqr	0.083	0.078	0.118	0.161
Size (real sales)	$SIZE_{i,t}$	Thousands of euro; constant (2000) prices	median	5132.399	5766.713	4238.574	4940.771
			iqr	8334.813	12051.543	7419.084	9307.115
Age (# years since firm establishment)	$AGE_{i,t}$	Years	median	18	23	26	22
			iqr	15	15	20	17
Labor productivity (real value added/# employees)	$PRODUCTIVITY_{i,t}$	Thousands of euro per employee; constant (2000) prices	median	46.081	46.161	47.517	46.554
			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
			iqr	0.637	0.671	0.563	0.623
Intangible intensity	$INTANG_{i,t}$	Thousands of euro per employee; constant (2000) prices	median	1.541	1.398	1.010	1.347
			iqr	3.903	4.317	3.536	3.948

4. Econometric analysis

The "backbone" of the econometric analysis is the following empirical model:

$$GR_{i,t} = \alpha_0 + \boldsymbol{\beta}'\mathbf{QVINT}_{\mathbf{i,t-1}}^{\mathbf{p}} + \boldsymbol{\gamma}'\mathbf{Z}_{\boldsymbol{t-1}} + \boldsymbol{\tau_t} + \boldsymbol{\eta_j} + \varepsilon_{i,t}, \quad (4)$$

where $GR_{i,t}$ is the growth rate of the i^{th} firm in year t, $\mathbf{QVINT}_{\mathbf{i,t-1}}^{\mathbf{p}}$ is the tercile ($p = \{1,2,3\}$) of the vertical integration distribution the i^{th} firm belongs to in year *t-1*, and $\mathbf{Z}_{\boldsymbol{t-1}}$ is the vector of 1-year lagged control variables. Moreover, in order to control for unobserved heterogeneity in the type of machinery produced, *(j-1)* dummies $\boldsymbol{\eta_j}$ are included in Eq. 4 (where $j = \{1,2,3\}$; see Table A.2 in the Data Appendix for a breakdown of observations by type of production). Finally, a vector of year dummies, $\boldsymbol{\tau_t}$, is introduced in the model in order to control for yearly sectoral shocks common to all firms.

Two different but related methods of estimation are applied to Eq. 4. First, a quantile regression approach is employed (Koenker, 2005) to the pooled cross-section of 1-year growth rates from 1999 to 2007. Second, the information is collapsed into one single cross-section in order to estimate the relation between the (natural log of the) standard deviation of growth rates of the i^{th} firm in the period from 2002 to 2007 and the average degree of vertical integration of the i^{th} firm in the (non-overlapping) period from 1998 to 2001.[18]

Even if the two approaches are related, the application of both of them is based on two main reasons. On the one hand, the possibility of looking at the relation between vertical integration and firm growth along different quantiles of the (conditional) growth rates distribution, being able to identify that part of the distribution in which the correlation is stronger: to this end the use of quantile regression techniques -- which also permit to take the longitudinal dimension of the database into account -- is key. On the other hand, analyzing the relation between the (within-firm) standard deviation of growth rates and the previous (non-overlapping) average degree of firm vertical integration allows one to better cope with noise and measurement errors typically affecting 1-year growth rates and to minimize possible reverse causality.

4.1. Quantile regressions

Quantile regressions are particularly well-tailored for the purpose of the present work for several reasons:

i. if one wants to verify that vertically integrated firms are characterized, *ceteris paribus*, by more "moderate" positive and negative growth rates than their dis-integrated counterparts, a method which allows one to verify this hypothesis at different quantiles of the entire (conditional) growth rates distribution is needed;
ii. the normally distributed errors assumption (assumed in the "average" OLS regression model) may be relaxed. This is relevant in our case given the heavy-tailed distribution depicted in Fig. 1[19];

[18] Capasso et al. (2013, p. 630) have formally shown (for the growth-size *nexus*) that the variance scaling effect (i.e. the reduction of the variance of firm growth rates as firm size increases) implies "declining" quantile regression coefficients for firm size. If a variable has a reducing-variance effect on the growth rates 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.

[19] The non-normality of sales growth rates has been shown in a number of previous studies. See Bottazzi and Secchi (2006); Coad and Rao (2008), among others.

iii. quantile regressions acknowledge some heterogeneity: slope parameters may vary at different quantiles of the conditional growth rate distribution.

After having defined $\mathbf{X_{i,t-1}} = \left[\mathbf{QVINT^{p}_{i,\mathit{t}-1}}, \mathbf{Z_{\mathit{t}-1}}, \mathbf{YEAR_t}\right]$ and $\boldsymbol{\delta}' = [\boldsymbol{\beta}', \boldsymbol{\gamma}', \boldsymbol{\tau_t}]$, the quantile regression model may be written as:

$$GR_{i,t} = \boldsymbol{\delta}'_{\boldsymbol{\theta}}\mathbf{X_{i,t-1}} + \varepsilon_{\theta i,t} \qquad (5),$$

where $GR_{i,t}$ refers to the 1-year growth rates defined by Eq. (1), $\mathbf{X_{i,t-1}}$is the vector of regressors (vertical integration and controls) at the beginning of the period, $\boldsymbol{\delta_\theta}$ is the vector of parameter to be estimated and $\varepsilon_{\theta i,t}$ is the error component. The quantile regression estimator is the vector of parameters δ which solves the following operation[20]:

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

Results of the quantile regression estimator are reported in Tables 3 and 4. In Table 3, for the time being, just firm size is included as control variable, while in Table 4 the full vector of control variables $\mathbf{Z_{\mathit{t}-1}}$ is included.

The role of vertical organization of production is analyzed in five points of the growth rate distribution, namely the 5th, 25th, 50th, 75th and 95th percentiles. Higher vertical integration (both for $QVINT^2_{t-1}$ and $QVINT^3_{t-1}$ categories) shows the expected negative sign for the fastest growing firm (q95) and positive sign for those firms which have shrunk the most (q5). These coefficients claim that being more vertically integrated implies lower (in absolute value) positive and negative growth rates -- constrained growth and slower output reduction -- with respect to vertically dis-integrated firms ($QVINT^1_{t-1}$, omitted category). This is especially true for the most vertically integrated firms (category $QVINT^3_{t-1}$), which systematically show at each quantile of the distribution more "moderate" growth rates.

This first econometric evidence is in line with the hypothesis of the paper: a declining quantile regression coefficient for the vertical integration dummies stands for a more stable growth profile for vertically integrated firms. This may be the result of several concurring factors: the existence of adjustment costs and organizational slacks, together with the growth advantages ensured by dis-integration strategies may explain a more "moderate" positive growth for vertically integrated firms; at the same time, these firms may be characterized by a lower number of episodes of heavy output reduction thanks to smoother fluctuations in the supply of the intermediates inputs and a better management of unexpected changes in customers' needs.

Incidentally, firm size at the beginning of the period shows a negative relation with growth at the 75th and 95th quantiles, suggesting that smaller firms grow faster (see Hall 1987; Wagner 1992; among others); however, at the 25th quantile (modest shrinking) size shows a positive coefficient, claiming that, among those firms which become smaller, larger firms are those which shrink the less. This is an ancillary interesting result that is in line with some recent works (Serrasquiero et al., 2010; Capasso et al. 2013). Larger firms show more "stable" profiles of growth, which has been traditionally explained by the existence of diseconomies of growth and

[20] Eq. (6) is the objective function and is an asymmetric linear loss function. θ is the quantile defined as $Q_\theta\left(GR_{i,t}\middle|X_{i,t-1}\right) \equiv inf\left\{GR_{i,t}: F\left(GR_{i,t}|X_{i,t-1}\right) \geq \theta\right\}$, in which $0 < \theta < 1$ and $GR_{i,t}$ is a random sample from a random variable with a conditional distribution function $F\left(\cdot\,|X_{i,t-1}\right)$. For $\theta = 0.5$ the estimator is a Least Absolute Deviation (LAD, median) regressor.

managerial attention issues. However, for the purpose of the present paper, results in Table 3 show that after controlling for firm size, a further "moderating" effect is played by the vertically integrated form of organization.

In order to limit the risk of omitted-variables bias, in Table 4 the $\mathbf{Z}_{t-1}$ vector of controls at the beginning of the period is included in the empirical specification. The main results of Table 3 are confirmed in Table 4. Once firm size, age, labor productivity, intangible assets intensity, long-term obligations, type of produced machinery and yearly sectoral shocks have all been controlled for, higher vertical integration is still 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 seems to be especially relevant in magnitude in the left-tail of the distribution which gathers (the heaviest) output reduction episodes, while weakly significant in the right-tail (fast-growth). Thus, this claims for a specific advantage by vertically integrated firms in coping with negative external shock such as fluctuations in intermediate supply and uncertainty in the final good market; at the same time, the expectation of more constrained growth for vertically integrated firms (due to adjustment costs and organizational slacks) is just partially confirmed by the data at the top 95th percentile when all controls have been taken into account.

The value of coefficients referring to other variables is also worthy of comment. The coefficients of firm size confirms its "declining" path. Firm age shows the expected negative sign, even if it is found to be significant only at the 75th percentile: given the stronger negative effect found in studies analyzing the entire manufacturing sector (see, Haltiwanger et al., 2013, among others), this weak albeit negative coefficient may be a confirmation of the relative maturity of the Italian MT industry. Rather surprisingly, labor productivity shows a negative (albeit never significant) relation with succeeding growth. Access to credit, proxied by the $LTDEBT_{i,t-1}$ variable, barely affects the lowest part of the growth rate distribution, whilst it has a strong positive effect on those firms experiencing the highest growth rates (Lee, 2011). Finally, intangible assets intensity shows a positive coefficient starting from the 50th percentile, but its effect at the 95th percentile is almost three times the one found for the median firm; in other words, technological capital (R&D investments, the use of patents and trademarks) and effective management practices (corporate goodwill) are crucial in order to be a fast-growing firm.

Summing up, after controlling for several firm characteristics and yearly sectoral shocks, the most vertically integrated organizations are found to be systematically associated with a higher number of episodes of "moderate" (positive and negative) growth with respect to their dis-integrated counterparts. Quantile regressions allows one to qualify this result, pointing to a significant advantage for the integrated firms in terms of slower output shrinking in front of negative external shocks, together with a weaker (albeit significant) constraint in episodes of positive growth.

Table 3 - *Quantile regressions: the effect of vertical organization of production and firm size on sales growth*

Dependent variable	(deflated) Sales growth				
	q05	q25	q50	q75	q95
Vertical integration category (tercile)					
$QVINT_{t-1}^{2}$	0.052**	0.012	0.003	-0.014	-0.065**
	(0.025)	(0.010)	(0.009)	(0.009)	(0.029)
$QVINT_{t-1}^{3}$	0.096***	0.016*	-0.004	-0.019**	-0.096***
	(0.026)	(0.008)	(0.009)	(0.007)	(0.025)
Control variables					
$SIZE_{i,t-1}$	0.014	0.012***	0.000	-0.018***	-0.067***
	(0.010)	(0.003)	(0.003)	(0.003)	(0.007)
Constant	-0.506***	-0.146***	0.081**	0.379***	1.063***
	(0.143)	(0.031)	(0.030)	(0.032)	(0.082)
Year dummies ($\boldsymbol{\tau_t}$)	Yes	Yes	Yes	Yes	Yes
Product dummies ($\boldsymbol{\eta_j}$)	Yes	Yes	Yes	Yes	Yes
Observations	3,822	3,822	3,822	3,822	3,822
Pseudo R^2	0.056	0.067	0.048	0.051	0.072

Table 4 ***-*** *Quantile regressions: the effect of vertical organization of production and other firm characteristics (controls) on sales growth*

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
	(0.033)	(0.011)	(0.010)	(0.013)	(0.023)
$QVINT_{t-1}^{3}$	0.089**	0.019*	0.006	0.005	-0.045*
	(0.035)	(0.011)	(0.011)	(0.014)	(0.023)
Control variables					
$SIZE_{i,t-1}$	0.022**	0.013***	0.005	-0.012**	-0.037***
	(0.011)	(0.004)	(0.004)	(0.004)	(0.010)
$AGE_{i,t-1}$	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
	(0.056)	(0.016)	(0.010)	(0.019)	(0.041)
$LTDEBT_{i,t-1}$	0.012*	0.006*	0.006	0.016	0.049**
	(0.006)	(0.003)	(0.008)	(0.017)	(0.021)
$INTANG_{i,t-1}$	-0.004	0.004	0.009***	0.013***	0.030***
	(0.007)	(0.003)	(0.002)	(0.004)	(0.009)
Constant	-0.399**	-0.117*	0.094*	0.445***	0.965***
	(0.179)	(0.060)	(0.051)	(0.078)	(0.171)
Year dummies ($\boldsymbol{\tau_t}$)	Yes	Yes	Yes	Yes	Yes
Product dummies ($\boldsymbol{\eta_j}$)	Yes	Yes	Yes	Yes	Yes
Observations	2,182	2,182	2,182	2,182	2,182
Pseudo R^2	0.112	0.093	0.067	0.069	0.117

4.2. Variance-vertical integration scaling relation

Results in Tables 3 and 4 may be affected by some econometric problems. In particular:

i. noise and measurement errors that usually characterize yearly measured variables (especially 1-year growth rates and the Adelman index);

ii. some reverse causality may be at work from 1-year growth rates to vertical organization choices.

In order to cope with these issues, the following equation is estimated:

$$ln\sigma_{GR_{i,2002\le t\le 2007}} = \alpha_0 + \boldsymbol{\beta}'\overline{\mathbf{QVINT}}^{\mathbf{p}}_{i,1998\le t\le 2001} + \boldsymbol{\gamma}'\overline{\mathbf{Z}}_{i,1998\le t\le 2001} + \boldsymbol{\eta_j} + \epsilon_{i,2002\le t\le 2007}, \quad (7)$$

where $ln\sigma_{GR_{i,2002\le t\le 2007}}$ is the (natural log of the) standard deviation of growth rates of the i^{th} firm during the period 2002-2007, and $\overline{\mathbf{QVINT}}^{\mathbf{p}}_{i,1998\le t\le 2001}$ and $\overline{\mathbf{Z}}_{i,1998\le t\le 2001}$ are the average value of firms' characteristics (vertical integration and control variables) in the (non-overlapping) period 1998-2001.The vector $\boldsymbol{\eta_j}$ is included in Eq. 7 too.

Some properties of the empirical specification formalized in Eq. 7 are worthy to point out:

i. measures (within-firm standard deviations and averages) calculated over multi-year periods should be less sensitive to noise and measurement errors; this approach allows one to minimize undesirable variations in the vertical integration measure due to yearly fluctuations in prices which have nothing to do with the vertical structure of the firm, calculating the average over four years (1998-2001);

ii. the use of the period 2002-2007 for the dependent variable and the period 1998-2001 for vertical integration and controls allows one to avoid overlaps between the dependent variable and the regressors, possibly further limiting reverse causality from firm growth to vertical integration choices;

iii. the specification contained in Eq. 7 is a complementary approach to the quantile regression adopted in Section 4.1. (see Capasso et al., 2013; pp. 613-614).

Eq. 7 is estimated by means of the LAD estimator, assuming the residuals are Laplace distributed as in Capasso and Cefis (2012) and Capasso et al. (2013): results are reported in Table 5, col. (1).

As hypothesized in Section 2 and confirmed by quantile regression, being characterized by the highest degree of vertical integration in the period 1998-2001 (average value over the 4-year period corresponding to the third tercile of the $VINT_{i,t}$ distribution) is associated with a lower standard deviation of succeeding (2002-2007) firm growth rates with respect to their dis-integrated counterparts (first tercile of the $VINT_{i,t}$ distribution). That is, the result in Table 5, col. (1) confirms the quantile regression results, better coping with noise, measurement errors and possible reverse causality. However, as it has been effectively highlighted by Capasso and Cefis (2012, p. 194), coefficients' estimates of the vertical integration terciles 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.[21] To check for this possibility, Eq. 7 is re-estimated applying the correction suggested by Capasso and Cefis (2012) by calculating

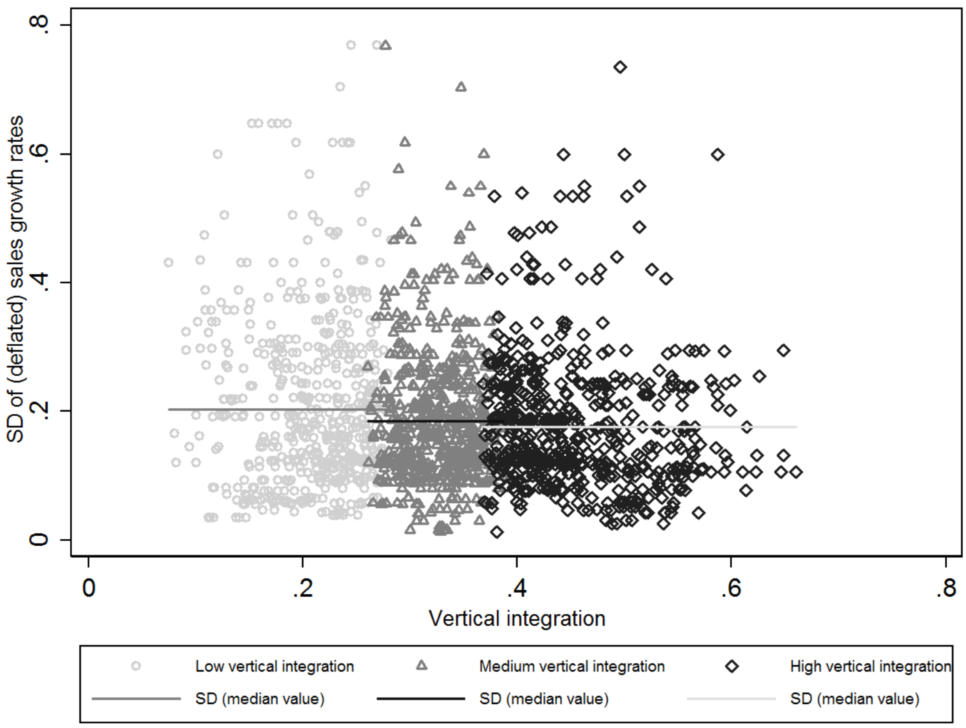
[21] In the case of the present paper, an exogenous threshold on firm sales applies to the sample under analysis: indeed, the Bureau Van Dijk's AIDA dataset contains information for firms with turnovers of over 500,000 euro. Moreover, a positive and significant (even if non-linear) correlation (0.034) between firm size and the degree of vertical integration is at work. For these two facts results contained in col. (1) of Table 5 may well suffer of an upward bias.

firm size as deflated sales minus the value of the exogenous threshold (500,000 € in the Bureau Van Dijk's AIDA dataset). Indeed, as shown by col. (2) of Table 5, the negative relation between $\overline{QVINT}^{3}_{1998\leq t\leq 2002}$ and the within-firm standard deviation of subsequent growth rates is even stronger in magnitude, once the correction has been applied. Results contained in Table 5 can be visually appreciated in Fig.2, by plotting the standard deviation of output growth rates against the vertical integration categories.

Table 5 *– LAD estimation of the (log of) standard deviation of growth rates on the vertical organization of production*

Dependent variable	SD of (deflated) sales growth ($2002 \leq t \leq 2007$)	
	(1)	(2)
	LAD estimation	LAD estimation (threshold: $SIZE_{i,t} \geq$ 500000 €)
Vertical integration category (tercile)		
$\overline{QVINT}^{2}_{1998\leq t\leq 2002}$	0.006	-0.024
	(0.050)	(0.056)
$\overline{QVINT}^{3}_{1998\leq t\leq 2002}$	-0.118**	-0.132**
	(0.047)	(0.056)
Control variables		
$\overline{SIZE}_{i,1998\leq t\leq 2002}$	-0.069***	-0.147***
	(0.012)	(0.016)
$\overline{AGE}_{i,1998\leq t\leq 2002}$	-0.002	-0.003**
	(0.001)	(0.001)
$\overline{PRODUCTIVITY}_{i,1998\leq t\leq 2002}$	-0.289***	-0.201***
	(0.051)	(0.060)
$\overline{LTDEBT}_{i,1998\leq t\leq 2002}$	-0.001	-0.003
	(0.005)	(0.006)
$\overline{INTANG}_{i,1998\leq t\leq 2002}$	-0.006	0.001
	(0.014)	(0.013)
Constant	0.057	0.566**
	(0.172)	(0.250)
Product dummies ($\boldsymbol{\eta_j}$)	Yes	Yes
Observations	368	323
Pseudo R^2	0.070	0.048

Fig. 2 – *Within-firm stardard deviation of (deflated) sales growth rates (2002-2007) and vertical integration categories (1998-2002).*



5. Discussion

All in all, econometric results in Sections 4.1. and 4.2. show that, once several firm-level characteristics and yearly sectoral shocks have been controlled for, vertically integrated firms are characterized by more "moderate" positive and negative growth rates, that is, 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.

Bigelow and Argyres (2008, p. 794) provides an interesting framework to interpret the coexistence of different types of vertical organizational forms within the same mature industry. 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 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. Disintegrated 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.

Qualitative evidence from the MT industry, as the one provided by Arnold (pp.22-28), seems to support the coexistence of different organizations in the industry, suggesting that the market of producers of MT is currently split into two segments. In the first segment, competition is based on lower-cost machineries with non-frontier technological content and good degree of modularization of the machine. 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 try to 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 analysis which has been conducted. First, notwithstanding (i) the use of categorical and 1-year lagged variables as proxies for the type of vertical organization and (ii) the estimation conducted in Section 4.2. between the (within-firm) standard deviation of growth rates and the previous and non-overlapping average degree of vertical integration, it is not possible to exclude that some residual endogeneity may still affect the results. This prevents one from giving a strict causal interpretation to the findings of this work.

Second, the adopted econometric approaches 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, 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), as effectively suggested by Das (1995, p. 114). 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 analyze the consequences, in terms firm success and growth, of different vertical organizational structures; moreover, those works which have done it, have mostly focused on the consequences of vertical dis-integration strategies for positive growth.

The contribution of this paper consists in analyzing how different vertical organizational forms – that is, firms characterized by vertical integration or dis-integration along the same link of production – perform along the entire (conditional) distribution of growth rates. By means of quantile regressions and studying the variance-vertical integration scaling relation in a sample of around 500 Italian producers of machine tools in the period 1998-2007, it is found that: once several firm-level characteristics and yearly sectoral shocks have been accounted for, 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 lower standard deviation) distribution of growth rates for vertically integrated firms.

From a theoretical point of view, several concurring factors may explain this result. On the one hand, the existence of adjustment costs and organizational slacks, which mainly affect integrated organizations, together with the beneficial effects of dis-integration strategies (reduction of fixed costs, exploitation of better inter-firm relationships and a greater *focus* on core competences) may lead vertically integrated firms to experience more “moderate” episodes of positive growth. On the other hand, the reduction of fluctuations in intermediate supply and a better management of changes in customers’ needs may allow integrated firms to experience less severe episodes of output shrinking with respect to dis-integrated firms.

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; World Trade Organization, 1998). 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).

More generally, this paper sheds light on the size dynamics of firms with different vertical organization forms which coexist within a mature industry. Thus, this paper is “tangent” to the (still open) field of research regarding the evolution of firms’ vertical structures as industries grow old (Helfat, 2015). Even if data do not allow to directly test this evolution for the Italian MT industry, the framework depicted by Helfat (2015; p. 7) may be useful for a plausible and broader interpretation of the results. Heterogeneous firms may coexist within a mature industry such as that of builders of machine tools in Italy (Wengel and Shapira, 2004). 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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A. Data Appendix

A.1. The database

This study exploits an original dataset, compiled by recovering data from several sources. The reference list of MT producers comes from *the Italian Machine Tools, Robots and Automation Manufacturers Association* (UCIMU). The list does not comprise only UCIMU associates, but also all firms covered by surveys and research questionnaires administered by the association.

Based on the reference list, balance sheet data for 524 firms over the period 1998-2007 were collected from Bureau Van Dijk's AIDA dataset, which contains information for firms with turnovers of over 500,000 euro. The number of observations with non-missing values both for firm growth rates (measured as the 1-year difference in log deflated sales) and vertical integration (measure by means of the Adelman index; see Section 3.2.2) amounted to 3,282 and 517 firms for the period 1998-2007. A higher number of missing observations affects the vector of control variables (described in Section 3.2.3). When the full vector of controls is taken into account, the dataset is reduced to 421 firms and 2,182 observations for the period 1998-2007. Sectoral deflators for revenues, value added, tangible and intangible assets come from the Italian National Institute of Statistics (ISTAT)[22].

Comparing the size distribution (in terms of annual sales) of firms surveyed by UCIMU in the industry report of 2007 (which may be considered as the reference population) with that shown by the dataset employed in this work, the analyzed sample represents rather well the reference population in terms of firm size.

Table A.1 *– Sample representativeness: percentages of firms in size classes*

	Sample (%)	UCIMU - Industry report, 2007 (%)
Size classes (sales)		
< 2.5 million euros	27.5	24.8
2,5 - 5 million euros	22.9	22.1
5 - 12,5 million euros	23.6	24.8
12.5 - 25 million euros	12.3	12.8
>25 million euros	13.6	15.4

A.2. Breakdown of firms by type of production

The industry report by UCIMU referring to 2007 affirms that the two largest product specializations among the Italian MT producers are metal cutting machinery (e.g. machining centers and lathes), and metal forming machinery (e.g. presses and machinery for sheet metal deformation). The report shows that after taking aside the other groups of product specializations, producers of metal cutting machinery account for the 52% of the population and producers of metal forming machines for the 48%. This breakdown is rather confirmed by the dataset employed in this work (Table A.2.) where (without taking into account the residual class of builders of other machines) producers of metal cutting machinery account for the 54% of the sample and producers of metal forming machinery for the 46%.

[22] See the ISTAT web page, http://www.istat.it/conti/nazionali.

Table A.2 *– Breakdown of firms by type of production*

Type of product	Observations	Firms
Builders of metal cutting machines	1,229	171
Builders of metal forming machines	1,016	139
Builders of other machines (unconventional-, welding-, heat treatment- and measuring-machines)	1,577	207
Total	3,822	517

A.3. Transition matrix

Table A.3. displays the yearly transitions across terciles of the $VINT$ distribution. It can be appreciated that persistence within the same vertical integration category is frequent.

Table A.3. *- Transition matrix*

Terciles of the $VINT$ distribution in year *t-1*	Terciles of the $VINT$ distribution in year *t*			
	QVINT_t^1	QVINT_t^2	QVINT_t^3	Total
QVINT_{t-1}^1	79.89%	17.81%	2.30%	100.00
QVINT_{t-1}^2	16.73%	63.59%	19.67%	100.00
QVINT_{t-1}^3	2.21%	18.30%	79.50%	100.00